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Oxidative and Transition-Metal Catalyzed Cross-Coupling Reactions, Preparation and Coupling of S-Heterocycles

von

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aus Stuttgart

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Erklärung

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Ehrenwörtliche Versicherung

Diese Dissertation wurde selbständig und ohne unerlaubte Hilfe bearbeitet.

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Marcel Patrik Kienle

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2. Gutachter: Prof. Dr. Manfred Heuschmann

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Parts of this Ph.D. thesis have been published:

Communications and Full Papers:

1 "A Practical Synthetic Procedure for the Preparation of Tertiary Amines via the Oxidative Coupling of Polyfunctional Aryl and Heteroaryl Amidocuprate"
M. Kienle, S. R. Dubbaka, V. del Amo, P. Knochel, *Synthesis*, **2007**, 1272.

2 "Copper(I)-Mediated Oxidative Cross-Coupling Between Polyfunctional Alkynyllithium and Arylmagnesium Reagents"
S. R. Dubbaka, **M. Kienle**, H. Mayr, P. Knochel, *Angew. Chem. Int. Ed.* **2007**, *46*, 9093.

3 "Directed Manganation of Functionalized Arenes and Heterocycles Using $TMP_2Mn\cdot 2MgCl_2\cdot 4LiCl$"
S. H. Wunderlich, **M. Kienle**, P. Knochel, *Angew. Chem. Int. Ed*. **2009**, *48*, 7256.

4 "Oxidative Amination of Heteroaromatic Zinc Reagents Mediated by $PhI(OAc)_2$"
M. Kienle, C. Dunst, P. Knochel, *Org. Lett*. **2009**, *11*, 5158.

5 "New Synthesis of Dibenzothiophenes and Related Classes of S-Heterocycles via an Anionic Electrocyclization"
M. Kienle, A. Unsinn, P. Knochel, *Angew. Chem. Int. Ed*. manuscript accepted.

6 "*i*PrI-Acceleration of Negishi Cross-Coupling Reactions"
M. Kienle, P. Knochel, *Org. Lett*. manuscript submitted.

7 „Convenient Preparation of Transition Metal Organometallics via Directed Metalation"
S. H. Wunderlich, **M. Kienle**, S. Matthe, P. Knochel, manuscript in preparation.

8 „Oxidative Amination Reaction of Zinc Organometallics Mediated by Cu(I) and Oxidative Cycloamination for the Preparation of Annulated Indole Derivatives"
M. Kienle, A. J. Wagner, C. Dunst, P. Knochel, manuscript in preparation.

9 "Optically Active Biphenylene Bridged Periodic Mesoporous Organosilica in Confined Environments"
Y. Li, A. Keilbach, S. Inagaki, **M. Kienle**, P. Knochel, T. Bein, manuscript in preparation.

10 „Synthesis of Thiazole Oligomers and Their Potential Application in Blended Organic Solar Cells"
M. Kienle, M. Hallermann, I. Kriegel, E. Da Como, P. Knochel, manuscript in preparation.

11 „Preparation of Heterocyclic Amines via a Cu(I)-Mediated Oxidative Cross-Coupling of Organozinc Reagents with Lithiumamides"
C. Dunst, **M. Kienle**, P. Knochel, manuscript in preparation.

Reviews:

1 “Modern Amination Reactions“
M. Kienle, S. R. Dubbaka, K. Brade, P. Knochel, *Eur. J. Org. Chem.* **2007**, 4166.

To Sonja and Isabel

Table of Contents

Abbreviations

Ar	aryl	m	multiplet
Bn	benzyl	Me	methyl
Boc	*tert*-butoxycarbonyl	Met	metal
br	broad	mmol	millimole
Bu	butyl	mp	melting point
n-Bu	*n*-butyl	MS	mass spectroscopy
s-Bu	*s*-butyl	NMR	nuclear magnetic resonance
t-Bu	*t*-butyl	Nu	nucleophile
calc.	calculated	*o*	ortho
conc.	concentrated	*p*	para
Cy	cyclohexyl	Ph	phenyl
δ	chemical shifts in parts per million	*i*-Pr	iso-propyl
		q	quartet
d	doublet	rt	room temperature
DMF	*N*,*N*-dimethylfomamide	s	singlet
DMSO	dimethyl sulfoxide	sat.	saturated
equiv	equivalent	t	triplet
EI	electron-impact	TBAF	tetrabutylammonium fluoride
ESI	electrospray ionization		
Et	ethyl	tfp	tri-2-furylphosphine
FG	functional group	THF	tetrahydrofuran
GC	gas chromatography	TLC	thin layer chromatography
HRMS	high resolution mass spectroscopy	TMEDA	*N*,*N*,*N´*,*N´*, tetramethylethylenediamine
IR	infra-red	TMS	trimethylsilyl
J	coupling constant (NMR)	TMP	2,2,6,6-tetramethylpiperidyl
M	molarity (mol L^{-1})	TMTD	tetramethylthiuramdisulfide
m	meta	TP	typical procedure

A

INTRODUCTION

1. Amination Reactions

Functionalized aromatic and heteroaromatic amines are important building blocks for the synthesis of pharmaceuticals,[1] polymers or materials.[2] For example, emorfazone (**1**) is a potent analgesic-anti-inflammatory agent.[3] Norfloxacin (**2**) is a well-known member of the family of quinolone antibiotics showing high activity against Gram-positive and Gram-negative bacteria like *Staphylococcus aureus*, *Escherichia coli* and *Pseudomonas aeruginosa*.[4] Mirtazapine (**3**),[5] an antidepressant, and Olanzapine (**4**),[6] a neuroleptic, are further medicinally active compounds, which show the need for efficient synthetic methods allowing the preparation of functionalized amines (Figure 1).

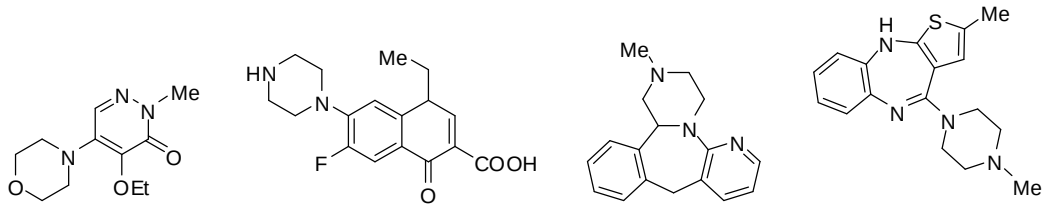

Figure 1: Examples of pharmaceuticals containing an amine.

1.1 Transition Metal Catalyzed Amination Reactions

1.1.1 Palladium

The palladium-catalyzed coupling of aryl halides with amines or other nitrogen containing substrates has become a versatile method for the preparation of aryl amines.[7] The first

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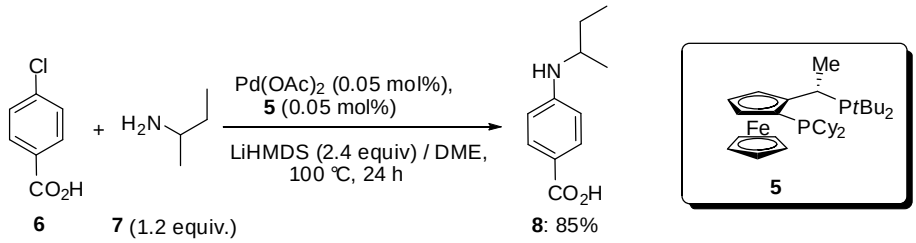
[2] a) A. G. MacDiarmid, *Synth. Met.* **1997**, *84*, 27; b) N. Gospodinova, L. Terlemezyan, *Prog. Polym. Sci.* **1998**, *23*, 1443.
[3] a) M. Takaya, M. Sato, K. Terashima, H. Tanizawa, *J. Med. Chem.* **1979**, *22*, 53; b) US 4379148.
[4] a) H. Koga, A. Itoh, S. Murayama, S. Suzue, T. Irikura, *J. Med. Chem.* **1990**, *23*, 1358; b) DE 2 804 097 C3.
[5] DE 2 614 406.
[6] a) V. P. Shevchenko, I. Y. Nagaev, Y. V. Kuznetsov, E. V. Polunin, A. A. Zozulya, N. F. Myasoedov, *Russ. J. Bioorgan. Chem.* **2005**, *31*, 378; b) J. K. Chakrabarti, J. Fairhurst, N. J. A. Gutteridge, L. Horsman, I. A. Pullar, C. W. Smith, D. J. Steggles, D. E. Tupper, F. C. Wright, *J. Med. Chem.* **1980**, *23*, 878; c) EP 454 436; d) EP 733 634; e) US 5 229 382; f) EP 733 367.
[7] For selected reviews, see: a) J. F. Hartwig in *Modern Arene Chemistry* (Ed.: D. Astruc), Wiley-VCH, Weinheim, **2002**, p. 107; b) J. F. Hartwig, *Acc. Chem. Res.* **1998**, *31*, 852; c) J. F. Hartwig, *Angew. Chem. Int. Ed.* **1998**, *37*, 2046; d) J. F. Hartwig, *Pure Appl. Chem.* **1999**, *71*, 1417; e) B. H. Yang, S. L. Buchwald, *J. Organomet. Chem.* **1999**, *576*, 125; f) J. P. Wolfe, S. L. Buchwald, *Angew. Chem. Int. Ed.* **1999**, *38*, 2413; g) J. P. Wolfe, S. Wagaw, J.-F. Marcoux, S. L. Buchwald, *Acc. Chem. Res.* **1998**, *31*, 805; h) A. R. Muci, S. L. Buchwald, *Top. Curr. Chem.* **2002**, *219*, 131; i) H.-U. Blaser, A. Indolese, F. Naud, U. Nettekoven, A. Schnyder,

palladium-catalyzed C(sp^2)-N bond formation was reported in 1983 by *Migital*. The reaction of aryl bromides with aminotin compounds in the presence of catalytic amount of palladium provides the corresponding aniline derivatives in moderate to good yields.[8] The limitations associated with the use of toxic tin derivatives were overcome by *Buchwald* and *Hartwig* in 1995.[9] Among all the efforts to increase the scope of substrates and the efficiency of the reaction, fine tuning of the ligands has shown the biggest impact. Recent developments led to two main and complementary ligand classes: chelating bisphosphine ligands and biaryl monophosphine ligands. Using commercially available Josiphos-type ligand **5**, the aryl chloride **6** possessing a free carboxylic acid function reacts with primary alkyl amine **7** to afford the secondary amine **8** using $LiN(SiMe_3)_2$ as base (Scheme 1).[10]



Scheme 1: Synthesis of a secondary amine using Pd-catalysis.

The steric hindrance, strong electron donation and tight chelation of the palladium center with ligand **5** results in a catalyst system possessing a long life-time and a high reactivity for reactions of primary nitrogen nucleophiles with aryl and heteroaryl chlorides. This catalyst system even allows the direct use of ammonia in the palladium-catalyzed amination reaction, opening new ways for the synthesis of primary arylamines.[11] In a typical reaction, the sterically hindered aryl bromide **9** is reacted with ammonia to yield arylamine **10** (Scheme 2). This reaction can be extended to aryl chlorides instead of aryl bromides. Furthermore, also lithium amide ($LiNH_2$) can be used as a convenient nitrogen source instead of gaseous NH_3, which may not be practical in some cases.

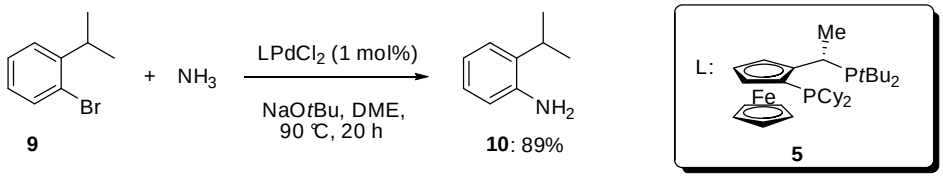
Adv. Synth. Catal. **2004**, *346*, 1583; j) B. Schlummer, U. Scholz, *Adv. Synth. Catal.* **2004**, *346*, 1599; k) S. L. Buchwald, C. Mauger, G. Mignani, U. Scholz, *Adv. Synth. Catal.* **2006**, *348*, 23.

[8] M. Kosugi, M. Kameyama, H. Sano, T. Migita, *Chem. Lett.* **1983**, 927.

[9] a) A. S. Guram, R. A. Rennels, S. L. Buchwald, *Angew. Chem. Int. Ed.* **1995**, *34*, 1348; b) J. Louie, J. F. Hartwig, *Tetrahedron Lett.* **1995**, *36*, 3609.

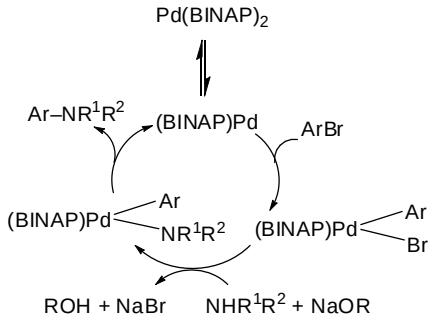
[10] Q. Shen. S. Shekhar, J. P. Stambuli, J. F. Hartwig, *Angew. Chem. Int. Ed.* **2005**, *44*, 1371.

[11] Q. Shen, J. F. Hartwig, *J. Am. Chem. Soc.* **2006**, *128*, 10028.



Scheme 2: Synthesis of a primary amine via a Pd-catalyzed amination reaction.

Buchwald, *Blackmond* and *Hartwig* have recently described a detailed study of the amination mechanism of aryl halides using palladium complexes of 2,2'-bis(diphenylphosphino)-1,1'-binaphthyl (BINAP).[12] Identification of the Pd-BINAP complexes present in the reaction mixture as well as rate measurements reveal that the oxidative addition of the bromoarene to [Pd(BINAP)] occurs prior to the amine addition. The reaction with the amine and the base with [Pd(BINAP)(Ar)(Br)] follows and the catalytic cycle is completed by a reductive elimination of the resulting amido complex providing the desired arylamine (Scheme 3).



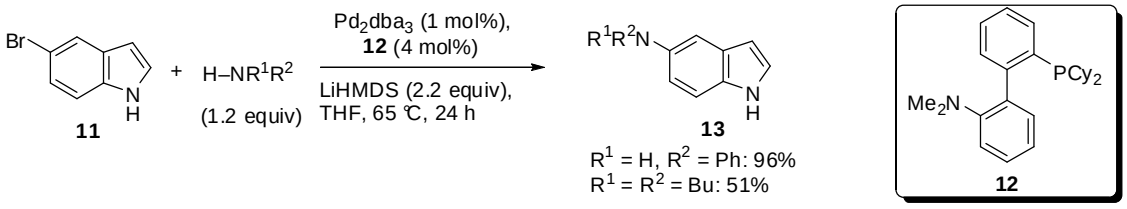
Scheme 3: Catalytic cycle for the transition metal-catalyzed amination.

Monophosphine ligands can also be successfully applied to palladium-catalyzed aminations.[13] Among them, biaryl ligands have proven to be particularly efficient.[14] Progress in the coupling of heteroaryl halides allows the access to a large variety of biologically and

[12] S. Shekhar, P. Ryberg, J. F. Hartwig, J. S. Mathew, D. G. Blackmond, E. R. Strieter, S. L. Buchwald, *J. Am. Chem. Soc*. **2006**, *128*, 3584.
[13] a) J. F. Hartwig, M. Kawatsura, S. I. Hauck, K. H. Shaughnessy, L. M. Alcazar-Roman, *J. Org. Chem.* **1999**, *64*, 5575; b) L. L. Hill, L. R. Moore, R. Huang, R. Craciun, A. J. Vincent, D. A. Dixon, J. Chou, C. J. Woltermann, K. H. Shaughnessy, *J. Org. Chem.* **2006**, *71*, 5117; c) X. Xie, T. Y. Zhang, Z. Zhang, *J. Org. Chem.* **2006**, *71*, 6522.
[14] a) J. P. Wolfe, H. Tomori, J. P. Sadighi, J. Yin, S. L. Buchwald, *J. Org. Chem.* **2000**, *65*, 1158; b) X. Huang, K. W. Anderson, D. Zim, L. Jiang, A. Klapars, S. L. Buchwald, *J. Am. Chem. Soc.* **2003**, *125*, 6653.

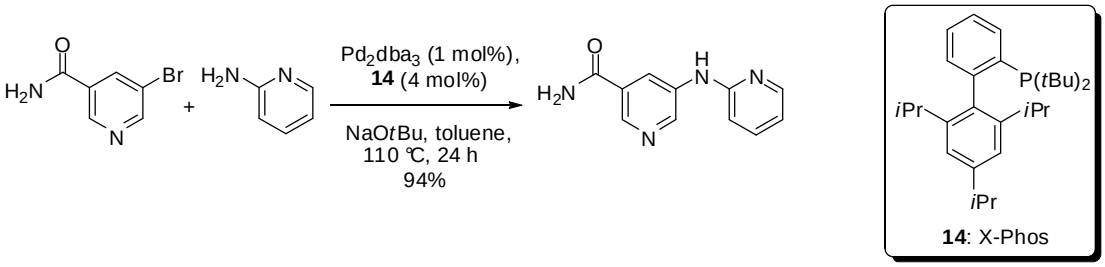
pharmaceutically important heteroarylamines.[15] Moreover, a range of highly active, bulky and electron-rich biaryl ligands are commercially available.[16]

Thus, 5-bromoindole (**11**) reacts with aniline and acyclic or cyclic secondary alkylamines using ligand **12** to furnish the 5-aminoindoles **13** in moderate to excellent yields (Scheme 4).[17] Furthermore, a protection of the free NH-function is not necessary in such aminations.



Scheme 4: Pd-catalyzed amination of 5-bromoindole (**11**).

Later generations of monodentate biaryl ligands possess bulky substituents on the 2,2'-positions for preventing a palladacycle formation[18] and additionally shifting the equilibrium between $[L_2Pd^0]$ and $[L_1Pd^0]$ to the latter, more reactive complex. Such palladium catalysts display high chemoselectivity for the reaction of an aniline NH_2 group over a primary amide.[14b] Ligand **14** (X-Phos) further allows the use of 2-amino-substituted heterocycles as nucleophiles (Scheme 5).[19] The presence of a bidentate ligand prevents a coordination of this "amidine-like" nucleophile to palladium.[20]

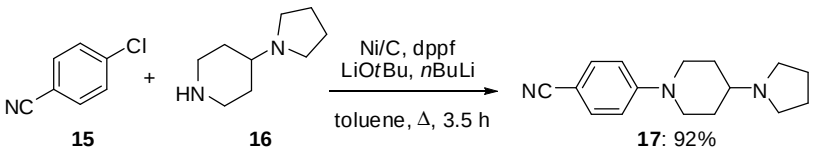


Scheme 5: 2-Amino substituted heterocycles as nucleophiles in Pd-catalyzed aminations.

[15] A. F. Pozharskii, A. T. Soldatenkov, A. R. Katrizky in *Heterocycles in Life and Society*, John Wiley & Sons, Weinheim, **1997**.
[16] Strem, Aldrich.
[17] M. D. Charles, P. Schultz, S. L. Buchwald, *Org. Lett.* **2005**, *7*, 3965.
[18] a) E. R. Strieter, S. L. Buchwald, *Angew. Chem. Int. Ed.* **2006**, *45*, 925; b) for an excellent review on biaryl phosphane ligands used in Pd-catalyzed amination reactions, see: D. S. Surry, S. L. Buchwald, *Angew. Chem. Int. Ed*. **2008**, *47*, 6338.
[19] K. W. Anderson, R. E. Tundel, T. Ikawa, R. A. Altman, S. L. Buchwald, *Angew. Chem. Int. Ed.* **2006**, *45*, 6523.
[20] a) J. Yin, M. M. Zhao, M. A. Huffman, J. M. McNamara, *Org. Lett.* **2002**, *4*, 3481; b) T. H. M. Jonckers, B. U. W. Maes, G. L. F. Lemière, R. Dommisse, *Tetrahedron* **2001**, *57*, 7027.

1.1.2 Nickel

Although palladium complexes certainly present the most widely used class of catalysts for amination reactions, many challenges still remain. One of them is the coupling of the readily available aryl chlorides which often requires the use of specially tailored ligands.[21] Despite the fact that Ni(0) easily inserts into aryl chlorides without the need for expensive ligands, relatively little work on their use in amination reactions has been done so far.[22] *Lipshutz* has developed an industrially attractive catalyst system which shows high efficiency for C-C, C-N and C-H bond formation reactions.[23] The catalyst consists of nickel atoms embedded in a charcoal matrix (Ni/C). Addition of *n*-BuLi to Ni^{II}/C in the presence of 1,1'-bis(diphenylphosphanyl) ferrocene (dppf) generates the phosphane-ligated active Ni^{0}/C catalyst, which shows very little bleeding into the reaction medium (0.15% relative to the substrate).[24] The catalyst is readily stored and simply filtered off after reaction. A wide range of aryl halides can be converted to their respective aniline derivatives with reaction times as short as 2.5 h. But still, long reaction times are needed for the coupling of electron-rich aryl chlorides like 4-chloroanisole (52 h). In a typical reaction, the aryl chloride **15** and the cyclic secondary amine **16** are coupled to the corresponding aryl amine **17** in 92 % yield (Scheme 6).

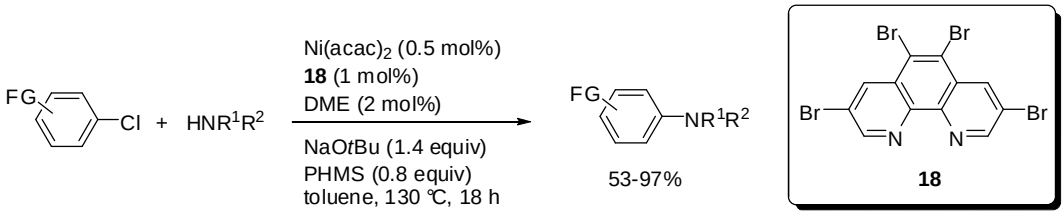


15 **16** **17**: 92%

Scheme 6: Ni-catalyzed amination of an aryl chloride.

Recently, *Knochel* showed that aryl chlorides can be aminated using a Ni-catalyst in the presence of PHMS (polymethylhydroxysiloxane) and the phenanthroline based ligand **18**. This catalyst system requires low loadings of 0.5 mol% and affords high yields in the amination of aryl and heteroaryl chlorides (Scheme 7)[25].

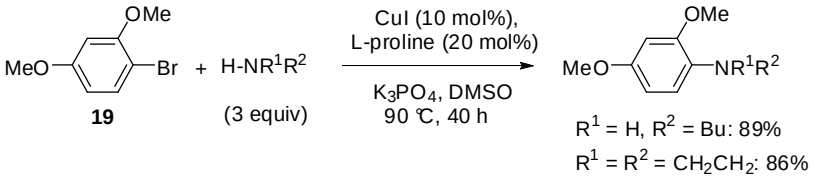
[21] For a review on Pd-catalyzed coupling reactions of aryl chlorides, see: A. F. Littke, G. C. Fu, *Angew. Chem. Int. Ed.* **2002**, *41*, 4176.
[22] a) R. Cramer, D. R. Coulson, *J. Org. Chem.* **1975**, *40*, 2267; b) H. J. Christau, J. R. Desmurs, *Ind. Chem. Libr.* **1995**, *7*, 240; c) J. P. Wolfe, S. L. Buchwald, *J. Am. Chem. Soc.* **1997**, *119*, 6054.
[23] B. A. Frieman, B. R. Taft, C.-T. Lee, T. Butler, B. H. Lipshutz, *Synthesis* **2005**, 2989.
[24] B. H. Lipshutz, H. Ueda, *Angew. Chem. Int. Ed.* **2000**, *39*, 4492.
[25] G. Manolikakes, A. Gavryushin, P. Knochel, *J. Org. Chem.* **2008**, *73*, 1429.



Scheme 7: Nickel-catalyzed amination of aryl chlorides.

1.1.3 Copper

Many efforts have been made to improve the Ullmann condensation reaction[26] and to turn it into a viable alternative to the more common Pd-catalyzed reactions.[27] The harsh reaction conditions (high temperatures, long reaction times, the presence of strong bases and the use of stochiometric amounts of copper or copper salts) make the Ullmann coupling unattractive. Significant progress towards the development of milder reaction conditions was achieved by using bidentate ligands like aliphatic diamines,[28] ethylene glycol,[29] diethylsalicylamide,[30] 1,10-phenanthroline and its derivatives,[31] amino acids[32] and amino-alcohols.[33] For instance, by using L-proline as promoter, the coupling of aryl iodides or bromides like **19** with aliphatic primary amines, aliphatic cyclic secondary amines or electron-rich primary aryl amines can be carried out already at temperatures between 60 °C and 90 °C (Scheme 8).[34]

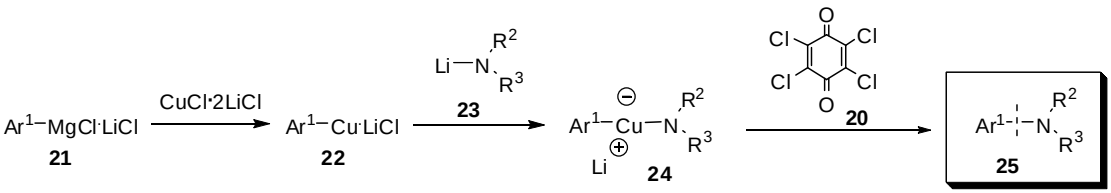


Scheme 8: Cu-catalyzed amination of an electron-rich aryl bromide.

[26] F. Ullmann, *Ber. Dt. Chem. Ges.* **1903**, *36*, 2382.
[27] K. Kunz, U. Scholz, D. Ganzer, *Synlett* **2003**, 2428.
[28] a) A. Klapars, J. C. Antilla, X. Huang, S. L. Buchwald, *J. Am. Chem. Soc.* **2001**, *123*, 7727; b) J. C. Antilla, J. M. Baskin, T. E. Barder, S. L. Buchwald, *J. Org. Chem.* **2004**, *69*, 5578.
[29] F. Y. Kwong, A. Klapars, S. L. Buchwald, *Org. Lett.* **2002**, *4*, 581.
[30] F. Y. Kwong, S. L. Buchwald, *Org. Lett.* **2003**, *5*, 793.
[31] a) R. K. Gujadhur, C. G. Bates, D. Venkataraman, *Org. Lett.* **2001**, *3*, 4315; b) D. van Allen, D. Venkataraman, *J. Org. Chem.* **2003**, *68*, 4590; c) R. A. Altman, S. L. Buchwald, *Org. Lett.* **2006**, *8*, 2779.
[32] a) D. W. Ma, Q. Cai, H. Zhang, *Org. Lett.* **2003**, *5*, 2453; b) Q. Cai, W. Zhu, H. Zhang, Y. D. Zhang, D. W. Ma, *Synthesis* **2005**, 496.
[33] a) Z. K. Lu, R. J. Twieg, S. P. D. Huang, *Tetrahedron Lett.* **2003**, *44*, 6289; b) Z. Lu, R. J. Twieg, *Tetrahedron* **2005**, *61*, 903.
[34] H. Zhang, Q. Cai, D. Ma, *J. Org. Chem.* **2005**, *70*, 5164.

1.2 Oxidative Amination Reaction

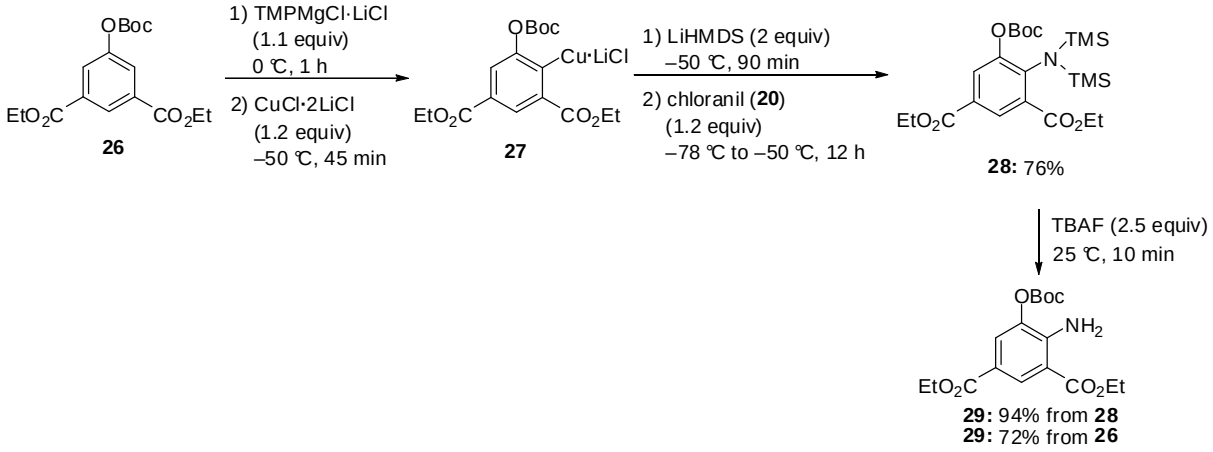
The oxidative amination reaction of amidocuprates is a complement to transition-metal-catalyzed amination reactions. Inspired by the previous studies by *Ricci*[35] as well as *Yamamoto* and *Maruoka*,[36] focused on the use of oxygen as oxidant for converting amidocuprates to various amines, the *Knochel* group examined further oxidation reagents for their use in such cross-coupling reactions. In this new synthetic protocol for the preparation of polyfunctional primary, secondary and tertiary aryl and heteroaryl amines *via* oxidative coupling of amidocuprates, chloranil (**20**) proved to be the most efficient oxidant.[37] Organomagnesium reagents of type **21** are transmetalated with CuCl·2LiCl to the corresponding copper derivatives **22**, which after treatment with a lithium amide of type **23** result in the formation of amidocuprates **24**. Oxidation with chloranil (**20**) finally affords the amines of type **25** in good yields (Scheme 9).



Scheme 9: General scheme for the oxidative amination reaction.

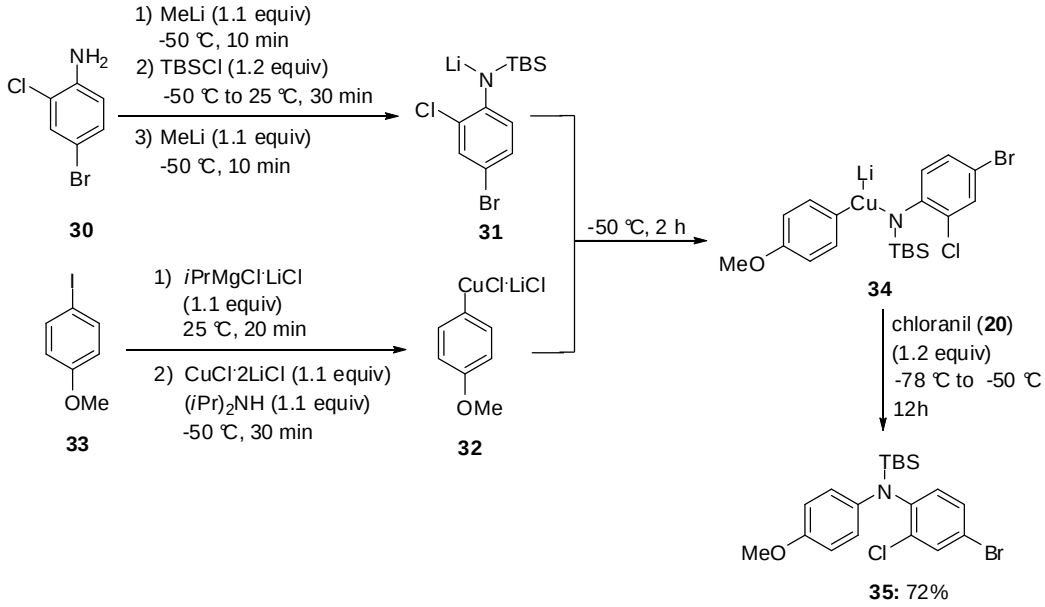
For the synthesis of primary amines, the diester **26** was magnesiated with TMPMgCl·LiCl (TMP = 2,2,6,6-tetramethylpiperidyl)[38] leading to an arylmagnesium derivative which was treated with CuCl·2LiCl giving the corresponding arylcopper derivative **27** followed by the addition of LiHMDS furnishing an amidocuprate. This copper reagent reacted with chloranil (**20**) leading to the *N*,*N*-bis(trimethylsilyl)amine derivative **28** in 76% yield. A facile desilylation was achieved with TBAF providing the arylamine **29** in 94% yield (Scheme 10).

[35] a) A. Casarini, P. Dembech, D. Lazzari, E. Marini, G. Reginato, A. Ricci, G. Seconi, *J. Org. Chem.* **1993**, *58*, 5620; b) A. Alberti, F. Canè, P. Dembech, D. Lazzari, A. Ricci, G. Seconi, *J. Org. Chem.* **1996**, *61*, 1677; c) F. Canè, D. Brancaleoni, P. Dembech, A. Ricci, G. Seconi, *Synthesis* **1997**, 545; d) P. Bernardi, P. Dembech, G. Fabbri, A. Ricci, G. Seconi, *J. Org. Chem.* **1999**, *64*, 641.
[36] H. Yamamoto, K. Maruoka, *J. Org. Chem.* **1980**, *45*, 2739.
[37] a) V. del Amo, S. R. Dubbaka, A. Krasovskiy, P. Knochel, *Angew. Chem. Int. Ed.* **2006**, *45*, 7838; b) M. Kienle, S. R. Dubbaka, V. del Amo, P. Knochel, *Synthesis* **2007**, 1272.
[38] A. Krasovskiy, V. Krasovskaya, P. Knochel, *Angew. Chem. Int. Ed.* **2006**, *45*, 2958.



Scheme 10: Oxidative amination affording a primary amine.

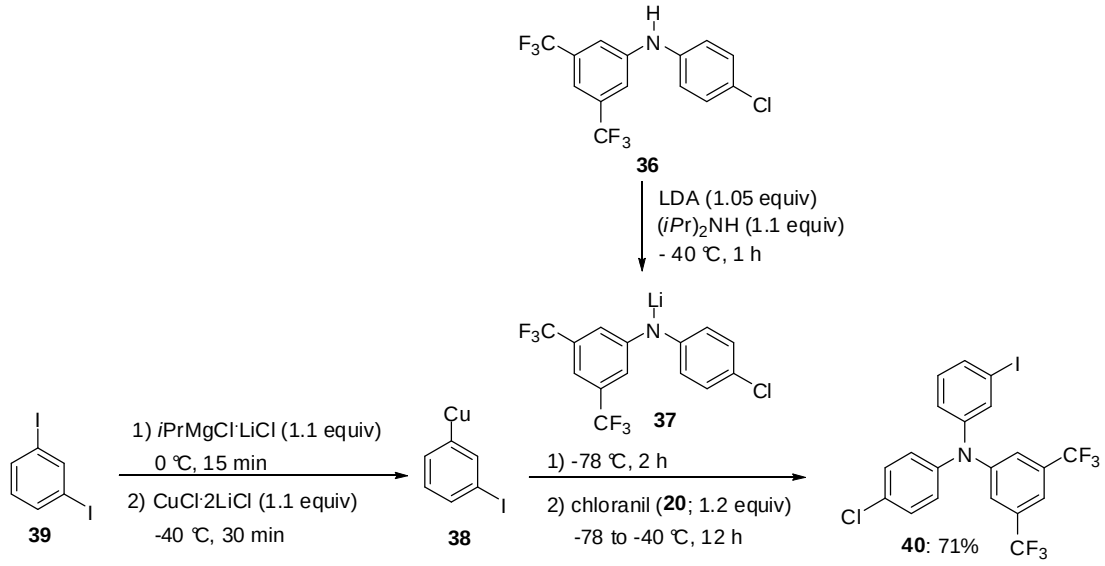
Secondary amines were prepared from an aniline derivative such as **30** (Scheme 11). Its *in situ* protection with a *tert*-butyldimethylsilyl group was performed by lithiation with methyllithium followed by the addition of *tert*-butylchlorodimethylsilane leading to a *N*-silylamine. Further treatment with methyllithium gave the lithium amide **31** which was treated with the arylcopper reagent **32**. This copper reagent was prepared from 4-iodoanisole (**33**) by an I/Mg-exchange reaction using *i*PrMgCl·LiCl[39] and subsequent transmetalation with CuCl·2LiCl. The resulting lithium amidocuprate **34** was treated with chloranil (**20**) providing the silyl-protected polyfunctional diarylamine **35** in 72% yield.



Scheme 11: Oxidative amination affording a protected secondary amine.

[39] A. Krasovskiy, P. Knochel, *Angew. Chem. Int. Ed.* **2004**, *43*, 3333.

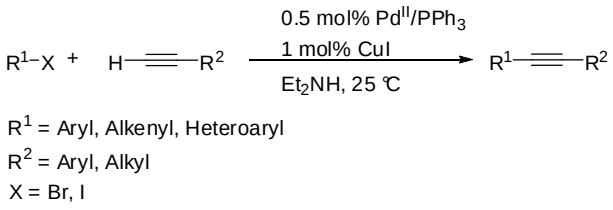
Finally, the preparation of triarylamines can be performed using the same approach. For example, the lithiation of the secondary amine **36** with LDA afforded the lithium amide **37** which reacted with the copper reagent **38** furnishing the corresponding lithium amidocuprate. The copper reagent **38** was prepared by an I/Mg-exchange on 1,3-diiodobenzene (**39**), followed by the transmetalation with CuCl·2LiCl. After treatment with chloranil the polyfunctional triarylamine **40** was obtained in 71% yield.



Scheme 12: Oxidative amination affording a tertiary amine.

2. Sonogashira Reactions

Polyfunctional alkynes are important intermediates for the preparation of natural products, pharmaceuticals and organic materials[40] such as molecular wires.[41] The Sonogashira reaction[42] and the Negishi cross-coupling[43] are very powerful methods for preparing polyfunctional alkynes via the formation of a $C(sp^2)$-C(sp) bond (Scheme 13). Thus, aryl bromides and aryl iodides are successfully coupled with acetylenes in the presence of an amine (e.g. Et_2NH, NEt_3) and a palladium catalyst to the corresponding functionalized acetylenes.

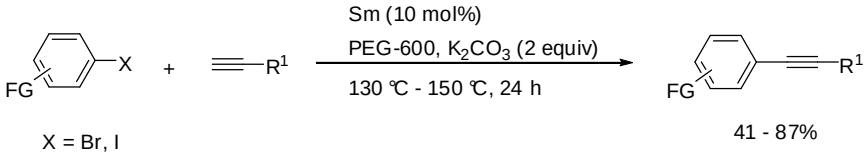


Scheme 13: General scheme for a Sonogashira reaction.

Recently, a palladium- and ligand-free Sonogashira coupling reaction was published.[44] In this protocol, various aryl bromides and –iodides were smoothly coupled with arylacetylenes

[40] Modern Acetylene Chemistry (Eds.: P. J. Stang, F. Diederich), Wiley-VCH, Weinheim, **1995**.
[41] a) C. S. Hartley, E. L. Elliott, J. S. Moore, *J. Am. Chem. Soc.* **2007**, *129*, 4512; for excellent reviews, see: b) W. Zhang, J. S. Moore, *Angew. Chem. Int. Ed.* **2006**, *46*, 4416; c) J. Wu, W. Pisula, K. Müllen, *Chem. Rev.* **2007**, *107*, 718.
[42] a) K. Sonogashira, Y. Tohda, N. Hagihara, *Tetrahedron Lett.* **1975**, *16*, 4467; b) K. Takahashi, Y. Kuroyama, K. Sonogashira, *Synthesis* **1980**, 627; c) K. Sonogashira, *J. Organomet. Chem.* **2002**, *653*, 46; d) L. A. Agrofoglio, I. Gillaizeau, Y. Saito, *Chem. Rev.* **2003**, *103*, 1875; e) *Metal-Catalyzed Cross-Coupling Reactions;* (Eds.: F. Diederich, P. J. Stang), Wiley-VCH, Weinheim, **1998**; f) J. Hassan, M. Sévignon, C. Gozzi, E. Schulz, M. Lemaire, *Chem. Rev.* **2002**, *102*, 1359; g) S. Kotha, K. Lahiri, D. Kashinath, *Tetrahedron* **2002**, *58*, 9633; h) A. F. Littke, G. C. Fu, *Angew. Chem. Int. Ed.* **2002**, *41*, 4176; i) S. P. Stanforth, *Tetrahedron* **1998**, *54*, 263; j) R. R. Tykwinski, *Angew. Chem. Int. Ed.* **2003**, *42*, 1566; k) for an excellent review, see: H. Doucet, J.-C. Hierso, *Angew. Chem. Int. Ed.* **2007**, *46*, 834; related papers, see : l) D. Gelman, S. L. Buchwald, *Angew. Chem. Int. Ed.* **2003**, *42*, 5993; m) M. Eckhardt, G. C. Fu, *J. Am. Chem. Soc.* **2003**, *125*, 13642; n) T. Hundertmark, A. F. Littke, S. L. Buchwald, G. C. Fu, *Org. Lett.* **2000**, *2*, 1729; o) A. Köllhofer, T. Pullmann, H. Plenio, *Angew. Chem. Int. Ed.* **2003**, *42*, 1056; p) P. W. Böhm, W. A. Hermann, *Eur. J. Org. Chem.* **2000**, 3679; q) S. R. Dubbaka, P. Vogel, *Adv. Synth. Catal.* **2004**, *346*, 1793; r) C. Nájera, J. Gil-Moltó, S. Karlström, L. R. Falvello, *Org. Lett.* **2003**, *5*, 1451; s) M. Ansorge, T. J. J. Müller, *J. Organomet. Chem.* **1999**, *585*, 174; t) S. Thorand, N. Krause, *J. Org. Chem.* **1998**, *63*, 8551.
[43] a) E.-I. Negishi, *Acc. Chem. Res.* **1982**, *15*, 340; b) E.-I. Negishi, *J. Organomet. Chem.* **2002**, *653*, 34; c) E.-I. Negishi, L. Anastasia, *Chem. Rev.* **2003**, *103*, 1979; d) E.-I. Negishi, M. Qian, F. Zeng, L. Anastasia, D. Babinski *Org. Lett.* **2003**, *5*, 1597; e) L. Anastasia, E.-I. Negishi, *Org. Lett.* **2001**, *3*, 3113; f) B. Wang, M. Bonin, L. Micouin, *Org. Lett.* **2004**, *6*, 3481.
[44] J. Mao, M. Wu, G. Xie, S. Ji, *Adv. Synth. Catal.* **2009**, *351*, 2101.

using Samarium powder as catalyst providing the corresponding diarylacetylenes in moderate to very good yields (Scheme 14).



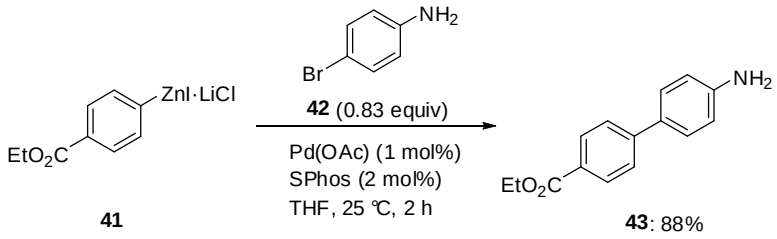
Scheme 14: Sm-catalyzed Sonogashira-type coupling reaction.

However, all these Sonogashira coupling reactions fail for the selective mono coupling of dihaloarenes and dihaloalkenes as well as for the coupling of sterically shielded haloarenes.

3. Negishi Cross-Coupling Reactions

Beside the Suzuki cross-coupling reaction, the Negishi reaction is one of the most powerful and widely used methods for making C_{sp2}-C_{sp2} bonds in organo metallic chemistry.[42, 45] In contrast to organoboron reagents (Suzuki reaction), organozinc reagents have proven to react under very mild conditions.[46] Thus, the Negishi cross-coupling allows the synthesis of products of high value for applications as pharmaceuticals and agrochemicals as well as for the preparation of new materials or natural products. Recently, *Knochel* reported that acidic hydrogens of amines, alcohols, phenols, and amides are compatible with the Negishi cross-coupling conditions and do not require the use of protecting groups.[47] Thus, the Pd(0)-catalyzed coupling of the zinc reagent **41** with 4-bromoaniline (**42**) furnished the desired biphenyl **43** in 88% yield. It is noteworthy that the zinc reagent had to be added over 90 min to the reaction mixture in order to avoid hydrolysis of the zinc reagent.

[45] a) *Metal-Catalyzed Cross-Coupling Reactions*, 2nd ed. (Eds.: A. de Meijere, F. Diederich), Wiley-VCH, Weinheim, **2004**; b) *Transition Metals for Organic Synthesis* (Eds.; M. Beller, C. Bolm) Wiley-VCH, Weinheim, **1998**; c) J. Tsuji, *Transition Metal Reagents ans Catalysts*, Wiley, New York, **1995**.
[46] a) E.-I. Negishi, L. F. Valente, M. Kobayashi, *J. Am. Chem. Soc.* **1980**, *102*, 3298; b) C. Han, S. L. Buchwald, *J. Am. Chem. Soc.* **2009**, *131*, 7532; c) S. Sase, M. Jaric, A. Metzger, V. Malakhov, P. Knochel, *J. Org. Chem.* **2008**, *73*, 7380; d) S. Son, G. C. Fu, *J. Am. Chem. Soc.* **2008**, *130*, 2756; e) X. Zeng, M. Quian, Q. Hu, E.-I. Negishi, *Angew. Chem. Int. Ed.* **2004**, *43*, 2259; f) B. H. Lipshutz, P. A. Blomgren, *J. Am. Chem. Soc.* **1999**, *121*, 5819.
[47] a) G. Manolikakes, Z. Dong, H. Mayr, J. Li, P. Knochel, *Chem. Eur. J.* **2009**, *15*, 1324; b) G. Manolikakes, M. A. Schade, C. Munoz Hernandez, H. Mayr, P. Knochel, *Org. Lett.* **2008**, *10*, 2765; c) G. Manolikakes, C. Munoz Hernandez, M. A, Schade, A. Metzger, P. Knochel, *J. Org. Chem.* **2008**, *73*, 8422.

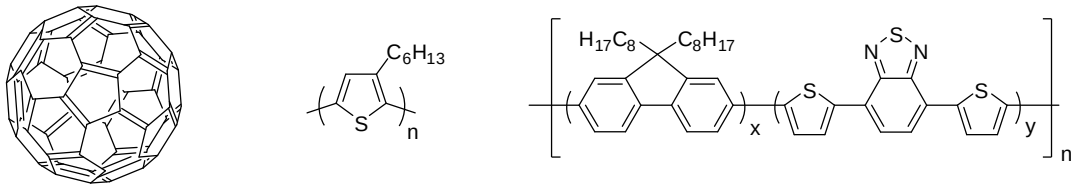


Scheme 15: Palladium-catalyzed cross-coupling of the zinc reagent **41** with 4-bromoaniline (**42**).

4. Preparation of Small Oligomers for the Application in Organic Solar Cells

One of the largest challenges for the global society is to find and develop inexpensive renewable energy sources. Solar energy might be one of the best solutions for this major problem, since the sun provides about 120 000 terawatts to the earths's surface.[48] Whereas silicon-based photovoltaic cells already find broad application in daily life, their production still consumes a lot of energy. Furthermore, their highest efficiency is limited to a range between 20% and 30%. Thus, the development of organic solar cells is of great interest. The first organic solar cell was reported by *Tang* more than 20 years ago. Since this initial work organic solar cells have undergone a great progress leading to efficiencies of more than 5% nowadays and are envisioned to reach efficiencies of more than 30%.[49] Organic solar cells are mainly based upon the concept of donor-acceptor heterojunctions.[50] These materials consist of two organic semiconductors, the electron-donor and the electron-acceptor.[51] In a typical bulk heterojunction photovoltaic cell, the acceptor is made up of a fullerene **44**. For the donor, mainly P3HT (**45,** poly-3-hexylthiophene) is used. The latest generations of organic solar cells contain a copolymer of type **46**.

[48] M. Grätzel, *Acc. Chem. Res*. **2009**, *42*, 1788.
[49] a) J. Chen, Y. Cao, *Acc. Chem. Res*. **2009**, *42*, 1709; b) P. Heremans, D. Cheyns, B. P. Rand, *Acc. Chem. Res*. **2009**, *42*, 1740.
[50] D. Wynands, B. Männig, M. Riede, K. Leo, E. Brier, E. Reinold, P. Bäuerle, *J. Appl. Phys.* **2009**, *106*, 054509.
[51] a) J.-L. Brédas, J. E. Norton, J. Cornil, V. Coropceanu, *Acc. Chem. Res*. **2009**, *42*, 1691; b) O. Inganäs, F. Zhang, M. R. Andersson, *Acc. Chem. Res*. **2009**, *42*, 1731; J. Roncali, *Acc. Chem. Res*. **2009**, *42*, 1719.



44 **45** **46**

Figure 2: Examples of an acceptor and donors used in blended organic solar cells.

After absorption of light an electron of the donor (P3HT) is ecited and transferred to the acceptor (fullerene). After forming these excitons, they start to diffuse. As soon as the excitons are dissociated, a charge is generated which can then be collected (Figure 3).[52]

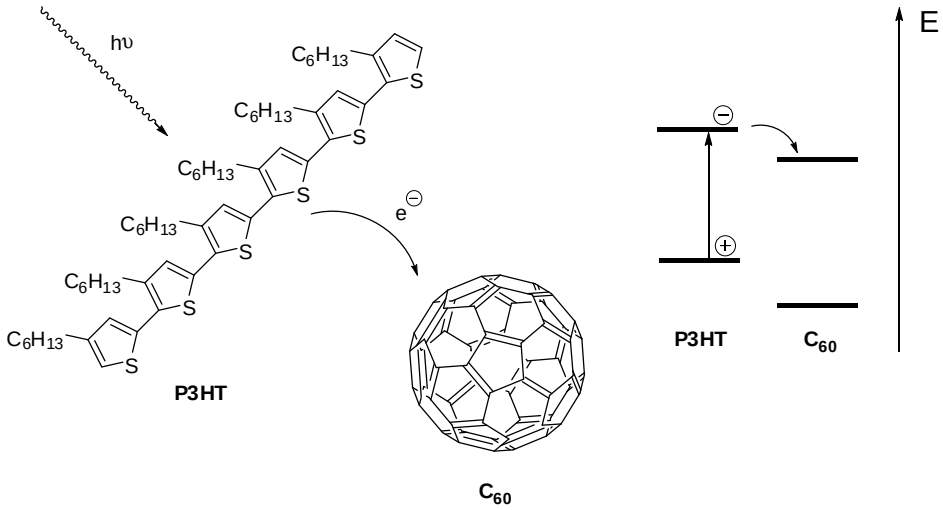


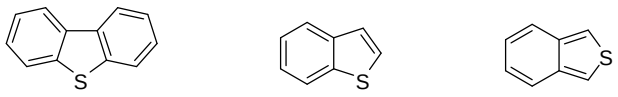
Figure 3: Illustration of a photoinduced charge transfer and exciton formation.

The efficiency of organic solar cells can be tuned by the used donors and acceptors bearing functional groups. Since the selective functionalization of fullerenes is still a problem, the fine tuning of donors seems to be more promising.

[52] a) B. C. Thompson, J. M. J. Fréchet, *Angew. Chem. Int. Ed.* **2008**, *47*, 58; b) S. Günes, H. Neugebauer, N. S. Sariciftci, *Chem. Rev*. **2007**, *107*, 1324.

5. Synthesis of Dibenzothiophenes and Related Classes of S-Heterocycles via an Anionic Electrocyclization

Polycylic systems like dibenzothiophenes **47**, benzo[*b*]thiophenes **48**, and benzo[*c*]thiophenes **49** have found numerous applications as dyes, pharmaceuticals, agrochemicals, or as building blocks for the synthesis of conducting polymers (Figure 4).[53,54]

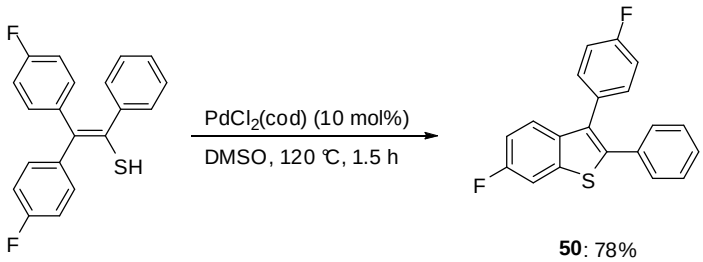


47 **48** **49**

Figure 4: Benzothiophenes **47**-**49**.

Several straightforward syntheses of such S-heterocycles have been recently reported using various synthetic strategies.[55]

For example, *Inamoto* reported a Pd-catalyzed synthesis of benzo[*b*]thiophenes from thioenols.[55e] A C-H-activation and subsequent intramolecular cyclication ring closure gave the desired benzothiophene **50** in up to 78% yield (Scheme 16).



50: 78%

Scheme 16: Pd-catalyzed ring closure leading to the benzothiophene **50**.

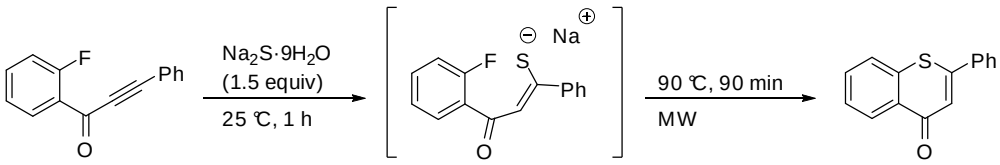
[53] a) M. D. Andrews, *Science of Synthesis,* Ed. E. J. Thomas, **2000**, *10*, 211; b) C. M. Rayner, M. A. Graham, *Science of Synthesis,* Ed. E. J. Thomas, **2000**, *10*, 155; c) T. L. Gilchrist, S. J. Higgins, *Science of Synthesis,* Ed. E. J. Thomas, **2000**, *10*, 185.

[54] For reviews on modern aspects of S-substituted aromatics and S-heterocycles, see: M. Gingras, J.-C. Raimundo, Y. M. Chabre, *Angew. Chem. Int. Ed.* **2006**, *45*, 1686.

[55] a) I. Nakamara, T. Sato, Y. Yamamoto, *Angew. Chem. Int. Ed.* **2006**, *45*, 4473; b) R. Sanz, Y. Fernandez, M. P. Castroviejo, A. Perez, F. J. Fananas, *J. Org. Chem.* **2006**, *71*, 629; c) K. Sadorn, W. Sinananwanich, J. Areephong, C. Nerungsi, C. Wongma, C. Pakawatchai, T. Thongpanchang, *Tetrahedron Lett.* **2008**, *49*, 4519; d) Q. Zhao, L. Li, Y. Fang, D. Sun, C. Li, *J. Org. Chem.* **2009**, *74*, 459; e) K. Inamoto, Y. Arai, K. Hiroya, T. Doi, *Chem. Commun.* **2008**, 5529 ; f) T. Dahl, C. W. Tornoe, B. Bang-Andersen, P. Nielson, M. Jorgensen, *Angew. Chem. Int. Ed.* **2008**, *47*, 1726; g) P. P. Singh, A. K. Yadav, H. Ila, H. Junjappa, *J. Org. Chem*. **2009**, *74*, 5496; h) O. Goyot, M. Gingras, *Tetrahedron Lett.* **2009**, *50*, 1977; i) J. T. Henssler, A. J. Matzger, *Org. Lett*. **2009**, *11*, 3144.

Palladium-catalyzed ring closures of this type leading to S-heterocycles are especially difficult, but could be realized recently despite the deactivating effect of sulfur on transition metal catalysts.[56]

Recently, Müller reported a novel Palladium-free ring closure for the preparation of 4*H*-thiochromen-4-ones. Thus, a Michael addition of sodium sulfide nonahydrate to readily available alkynones led to the hydrosulfide adduct **51**.[57] Then, an intramolecular nucleophilic aromatic substitution (S_NAr) gave the desired 4*H*-thiochromen-4-ones of type **52**.



51 **52**

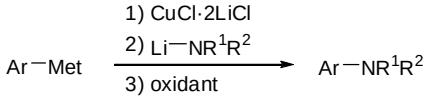
Scheme 17: S_NAr reaction leading to the S-heterocycle of type **52**.

[56] a) C. S. Bryan, J. A. Braunger, M. Lautens, *Angew. Chem. Int. Ed.* **2009**, *48*, 7064; b) J.-Y. Lee, P. H. Lee, *J. Org. Chem.* **2008**, *73*, 7413; c) M. A. Fernandez-Rodriguez, Q. Shen, J. F. Hartwig, *J. Am. Chem. Soc*. **2006**, *128*, 2180; d) C. Mispelaere-Canivet, J.-F. Spindler, S. Perrio, P. Beslin, *Tetrahedron* **2005**, *61*, 5253; e) M. Murata, S. L. Buchwald, *Tetrahedron* **2004**, *60*, 7397.

[57] a) B. Willy, T. J. J. Müller, *Synlett*, **2009**, 1255; b) B. Willy, W. Frank, T. J. J. Müller, *Org. Biomol. Chem.* **2010**, *8*, 90.

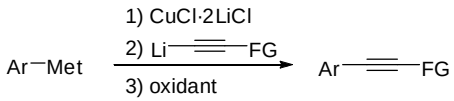
6. Objectives

The Pd(0)-catalyzed amination of aryl halides is one of the most powerful tools for the introduction of amines. However, this reaction often requires harsh reaction conditions such as strong bases and high temperatures. Therefore, the extension of the oxidative amination towards the tolerance of further functional groups was studied. In addition, the use of various aliphatic as well as aromatic amines was investigated. Furthermore, the use of other organometallic reagents (e.g. zinc or manganese) beside organomagnesium reagents was developed (Scheme 18).



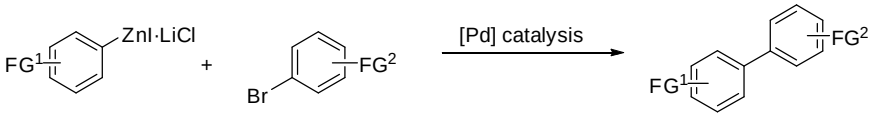
Scheme 18: Oxidative amination employing various organometallic reagents.

Moreover, the concept of the oxidative cross-coupling was extendend from the amination reaction towards the formation of carbon-carbon bonds. Particularly, an "Oxidative Sonogashira Reaction" has been studied in detail (Scheme 19).



Scheme 19: Oxidative Sonogashira-type reaction.

Another subject dealt with the improvement of the Negishi cross-coupling reaction with regard to tolerance of acidic protons. The objective was to accelerate the reaction dramatically. This would make the *in situ* hydrolysis of the zinc-reagents negligible (Scheme 20). Thus, the cross-coupling of zinc reagents with aryl halides bearing acidic protons would be possible without the need of protection.

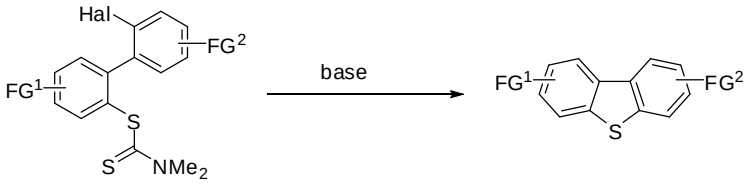


Scheme 20: Pd-catalyzed cross-coupling reactions with organozinc compounds.

Although various kinds of donors for organic blended solar cells are already tested, new oligomers are still required in order to improve the efficiency of these solar cells. In this work, various small oligomers with several functional groups were synthesized. Thus, the preparation of dimers, trimers and tetramers possessing both electron-donating and electron-withdrawing groups was studied in detail (Figure 5).

Figure 5: Various heterocyclic oligomers.

A new approach for the synthesis of functionalized dibenzothiophenes and annulated benzothiophenes was developed. The aim of this work was to avoid a transition metal catalyzed reaction for the ring closure. Thus, a facile access S-heterocycles would be avaible without the problem of deactivation of sulfur on transition metal catalyst.



Scheme 21: Intramolecular ring closing reaction leading to functionalized dibenzothiophenes.

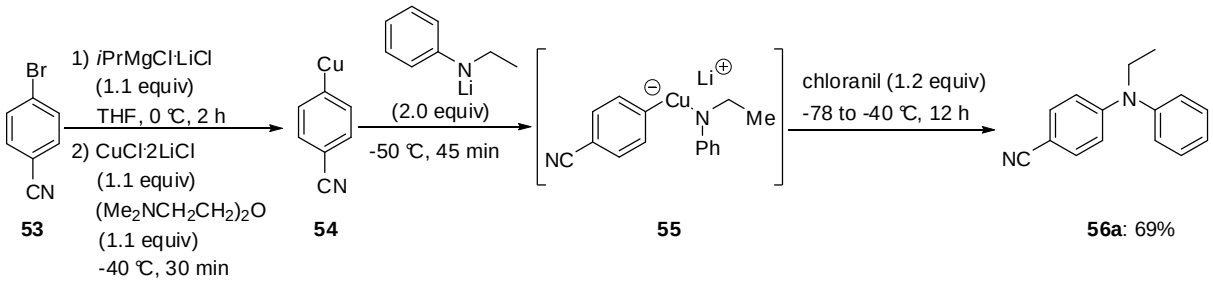
B

RESULTS AND DISCUSSION

1. Oxidative Amination Using Organomagnesium Reagents

As mentioned above, the Pd-catalyzed amination reaction is widely used and gives access to a wide range of functionalized amines. However, the group tolerance is limited in some cases, especially the monoamination of dihaloarenes is an ongoing problem.

Thus, the aim of this work was to extend the scope of this amination procedure towards the tolerance of functional groups as well as the tolerance of sterically hindered substrates. Furthermore, the use of aliphatic and benzylic amines should be tested. Therefore, the amination of 4-bromobenzonitrile was accomplished: 4-Bromobenzonitrile (**53**) was treated with *i*PrMgCl·LiCl (1.1 equiv, 0 °C, 2 h) furnishing the corresponding organomagnesium reagent which was transmetalated providing the organocopper species **54** (Scheme 22). The addition of *bis*[2-(dimethylamino)ethyl]ether (1.1 equiv) proved to be of importance to suppress the formation of the corresponding aryl-homocoupling product. Then, further addition of lithium ethylanilide (2 equiv, –50 °C, 45 min) gave the lithium amidocuprate **55**. This amidocuprate was oxidized with chloranil (1.2 equiv, –78 to –50 °C, 12 h) yielding the biarylamine **56a** in 69%.

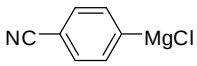
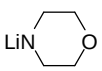
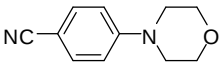
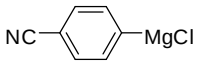
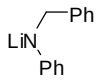
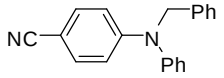
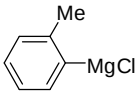
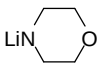
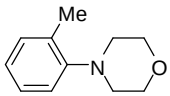
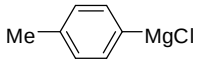
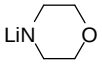
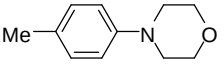
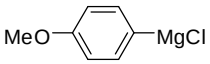
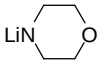
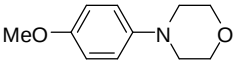
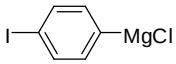
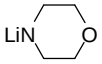
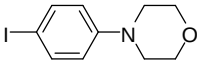
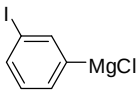
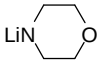
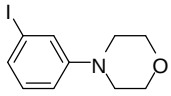
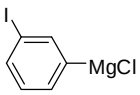
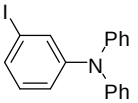
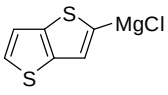
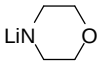
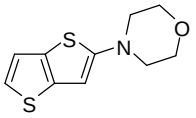


Scheme 22: Oxidative amination of 4-bromobenzonitrile (**53**).

In order to investigate the scope of this oxidative amination, the magnesium reagent **58a** was treated with the amines **59a** and **59b** in the same manner, furnishing the amines **56b** and **56c** and 78% and 69% yield, respectively (Table 1, entries 1-2). Additionally, lithium morpholide was used in reactions with various organomagnesium reagents. Thus, the sterically hindered *ortho*-tolylmagnesium chloride (**58b**) as well as *para*-tolylmagnesium chloride (**58c**) were successfully aminated providing the amines **56d** and **56e** in 58% and 71% yield (Table 1, entries 3-4). Furthermore, the reaction of the electron-donating magnesium reagent **58d** with lithium morpholide **59a** gave the desired amine **56f** in 55% yield (Table 1, entry 5). The

magnesium reagents **58e** and **58f**, obtained from the corresponding diiodobenzenes by a selective I/Mg-exchange reacted with several lithium amides providing the tertiary amines **56g** and **56h** and the functionalized triaryl amine **56i** in 59% - 65% yield (Table 1, entries 6-8). Thienothiophene was smoothly magnesiated using TMPMgCl·LiCl leading to the magnesium reagent **58g**. Oxidative amination with lithium morpholide **59a** gave the amine **56j** in 61% yield (Table 1, entry 9).

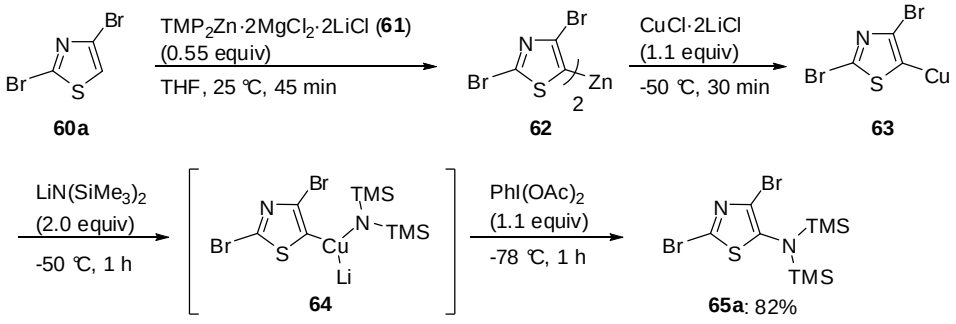
Table 1: Oxidative amination of various arylmagnesium reagents mediated by Cu(I).

entry	substrate	amine	product	yield, %[a]
1	 **58a**	 **59a**	 **56b**	78
2	 **58a**	 **59b**	 **56c**	69
3	 **58b**	 **59a**	 **56d**	58
4	 **58c**	 **59a**	 **56e**	71
5	 **58d**	 **59a**	 **56f**	55
6	 **58e**	 **59a**	 **56g**	65
7	 **58f**	 **59a**	 **56h**	59
8	 **58f**	 **59c**	 **56i**	65
9	 **58g**	 **59a**	 **56j**	61

[a] Yield of isolated, analytically pure product.

2. Oxidative Amination Using Organozinc Reagents

For the oxidative amination of heterocyclic copper derivatives obtained by transmetalation from the corresponding zinc organometallics, the use of chloranil as oxidation reagent was unsatisfactory. The reaction of such systems gave beside the expected amines large quantities of undesired homocoupling products of the zinc reagents. Furthermore, the scale-up of such aminations was difficult with this oxidation reagent. Thus, we extended our previously described protocol towards the oxidative amination of arylzinc reagents in the presence of CuCl and the new oxidation reagent $PhI(OAc)_2$. We started our investigations on the amination of functionalized thiazoles. Thus, 2,4-dibromothiazole (**60a**) was zincated using $TMP_2Zn{\cdot}2MgCl_2{\cdot}2LiCl$[58] (**61**), furnishing the diarylzinc compound **62**. This zinc reagent was very stable and did not undergo halogen dance reactions as it is usually the case for electron-rich heteroarylzinc compounds.[59] After the addition of CuCl·2LiCl (1.1 equiv) the corresponding copper derivative **63** was obtained. Further addition of $LiN(SiMe_3)_2$ (2.0 equiv) afforded the amidocuprate **64**. The subsequent oxidation of **64** using $PhI(OAc)_2$ (1.1 equiv) provided the thiazole amine derivative **65a** in 82% yield with only traces of the corresponding homocoupling product as by-product (Scheme 23; Table 2, entry 1).



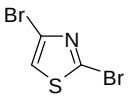
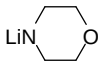
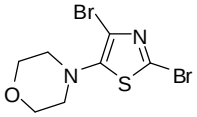
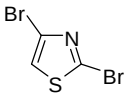
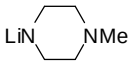
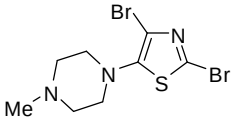
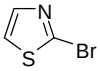
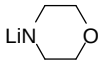
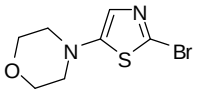
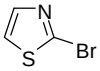
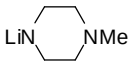
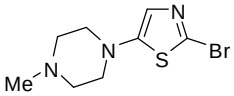
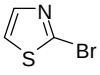
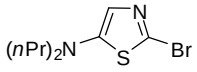
Scheme 23: Zincation of 2,4-dibromothiazole (**60a**) with TMP_2Zn (**61**) followed by an oxidative amination reaction.

[58] a) S. H. Wunderlich, P. Knochel, *Angew. Chem. Int. Ed*. **2007**, *46*, 7685; b) S. H. Wunderlich, P. Knochel, *Chem. Commun*. **2008**, 6387; c) S. H. Wunderlich, P. Knochel, *Org. Lett.* **2008**, *10*, 4705; d) M. Mosrin, P. Knochel, *Org. Lett.* **2009**, *11*, 1837.

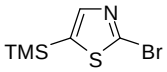
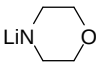
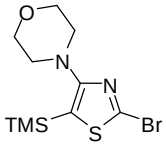
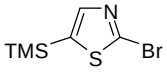
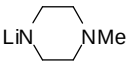
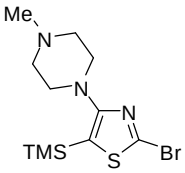
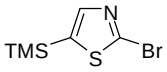
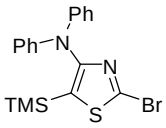
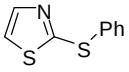
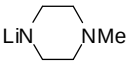
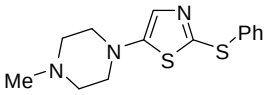
[59] a) J. Clayden, *Organolithiums: Selectivity for Synthesis*; Pergamon, 2002; b) M. Mallet, G. Quéguiner, *Tetrahedron* **1982**, *38*, 3035; c) P. Rocca, C. Cochennec, F. Marsais, L. Thomas-dit-Dumont, A. Godard, G. Quéguiner, *J. Org. Chem.* **1993**, *58*, 7832; d) E. Arzel, P. Rocca, F. Marsais, A. Godard, G. Quéguiner, *Tetrahedron* **1999**, *55*, 12149.

A range of thiazoles were aminated in 61 – 76% by this procedure (Table 2). Thus, the copper derivative **63** was also reacted with lithium morpholide and lithium *N´*-methylpiperazide, leading to the tertiary amines **65b** and **65c** in 70% and 61% yield, respectively (Table 2, entries 1-2). 2-Bromothiazole (**60b**) was aminated with various cyclic and acyclic amines as well, furnishing the 2-bromothiazole amines **65d**-**65f** in 63% – 75% yield (Table 2, entries 3-5). Using this method, thiazole-4-amines are also available. Thus, the zincation and subsequent transmetalation and amination of 2-bromo-5-trimethylsilylthiazole (**60c**) resulted in the formation of the tertiary amines **65g** and **65h** in 73- 75% yield and the triarylamine **65i** in 76% yield (Table 2, entries 6–8). 2-(Phenylthio)thiazole (**60c**) was also successfully aminated, providing the amine **65j** in 72% yield (Table 2, entry 9). (Phenylthio)thiazoles of this type are useful intermediates, since the phenylthio group can serve as a leaving group in cross-coupling reactions.[60]

Table 2: Oxidative amination of various functionalized thiazoles after zincation with TMP_2Zn (**61**) and subsequent oxidative amination.

entry	substrate	conditions[a]	amine	product	yield, %[b]
1	 **60a**	25, 0.75	 **59a**	 **65b**	70
2	 **60a**	25, 0.75	 **59d**	 **65c**	61
3	 **60b**	25, 2	 **59a**	 **65d**	75
4	 **60b**	25, 2	 **59d**	 **65e**	71
5	 **60b**	25, 2	 **59e**	 **65f**	63

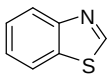
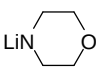
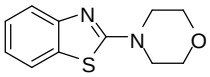
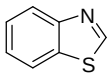
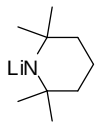
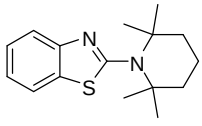
[60] a) M. Egi, L. S. Liebeskind, *Org. Lett*. **2003**, *5*, 801; b) A. Metzger, L. Melzig, C. Despotopoulou, P. Knochel, *Org. Lett*. **2009**, *11*, 4228.

6	 **60c**	25, 8	 **59a**	 **65g**	73
7	 **60c**	25, 8	 **59d**	 **65h**	75
8	 **60c**	25, 8	 **59c**	 **65i**	76
9	 **60c**	25, 2	 **59d**	 **65j**	72

[a] Reaction conditions for the metalation with $TMP_2Zn \cdot 2MgCl_2 \cdot 2LiCl$ (°C, h). [b] Yield of isolated, analytically pure product.

We also have applied this method to the amination of other heteroaromatics, such as benzothiazole (**60d**). Thus, benzothiazole (**60d**) was smoothly zincated at 25 °C using TMP_2Zn (**61**). Subsequent oxidative amination with lithium morpholide (**59a**) and TMPLi (**59f**) furnished the tertiary amines **65k** and **65l** in yields of 60 – 73% (Table 3, entries 1–2).

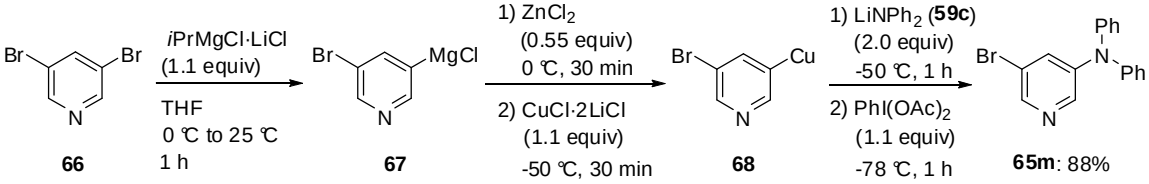
Table 3: Oxidative amination of benzothiazole (**60d**) leading to tertiary amines.

entry	substrate	conditions[a]	amine	product	yield, %[b]
1	 **60d**	25, 1	 **59a**	 **65k**	73
2	 **60d**	25, 1	 **59f**	 **65l**	60

[a] Reaction conditions for the metalation with $TMP_2Zn \cdot 2MgCl_2 \cdot 2LiCl$ (°C, h). [b] Yield of isolated, analytically pure product.

Furthermore, we have found that these zinc reagents are suitable for larger-scale oxidative amination reactions, regardless if the zinc reagent is formed by metalation using $TMP_2Zn \cdot 2MgCl_2 \cdot 2LiCl$ or by addition of a $ZnCl_2$ solution to a preformed magnesium reagent.

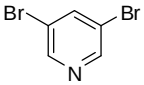
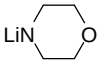
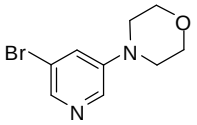
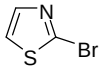
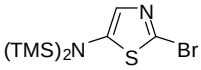
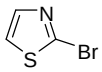
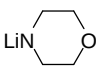
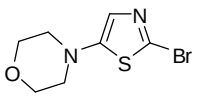
Thus, the treatment of 3,5-dibromopyridine (**66**, 10 mmol) with *i*PrMgCl·LiCl provided the corresponding magnesium reagent **67**. Subsequent addition of $ZnCl_2$ (0.55 equiv) and CuCl·2LiCl (1.1 equiv) provided the copper species **68**. After the reaction with lithium diphenylamide (**59c**) and $PhI(OAc)_2$ the desired triarylamine **65m** is obtained in 88% yield (Scheme 24).

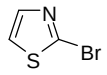
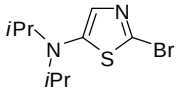


Scheme 24: Oxidative amination of 3,5-dibromopyridine (**66**) performed on a 10 mmol scale.

Similarly, the amination of 3,5-dibromopyridine (**66**) with lithium morpholide (**59a**) furnished the tertiary amine **65n** in 71% yield (Table 4, entry 1). Additionally, after zincation of 2-bromothiazole (**60b**) with TMP_2Zn (**61**) the corresponding zinc species was also smoothly aminated on a 10 mmol-scale and the desired amines **65d** and **65o** – **65p** were obtained in 75% to 80% yield (Table 4, entries 2–4). The amine **65p** proved to be of special interest for the synthesis of small oligomers which can serve as donors in blended organic solar cells (see Chapter 6).

Table 4: Oxidative amination of zinc reagents on a 10 mmol scale.

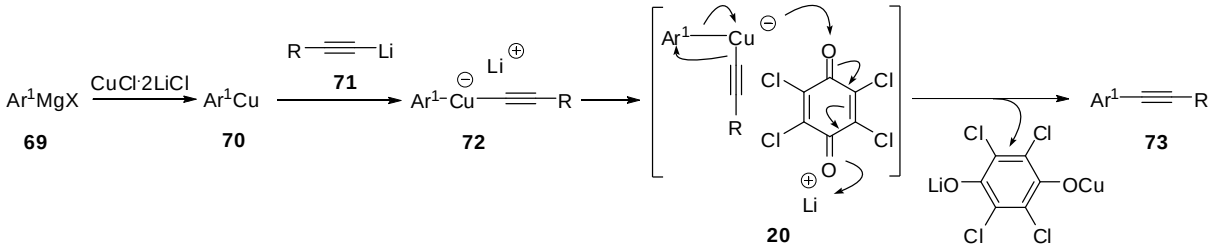
entry	substrate	conditions[a]	lithium amide	product	yield, %[b]
1	 **66**	*i*PrMgCl·LiCl (25, 1)	 **59a**	 **65n**	71
2	 **60b**	$TMP_2Zn·2MgCl_2·2LiCl$ (25, 0.75)	$LiN(SiMe_3)_2$	 **65o**	75
3	 **60b**	$TMP_2Zn·2MgCl_2·2LiCl$ (25, 0.75)	 **59a**	 **65d**	80

4	 **60b**	$TMP_2Zn \cdot 2MgCl_2 \cdot 2LiCl$ (25, 0.75)	LDA	 **65p**	65

[a] Reaction conditions for the metalation with $TMP_2Zn \cdot 2MgCl_2 \cdot 2LiCl$ or Br/Mg-exchange with *i*PrMgCl·LiCl (°C, h). [b] Yield of isolated, analytically pure product.

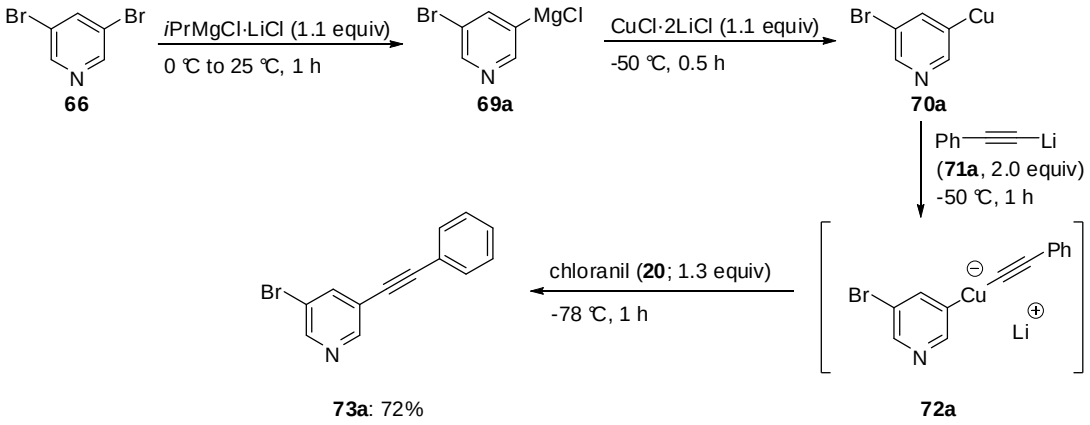
3. Copper(I)-Mediated Oxidative Coupling of Lithium Acetylides and Aryl Magnesium Reagents in the Presence of Chloranil

The transmetalation of an aryl or heteroaryl magnesium halide Ar^1MgX (**69**) to the corresponding copper reagent Ar^1Cu (**70**) using the THF soluble complex CuCl·2LiCl and its reaction with an alkynyllithium of type (**71**) should result in the formation of a mixed lithium aryl(alkynyl)cuprate **72.**[61] Its treatment with chloranil (**20**) provides after an oxidative cross-coupling reaction polyfunctional alkynes of type **73** (Scheme 25).



Scheme 25: Tentative mechanism for the oxidative cross-coupling of arylcoppers **70** with alkynyllithiums **71** using chloranil (**20**) leading to alkynes of type **73.**

Accordingly, 5-bromo-3-pyridylmagnesium chloride (**69a**) prepared by a Br/Mg-exchange starting from 3,5-dibromopyridine (**66**), using *i*PrMgCl·LiCl (1.1 equiv, 0 °C to 25 °C, 1 h) was transmetalated to the corresponding organocopper species **70a** using CuCl·2LiCl (1.1 equiv, –50 °C, 25 min) (Scheme 26).



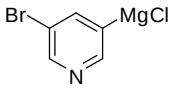
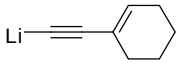
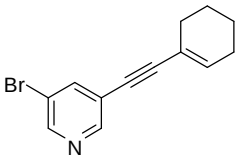
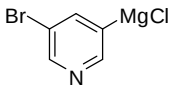
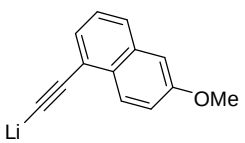
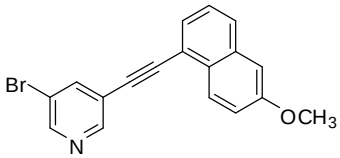
Scheme 26: Oxidative cross-coupling of a pyridine derivative.

[61] B. H. Lipshutz, S. Sengupta, *Org. React.* **1992**, *41*, 135.

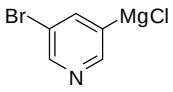
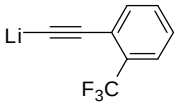
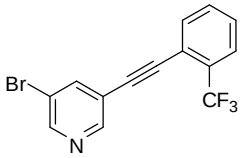
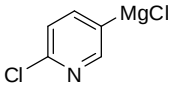
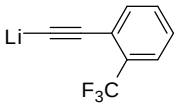
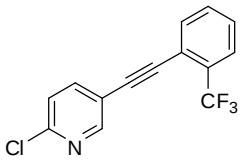
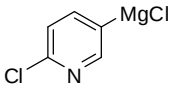
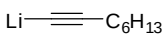
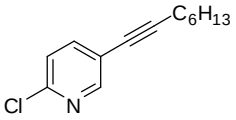
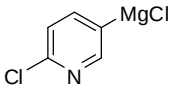
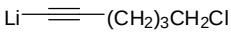
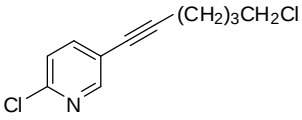
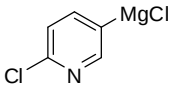
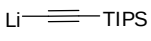
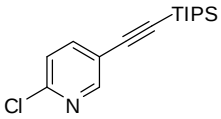
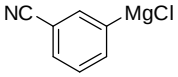
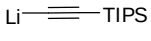
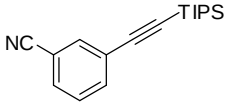
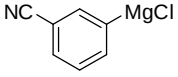
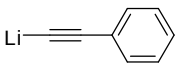
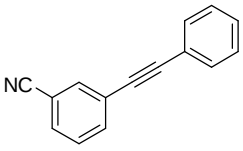
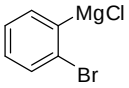
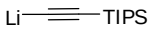
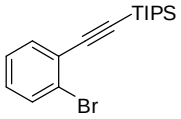
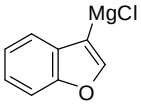
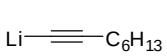
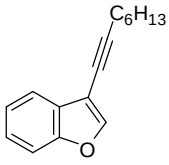
After the addition of phenylethynyllithium (**71a**, 2.0 equiv, –50 °C, 1 h) the resulting mixed cuprate **72a** was treated with chloranil (1.3 equiv, –78 °C to –50 °C, 3 h) providing the alkynylated pyridine **73a** in 72% yield.

Various alkynyllithiums bearing a cyclohexenyl ring (**71b**) or different aryl substituents (**71c-d**) were coupled successfully with the pyridine magnesium reagent **69a**, affording the desired polyfunctional alkynes **73b-73d** in 42-72% yields (Table 5, entries 1-3). Naphthyl derivatives related to **73c** have been used for the preparation of drugs, pesticides, dyes, polymers and other goods.[62] After a Br/Mg-exchange on 2-chloro-5-bromopyridine the resulting magnesium-reagent **69b** was oxidatively alkynylated with different alkynyllithiums **71d-71g**. Thus, the polyfunctional alkynes **73e-73h** bearing different subsitutents (Table 5, entries 4-7) were obtained in 58-70% yield. Beside heteroaromatics, different functional arylbromides were applied to this oxidative cross-coupling reaction. Thus, 3-bromobenzonitrile was smoothly converted to the corresponding magnesium reagent **69c**. After a copper-mediated oxidative cross-coupling the alkynes **73i** and **73j** were obtained in 62-72% yield (Scheme 5, entries 8-9). A monofunctionalization of 1,2-dibromobenzene can be performed as well. Thus, after a selective Br/Mg-exchange and subsequent transmetalation with CuCl·2LiCl, the corresponding copper-derivative was oxidatively alkynylated providing the alkyne **73k** in 68% yield (Table 5, entry 10). The heterocyclic magnesium derivative **69e** also reacted with **71e** affording the corresponding 3-alkynylbenzofuran derivative **73l** in 62% yield (Table 5, entry 11).

Table 5: Oxidative coupling of various organomagnesium reagents with lithium acetylides leading to alkynes.

entry	grignard reagent	lithium acetylide	alkyne	yield [%][a]
1	 **69a**	 **71b**	 **73b**	70
2	 **69a**	 **71c**	 **73c**	72

[62] a) R. E. Kirk, D. F. Othmer *Concise Encyclopedia of Chemical Technology*, Wiley-VCH, New York, **1985**; b) D. M. Bowles, J. E. Anthony, *Org. Lett.* **2000**, *2*, 85.

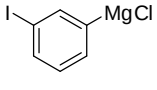
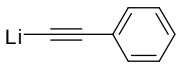
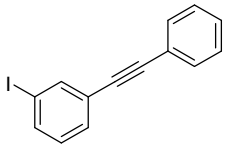
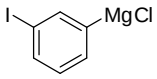
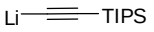
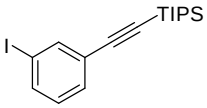
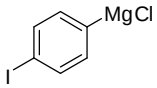
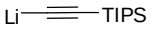
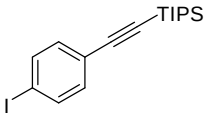
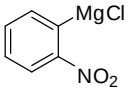
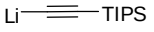
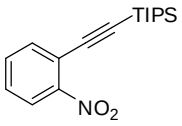
3	 **69a**	 **71d**	 **73d**	42
4	 **69b**	 **71d**	 **73e**	62
5	 **69b**	 **71e**	 **73f**	60
6	 **69b**	 **71f**	 **73g**	58
7	 **69b**	 **71g**	 **73h**	70
8	 **69c**	 **71g**	 **73i**	72
9	 **69c**	 **71a**	 **73j**	62
10	 **69d**	 **71g**	 **73k**	68
11	 **69e**	 **71e**	 **74l**	62

[a] Yield of isolated, analytically pure product.

Beside a Br/Mg-exchange, the magnesium-reagents can also be obtained by an I/Mg-exchange. Thus, 1,3-diiodobenzene was converted to the corresponding mono-magnesium reagent **58f** using *i*PrMgCl·LiCl. After transmetalation and oxidative cross-coupling with

various lithium acetylides the alkynes **73m** and **73n** were obtained in yields of 59% and 77%, respectively (Table 6, entries 1-2). In the same fashion the magnesium reagent **58e**, obtained from 1,4-diiodobenzene, was coupled with the lithium acetylide **71g** providing the alkyne **73o** in 63% yield (Table 6, entry 3). Even nitro groups were tolerated in this procedure. Thus, the treatment of 1-iodo-2-nitrobenzene with *i*PrMgCl·LiCl furnished the magnesium reagent **69f**. Subsequent transmetalation with CuCl·2LiCl, followed by the addition of alkynyllithium **71g** and chloranil gave the alkyne **73p** in 41% yield (Table 6, entry 4).

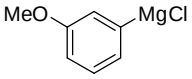
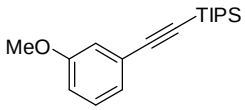
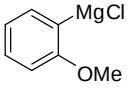
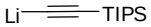
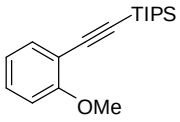
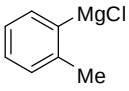
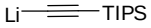
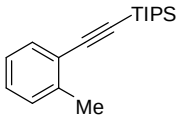
Table 6: Oxidative coupling of organomagnesium reagents obtaind by I/Mg-exchange with lithium acetylides in the presence of chloranil.

entry	grignard reagent	lithium acetylide	alkyne	yield [%][a]
1	 **58f**	 **71a**	 **73m**	59
2	 **58f**	 **71g**	 **73n**	77
3	 **58e**	 **71g**	 **73o**	63
4	 **69f**	 **71g**	 **73p**	41

[a] Yield of isolated, analytically pure product.

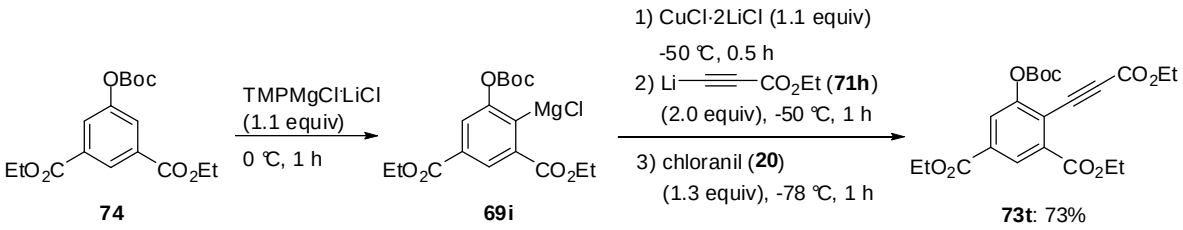
Electron-rich magnesium reagents like **69g**-**69h** and **58b** were obtained via Mg-insertion in the presence of LiCl. The generated magnesium reagents were transmetalated with CuCl·2LiCl and coupled with the lithium acetylide **71g** providing the alkynes **73q**-**73s** in 65-68 % yields (Table 7, entries 1-3).

Table 7: Oxidative coupling of organomagnesium reagents obtained by Mg-insertion and lithium acetylides using chloranil as oxidant.

entry	grignard reagent	lithium acetylide	alkyne	yield [%][a]
1	 **69g**	 **71g**	 **73q**	68
2	 **69h**	 **71g**	 **73r**	65
3	 **58b**	 **71g**	 **73s**	68

[a] Yield of isolated, analytically pure product.

Aromatics and heteroaromatics bearing acidic protons were magnesiated using TMPMgCl·LiCl. Thus, the direct magnesiation of the diester **74** with TMPMgCl·LiCl (1.1 equiv, 0 °C, 1 h) afforded the arylmagnesium chloride **69i**. Transmetalation with CuCl·2LiCl and the addition of the lithium acetylide **71h** followed by the oxidation with chloranil gave the unsaturated triester **73t** in 73% yield (Scheme 27).

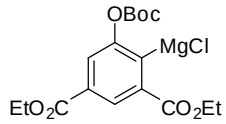
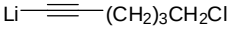
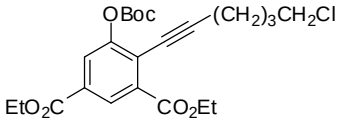
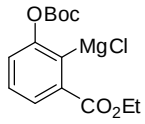
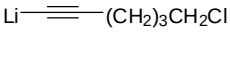
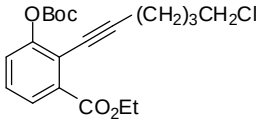
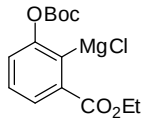
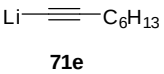
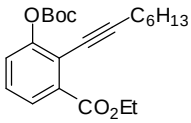
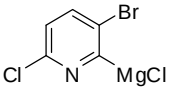
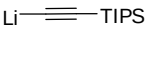
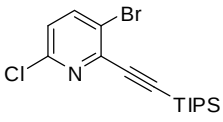


Scheme 27: Oxidative cross-coupling of a polyfunctional copper reagent.

A range of sterically hindered arylmagnesium reagents[63] **69i**-**69j** were found to undergo oxidative couplings with alkynyllithiums **71e**-**71f** leading to the polyfunctional alkynes **73u**-**73w** in 51-70% yield (Table 8, entries 1-3). 5-Bromo-2-chloropyridine can be selectively deprotonated using TMPMgCl·LiCl providing the corresponding pyridyl magnesium chloride **69k**. After an oxidative cross-coupling the corresponding functionalized alkyne **73x** is obtained in 68 % yield (Table 8, entry 4).

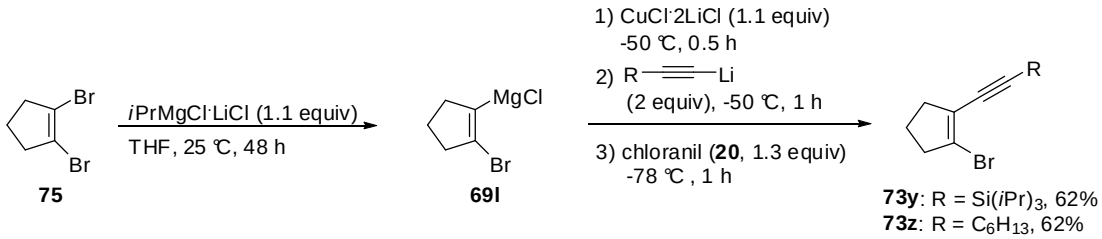
[63] W. Lin, O. Baron, P. Knochel, *Org. Lett* .**2006**, *8*, 5673.

Table 8: Oxidative coupling of magnesiated compounds and lithium acetylides.

entry	grignard reagent	lithium acetylides	alkyne	yield [%][a]
1	 **69i**	 **71f**	 **73u**	68
2	 **69j**	 **71f**	 **73v**	70
3	 **69j**	 **71e**	 **73w**	69
4	 **69k**	 **71g**	 **73x**	68

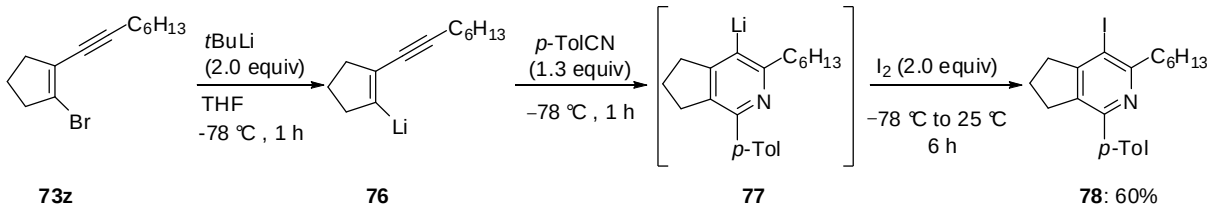
[a] Yield of isolated, analytically pure product.

This oxidative coupling has been extended to a preparation of enynes. Thus, 1,2-dibromocyclopentene **75** has been converted to the corresponding alkenylmagnesium reagent by the treatment with *i*PrMgCl·LiCl (1.1 equiv, 25 °C, 48 h) providing 2-bromocyclopentenylmagnesium chloride **69l** which was transmetalated to the corresponding copper reagent. Addition of an alkenyllithium followed by chloranil afforded the bromo-enynes **73y** and **73z** in 62 % yield (Scheme 28).



Scheme 28: Oxidative cross-coupling of cyclic alkenylcoppers with various alkynyllithiums using chloranil (**20)**.

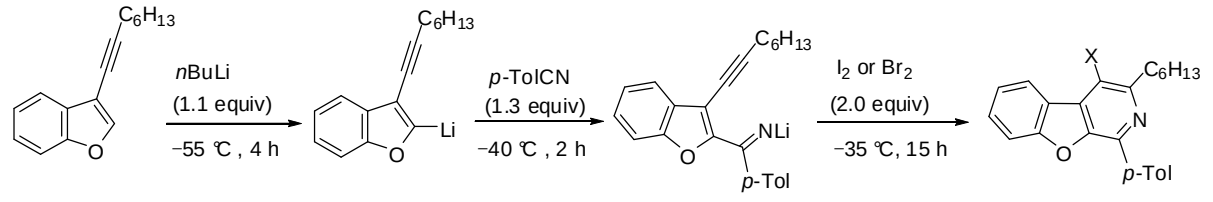
The alkyne **73l** as well as the unsaturated bromo-substituted alkyne **73z** is well suited for the preparation of new annulated pyridines.[64] Thus, the reaction of **73z** with *t*BuLi (2 equiv, –78 °C, 1 h) provides the lithium intermediate **76** which readily adds *p*-TolCN[65] (1.3 equiv, –78 °C, 1 h) leading via a remarkably fast 6-endo-dig ring closure[66] to the lithiated pyridine derivative **77**. After iodolysis the polyfunctional annulated pyridine **78** is obtained in 60% yield (Scheme 29).



73z **76** **77** **78**: 60%

Scheme 29: Reaction of 1-lithio-1,3-enynes with tolunitrile leading to the pyridine derivative **78**.

Furthermore, the lithiation of the 3-alkynylbenzofuran **73l** in position 2 using *n*BuLi (1.1 equiv, –55 °C, 4 h) followed by the addition of *p*-TolCN (1.3 equiv, –40 °C, 2 h) furnished the intermediate **79**. After addition of iodine or bromine, the corresponding products **80a** and **80b** were obtained in yields of 62% and 55% (Scheme 30).



73l **79** **80a**: X = I, 62% **80b**: X = Br, 55%

Scheme 30: Reaction of benzofuran derivatives with tolunitrile leading to the pyridine derivatives **80a** and **80b**.

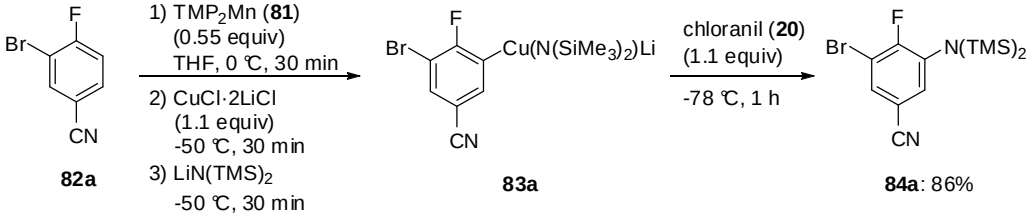
[64] For related syntheses of pyridine derivatives, see: a) Q. Huang, J. A. Hunter, R. C. Larock, *Org. Lett*. **2001**, *3*, 2973; b) K. R. Roesch, R. C. Larock, *J. Org. Chem*. **2002**, *67*, 86; c) M. Ohtaka, H. Nakamura, Y. Yamamoto, *Tetrahedron Lett*. **2004**, *45*, 7339; d) N. Asao, S. Yudha S., T. Nogami, Y. Yamamoto, *Angew. Chem. Int. Ed*. **2005**, *44*, 5526; e) D. Fischer, H. Tomeba, N. K. Pahadi, N. T. Patil, Y. Yamamoto, *Angew. Chem. Int. Ed*. **2007**, *46*, 4764; f) S. Obika, H. Kono, Y. Yasui, R. Yanada, Y. Takemoto, *J. Org. Chem*. **2007**, *72*, 4462; g) R. Yanada, S. Obika, H. Kono, Y. Takemoto, *Angew. Chem. Int. Ed*. **2006**, *45*, 3822; h) M. Nakamura, L. Llies, S. Otsubo, E. Nakamura, *Org. Lett*. **2006**, *8*, 2803.

[65] Cycloaddition of nitriles with monolithio- and dilithiobutadienes, see for example: J. Chen, Q. Song, C. Wang, Z. Xi, *J. Am. Chem. Soc*. **2002**, *124*, 6238.

[66] J. E. Baldwin, *J. Chem. Soc*., *Chem. Commun*. **1976**, 734.

4. Oxidative Cross-Coupling Reactions Using Organomanganese Reagents

The metalation of arenes and heterocycles is of considerable interest, since it allows the direct functionalization of an unactivated C-H bond by the stoichiometric formation of an organometallic intermediate. The use of sterically hindered metallic amides complexed by LiCl of the type $TMP_nMet^1 \cdot xMet^2X_m \cdot yLiCl$ (Met^1 = Mg,[38, 67] Zn,[56] Al;[68] Met^2 = Mg) has led to highly chemo- and regio selective metalations. The preparation of such amides where Met^1 is a transition metal has been envisioned since transition metals display reactivity pattern not accessible for main-group elements.[69] The new base $TMP_2Mn \cdot 2MgCl_2 \cdot 4LiCl$ (**81**) offers very convenient metalation conditions (close to room temperature, short reaction time) and has an excellent thermal stability.[70] Thus, it can be stored at 25 °C for more than eight weeks without appreciable decomposition. Besides the reaction of the generated organomanganese reagents with various electrophiles, we found that these compounds undergo Cu(I)-mediated oxidative cross-coupling reactions. Thus, the reaction of 3-bromo-4-fluorobenzonitrile (**82a**) with $TMP_2Mn \cdot 2MgCl_2 \cdot 4LiCl$ (**81**, 0.55 equiv, 0 °C, 30 min) followed by the reaction with CuCl·2LiCl (1.1 equiv, –50 °C, 30 min) and the addition of $LiN(SiMe_3)_2$ (2.0 equiv, –50 °C, 1 h) provided the lithium amidocuprate **83a** which by reaction with chloranil (**20**, 1.1 equiv, –78 °C, 1 h) afforded the TMS-protected aniline **84a** in 86% yield (Scheme 31).

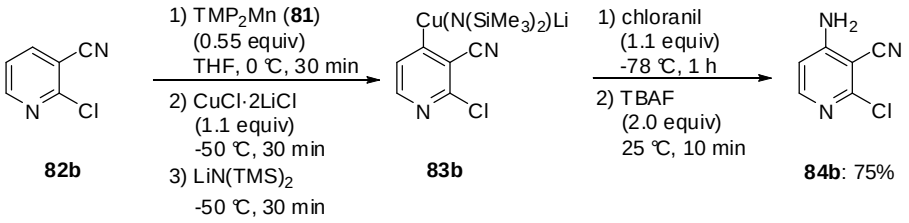


Scheme 31: Oxidative amination of a manganated arene leading to the polyfunctional amine **84a**.

Performing the same sequence with the corresponding arylmagnesium reagent provides a 10% lower yield of the aniline derivative **84a** (76%).

[67] a) N. Boudet, J. R. Lachs, P. Knochel, *Org. Lett.* **2007**, *9*, 5525; b) N. Boudet, S. R. Dubbaka, P. Knochel, *Org. Lett.* **2008**, *10*, 1715; c) A. H. Stoll, P. Knochel, *Org. Lett.* **2008**, *10*, 113; d) M. Mosrin, P. Knochel, *Org. Lett.* **2008**, *10*, 2497; e) G. C. Clososki, C. J. Rohbogner; P. Knochel, *Angew. Chem. Int. Ed.* **2007**, *46*, 7681; f) C. J. Rohbogner, G. C. Clososki, P. Knochel, *Angew. Chem. Int. Ed.* **2008**, *47*, 1503.
[68] S. H. Wunderlich, P. Knochel, *Angew. Chem. Int. Ed.* **2009**, *48*, 1501.
[69] B. Weidmann, D. Seebach, *Angew. Chem. Int. Ed.* **1983**, *22*, 31.
[70] S. H. Wunderlich, M. Kienle, P. Knochel, *Angew. Chem. Int. Ed.* **2009**, *48*, 7256.

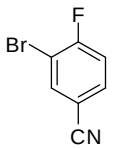
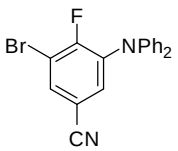
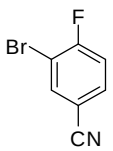
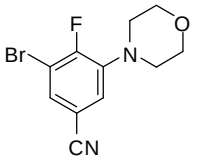
A similar amination was performed starting with the functionalized pyridine **82b**. The lithium amidocuprate **83b** underwent an oxidative amination mediated by chloranil and furnished after deprotection with TBAF (2.0 equiv, 25 °C, 10 min) the 4-aminopyridine **84b** in 75% yield (Scheme 32).

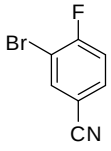
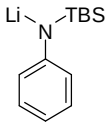
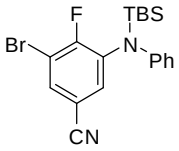
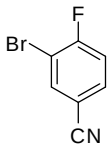
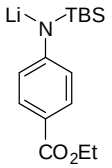
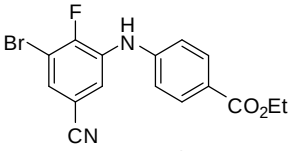
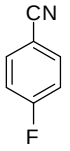
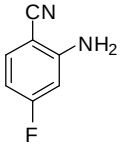
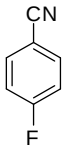
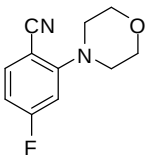
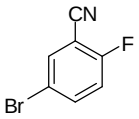
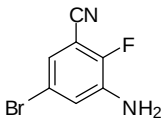
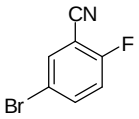
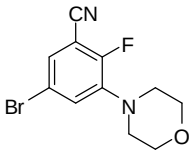
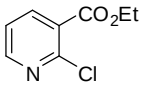
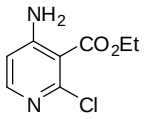
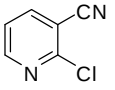
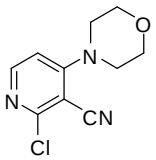


Scheme 32: Oxidative amination of a manganated heterocycle leading to polyfunctional amine **84b**.

This reaction sequence proved to be general and various aminated aromatics and pyridines have been prepared (Table 9). Thus, the treatment of the benzonitrile **82a** with several lithium amides afforded after oxidative amination the arylamines **84c**-**84f** in yields of 66-73% (Table 9, entries 1-4). The related functional benzonitriles **82c** and **82d** were oxidatively aminated leading to the amines **84g**-**84j** in 74-84% yield (Table 9, entries 5-8). Finally, the amination of the pyridine derivatives **82e** and **82b** with several amines provided the heteroarylamines **84k** and **84l** in 65% and 51% yield, respectively (Table 9, entries 9-10).

Table 9: Polyfunctional amines of type **84** obtained by the oxidative amination of diarylmanganese reagents with lithium amides mediated by chloranil.

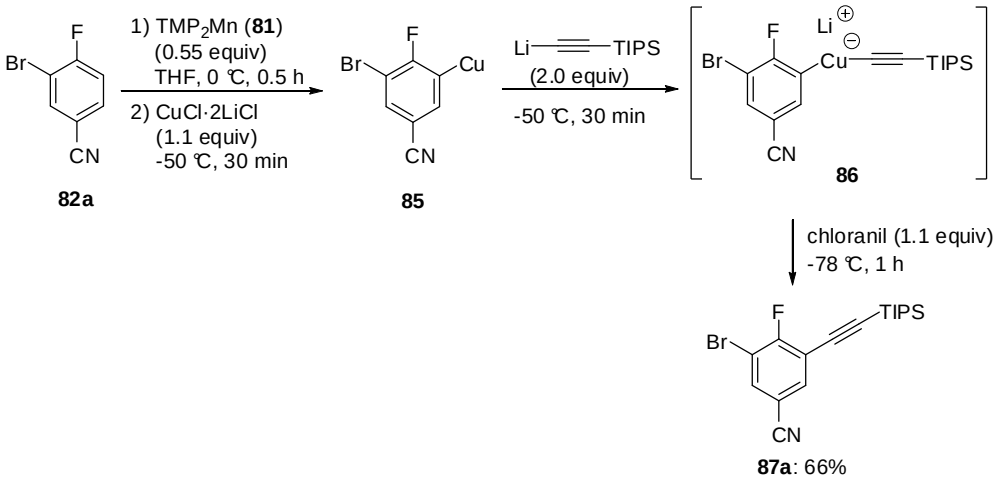
entry	substrate	conditions[a]	amine	product	yield, %[b]
1	 **82a**	0, 0.5		 **84c**	66 (59)[c]
2	 **82a**	0, 0.5		 **84d**	73 (62)[c]

3	 **82a**	0, 0.5		 **84e**	66
4	 **82a**	0, 0.5		 **84f**	66[d]
5	 **82c**	25, 2	$LiN(SiMe_3)_2$	 **84g**	75[e]
6	 **82c**	25, 2		 **84h**	81
7	 **82d**	0, 0.75	$LiN(SiMe_3)_2$	 **84i**	84[e]
8	 **82d**	0, 0.75		 **84j**	74
9	 **82e**	0, 0.5	$LiN(SiMe_3)_2$	 **84k**	65[e]
10	 **82b**	0, 0.5		 **84l**	51

[a] Reaction conditions for the metalation with $TMP_2Mn{\cdot}2MgCl_2{\cdot}4LiCl$ (°C, h). [b] Yield of isolated, analytically pure product. [c] The yield in parentheses refers to the reaction with the corresponding Mg-reagents. [d] A deprotection was performed using TBAF (1 equiv). [e] A deprotection was performed using TBAF (2 equiv).

Furthermore, this protocol could be extended to the oxidative cross-coupling of arylcopper reagents with lithum acetylides in the presence of chloranil. Thus, treatment of the copper-

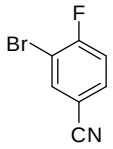
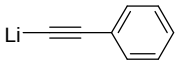
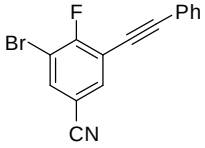
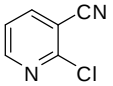
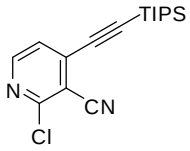
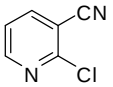
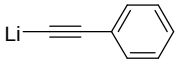
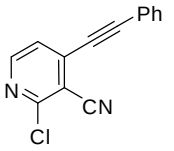
reagent **85** with the lithium acetylide **71g** gave the mixed cuprate **86** (Scheme 33). Subsequent oxidation with chloranil (**20**) provided the acetylene **87a** in 66% yield.



Scheme 33: Oxidative coupling of a manganated arene leading to the acetylene **87a**.

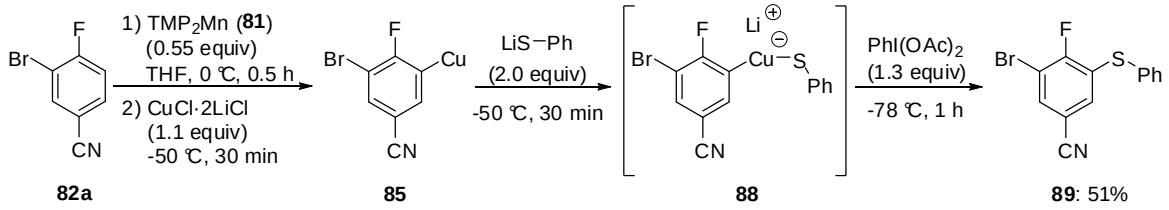
This procedure was applied to the oxidative coupling of the arene **82a** and the heterocycle **82b** with the lithium acetylides **71a** and **71g** furnishing the polyfunctional acetylenes **87b-87d** in yields of 52-62% yield (Table 10, entries 1-3).

Table 10: Oxidative coupling of manganated arenes with lithium acetylides.

entry	substrate	conditions[a]	lithium acetylide	product	yield, %[b]
1	 **82a**	0, 0.5	 **71a**	 **87b**	62
2	 **82b**	0, 0.5	**71g**	 **87c**	52
3	 **82b**	0, 0.5	 **71a**	 **87d**	54

[a] Reaction conditions for the metalation with $TMP_2Mn \cdot 2MgCl_2 \cdot 4LiCl$ (°C, h). [b] Yield of isolated, analytically pure product.

Interestingly, this oxidative cross-coupling can also be applied to the reaction of copper-reagents obtained from the corresponding manganese compounds with lithium benzenethiolate. Thus, the reaction of the copper-species **85** with lithium benzene thiolate afforded the cuprate **88** (Scheme 34). Since the oxidation with chloranil gave only traces of the expected product, $PhI(OAc)_2$ was used instead. Hence, this reaction provided the thioether **89** in 51% yield.

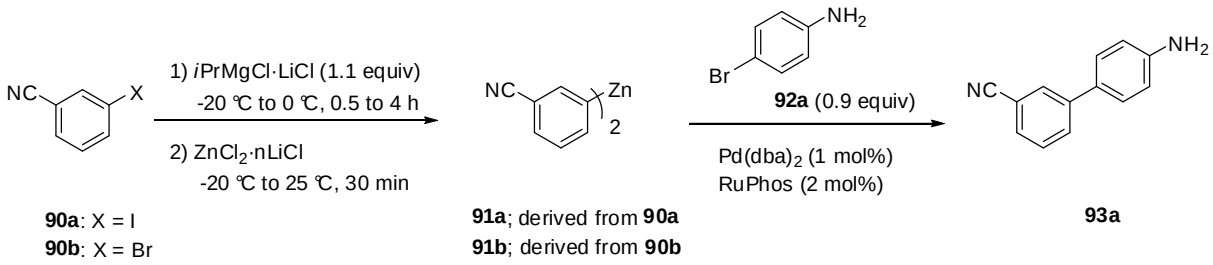


Scheme 34: Oxidative coupling of the arylcuprate **85** with lithium benzenethiolate forming the thioether **89**.

5. *i*PrI-Accelerated Negishi Cross-Coupling Reactions

As described above, the Negishi cross-coupling is a powerful tool for forming C_{sp2}-C_{sp2} bonds in organometallic chemistry. Recently, *Manolikakes* and *Knochel* reported that the Kumada cross-coupling is significantly accelerated in the presence of *i*PrI.[71] In this work we found that the Negishi cross-coupling can be accelerated by *i*PrI as well. Thus, allowing the Pd-catalyzed cross-coupling of diarylzinc reagents with arylbromides bearing various acidic protons without the need of protection.

Hence, the reaction of the zinc reagent **91a**, obtained from 3-iodobenzonitrile (**90a**) after exchange with *i*PrMgCl·LiCl and subsequent transmetalation with $ZnCl_2$·2LiCl (0.55 equiv), and 4-bromoaniline (**92a**) in the presence of $Pd(dba)_2$ (1 mol%) and RuPhos[72] (2 mol%) provided the biaryl **93a** in 89% after 10 min (Scheme 35; Table 11, entry 1).



Scheme 35: Pd-catalyzed cross-coupling of the zinc-reagent **91** with 4-bromoaniline (**92a**).

When stochiometric amounts of $ZnCl_2$·2LiCl (1.1 equiv) were used, the reaction proceeded slower, and reached full conversion after 1 h (Table 11, entry 2). Furthermore, the reaction of **91b**, derived from 3-bromobenzonitrile (**90b**) and transmetalated with 0.55 equiv of $ZnCl_2$·2LiCl, proceeded slowly and a conversion of only 26% was observed after 5 min and almost full conversion after 1 h (Table 11, entry 3). When the same reaction is carried out with 1.1 equiv of $ZnCl_2$·2LiCl, only traces of the expected are observed after 5 min (Table 11, entry 4). However, the accelerating effect can also be achieved by the addition of *i*PrI to the zinc reagent **91b** obtained from 3-bromobenzonitrile (**90b**) (Table 11, entry 5 compared to entry 1). Additionally, when $ZnCl_2$ (0.55 to 1.1 equiv) was used instead of $ZnCl_2$·2LiCl all reactions proceeded significantly slower (Table 11, entries 6-9).

[71] G. Manolikakes, P. Knochel, *Angew. Chem. Int. Ed.* **2009**, *48*, 205.
[72] For aryl-aryl Negishi cross-coupling reactions using RuPhos, see: J. E. Milne, S. L. Buchwald, *J. Am. Chem. Soc.* **2004**, 126, 13028.

This results showed that the fastest reaction can be obtained when $ZnCl_2 \cdot 2LiCl$ (0.55 equiv) were used and *i*PrI is present in the reaction mixture. Furthermore, this protocol allows for the first time the cross-coupling of aryl zinc reagents with arylbromides bearing acidic protons without the use of protecting groups or slow addition of the zinc reagent.[47]

Table 11: Negishi cross-coupling of the diarylzinc reagent **91** with 4-bromoaniline (**92**).

entry	X	$ZnCl_2 \cdot nLiCl$	Conv. 5 min[a]	Conv. 15 min[a]	Conv. 1 h[a]
1	I	n = 2; 0.55 equiv	86%	full conversion, 89% (isolated)	
2	I	n = 2; 1.10 equiv	26%	83%	full conversion[b]
3	Br	n = 2; 0.55 equiv	28%	52%	92%
4	Br	n = 2; 1.10 equiv	3%	10%	45%
5	Br	n = 2; 0.55 equiv	85%	93%	
6	I	n = 0; 0.55 equiv	62%	90%	full conversion
7	I	n = 0; 1.10 equiv	26%	69%	full conversion
8	Br	n = 0; 0.55 equiv	22%	67%	95%
9	Br	n = 0; 1.10 equiv	6%	21%	46%

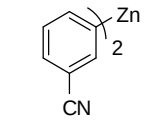
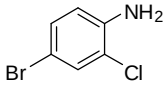
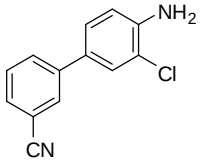
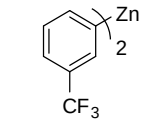
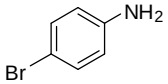
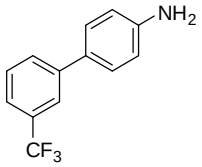
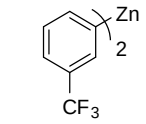
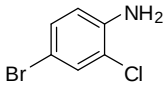
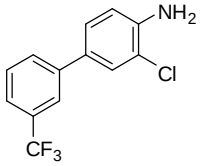
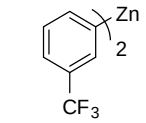
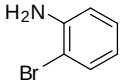
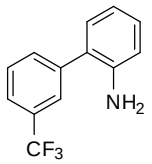
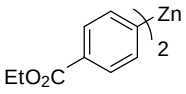
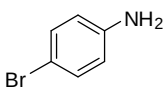
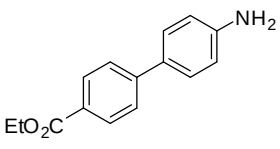
[a] Conversion was monitored by GC, based on consumption of 4-bromoaniline (**92a**). [b] Full conversion after 30 min.

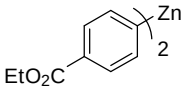
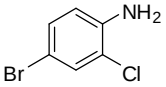
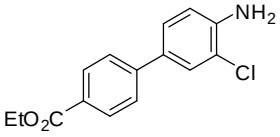
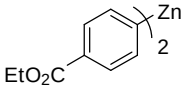
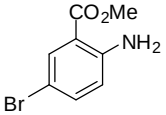
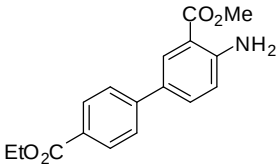
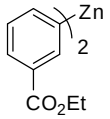
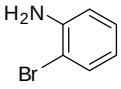
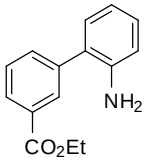
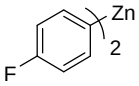
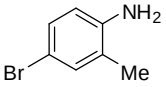
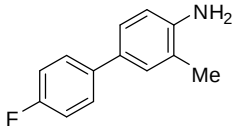
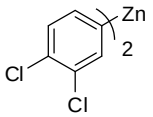
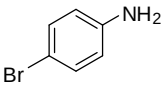
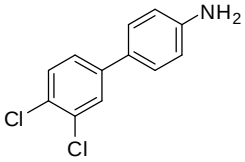
Having the best conditions in hand, we studied the scope of this new protocol towards the compatibility of other anilines and various functional groups.

By using this method, a range of functionalized organozinc species were efficiently coupled with functionalized aryl bromides bearing acidic protons. Thus, the reaction of bis(3-cyanophenyl)zinc **91a** with 4-bromo-2-chloroaniline (**92b**) in the presence of $Pd(dba)_2$ (1 mol%) and RuPhos (2 mol%) afforded the biphenyl **93b** within 5 min at 25 °C in 97% yield (Table 12, entry 1). In a similar manner, 3-iodobenzotrifluoride was converted to the corresponding bisarylzinc species **91b**. This reagent was successfully reacted with various bromoanilines **92a**-**92b** furnishing the amines **93c** – **93d** in 89-92 % yield (Table 12, entries 2–3). Furthermore, the zinc compound **91b** reacted with the sterically hindered 2-bromoaniline (**92c**) providing the biphenyl **93e** within 10 min in 80% yield (Table 12, entry 4). Additionally, this reaction also proceeds smoothly at larger scales (10 mmol), yielding the aniline derivative **93e** after the same time in 81%. Since functionalized magnesium reagents bearing an ester function show a low stability at room temperature this procedure was applied to the corresponding zinc reagents. Therefore, the zinc species **91c** reacted with the

bromoanilines **92a** and **92b** affording the biphenyls **93f** and **93g** in 88% and 91% yield (Table 12, entry 5-6). After reaction of **91c** with the methylester **92d**, the corresponding disester **93h** was obtained in 94% yield (Table 12, entry 7). 2-Bromoaniline (**92c**) was treated with the ester-substituted organozinc compound **91d** giving the aniline derivative **93i** within 10 min in 79% yield (Table 12, entry 8). We applied this procedure also for zinc reagents prepared by transmetalation from the corresponding arylmagnesium bromides. Thus, the reaction of the zinc reagent **91e** in the presence of *i*PrI with 4-bromo-2-methylaniline (**92e**) gave within 10 min the amine **93ji** in 94% yield (Table 12, entry 9). In a similar sequence the reaction of the dichlorozinc reagent **91f** with 4-bromoaniline (**92a**) furnished the biaryl **93k** in 76% yield (Table 12, entry 10).

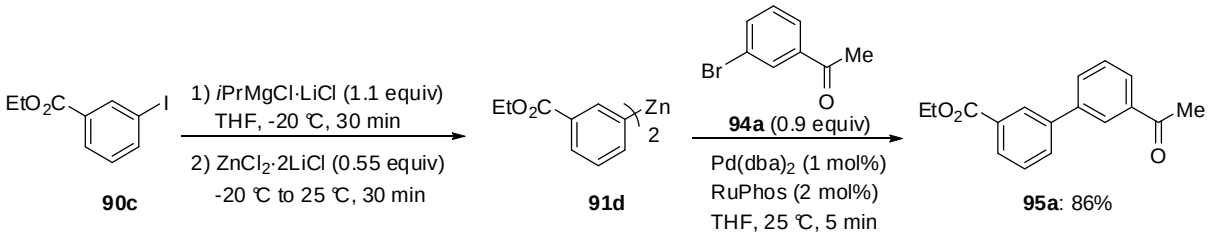
Table 12: Negishi cross-coupling of diarylzinc reagents of type **91** with various bromo anilines.

entry	substrate	time[a]	electrophile	product	yield, %[b]
1	 **91a**	5 min	 **92b**	 **93b**	97[c]
2	 **91b**	5 min	 **92a**	 **93c**	92[c]
3	 **91b**	5 min	 **92b**	 **93d**	89[c]
4	 **91b**	10 min	 **92c**	 **93e**	80[c], 81[d]
5	 **91c**	5 min	 **92a**	 **93f**	88[c]

6	 **91c**	5 min	 **92b**	 **93g**	91[c]
7	 **91c**	10 min	 **92d**	 **93h**	94[c]
8	 **91d**	10 min	 **92c**	 **93i**	79[c]
9	 **91e**	10 min	 **92e**	 **93j**	94[e]
10	 **91f**	5 min	 **92a**	 **93k**	76[f]

[a] Reaction time for the cross-coupling reaction. [b] Yield of isolated, analytically pure product. [c] Zinc reagent obtained after I/Mg-exchange and subsequent transmetalation with $ZnCl_2 \cdot 2LiCl$ (0.55 equiv). [d] Reaction was performed on a 10 mmol scale. [e] Zinc reagent obtained after Mg-insertion and subsequent transmetalation with $ZnCl_2 \cdot 2LiCl$ (0.55 equiv) and addition of *i*PrI (1.1 equiv). [f] Zinc reagent obtained after Br/Mg-exchange and subsequent transmetalation with $ZnCl_2 \cdot 2LiCl$ (0.55 equiv) and addition of *i*PrI (1.1 equiv).

We extended this protocol to the reaction of enolizable bromoarylketones. Ethyl 3-iodobenzoate (**90c**) was smoothly converted to the corresponding magnesium reagent using *i*PrMgCl·LiCl within 30 min at –20 °C. Transmetalation with $ZnCl_2 \cdot 2LiCl$ (0.55 equiv) furnished the diarylzinc species **91d** (Scheme 36). Subsequent palladium catalyzed cross-coupling with 3-bromoacetophenone (**94a**) afforded the ketone **95a** in 86% yield.

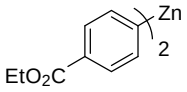
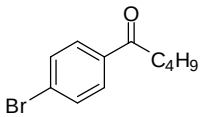
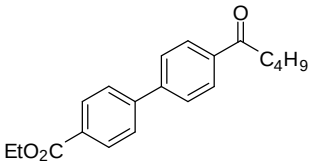
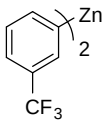
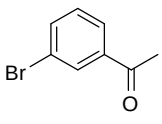
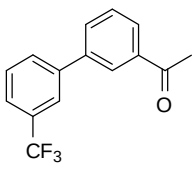


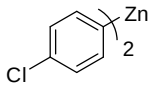
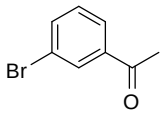
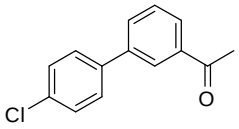
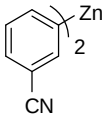
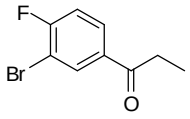
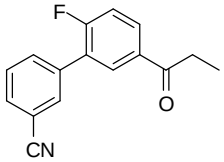
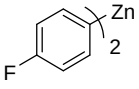
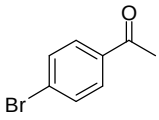
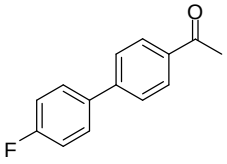
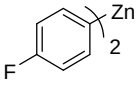
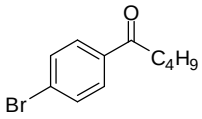
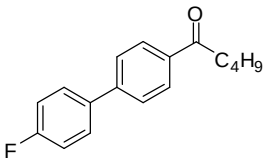
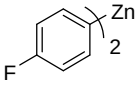
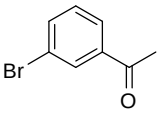
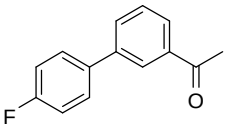
90c **91d** **95a**: 86%

Scheme 36: Negishi cross-coupling of a diarylzinc reagent **91d** with 3-bromoacetophenone (**94a**).

By applying this procedure, various arylzinc reagents were efficiently coupled with several bromoaryl ketones. Thus, the reaction of **91c** with 4-bromovalerophenone (**94b**) afforded the ester **95b** in 92% yield (Table 13, entry 1). Furthermore, the palladium-catalyzed cross-couplings of the zinc compounds **91b** and **91g** with 3-bromoacetophenone (**94a**) resulted in the asymmetrical biaryls **95c** and **95d** in yields of 86% and 85%, respectively (Table 13, entries 2-3). The coupling of **91a** with the sterically hindered 3-bromo-4-fluoropropiophenone (**94c**) gave the desired product **95e** within 12 min in 73% yield (Table 13, entry 4). This reaction was also applicable towards the reaction of zinc reagents obtained from the corresponding arlymagnesium bromides and addition of 1.1 equivalent of *i*PrI. Thus, the reaction of **91e** in the presence of *i*PrI, $Pd(dba)_2$ and RuPhos with various bromoaryl ketones **94a**-**94b** and **94d** provided the biaryls **95f**-**95h** in 91% yield (Table 13, entries 5-7).

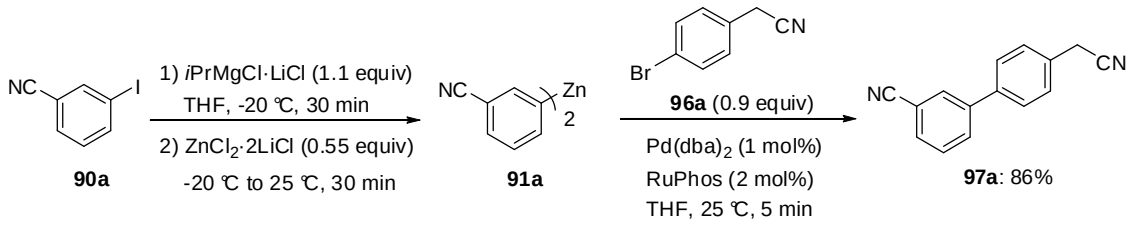
Table 13:

entry	substrate	time[a]	electrophile	product	yield, %[b]
1	 **91c**	5 min	 **94b**	 **95b**	97[c]
2	 **91b**	5 min	 **94a**	 **95c**	86[c]

3	 **91g**	5 min	 **94a**	 **95d**	85[c]
4	 **91a**	12 min	 **94c**	 **95e**	73[c]
5	 **91e**	5 min	 **94d**	 **95f**	91[d]
6	 **91e**	5 min	 **94b**	 **95g**	91[d]
7	 **91e**	5 min	 **94a**	 **95h**	91[d]

[a] Reaction time for the cross-coupling reaction. [b] Yield of isolated, analytically pure product. [c] Zinc reagent obtained after I/Mg-exchange and subsequent transmetalation with $ZnCl_2 \cdot 2LiCl$ (0.55 equiv). [d] Zinc reagent obtained after Mg-insertion and subsequent transmetalation with $ZnCl_2 \cdot 2LiCl$ (0.55 equiv) and addition of *i*PrI (1.1 equiv).

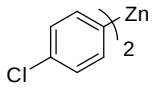
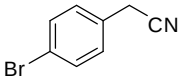
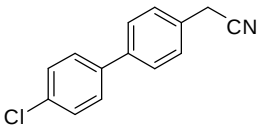
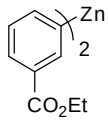
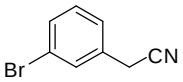
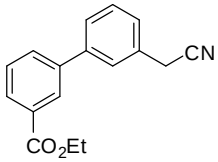
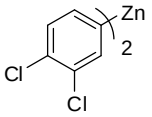
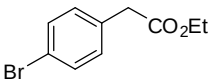
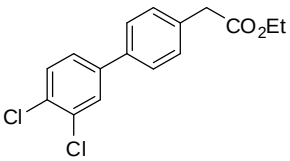
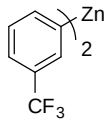
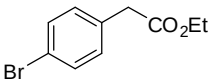
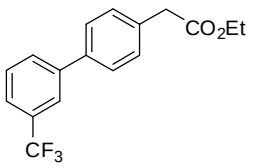
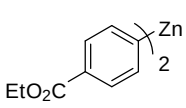
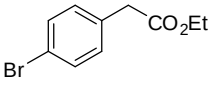
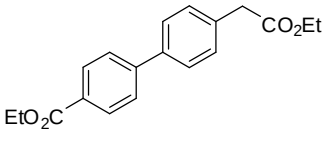
Moreover, we applied this method to the coupling of arylzinc reagents with aryl bromides bearing acidic benzylic protons. Thus, the I/Mg-exchange of 3-iodobenzonitrile (**90a**) with *i*PrMgCl·LiCl and transmetalation with $ZnCl_2 \cdot 2LiCl$ (0.55 equiv) yielded the diarylzinc species **91a** (Scheme 37). Subsequent Pd(0)-catalyzed cross-coupling with (4-bromophenyl)-acetonitrile (**96a**) gave the dinitrile **97a** within 5 min in 86% yield.



Scheme 37: Negishi cross-coupling of a biarylzinc reagent with 3-bromoacetophenone (**96a**).

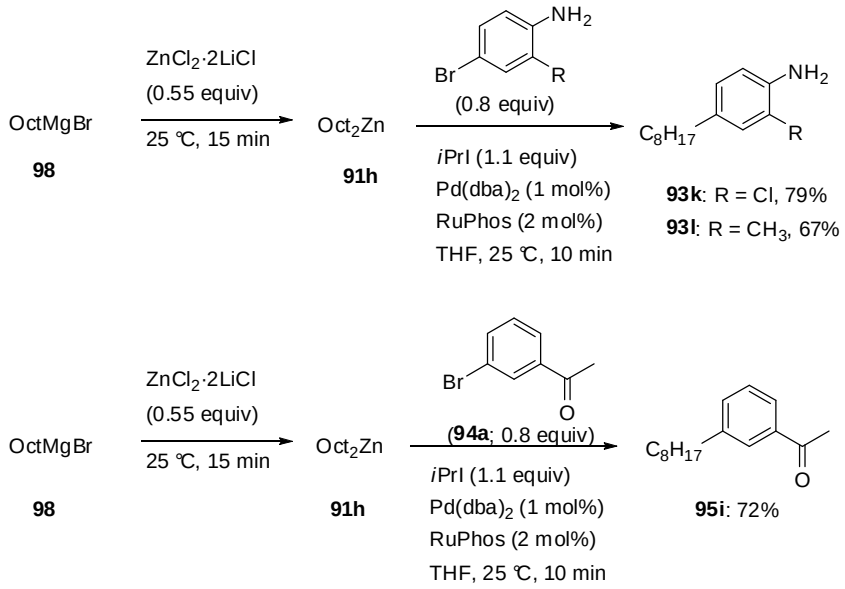
Also, the reaction of the chloroarylzinc reagent **91g** with **96a** yielded the biaryl **97b** in 97% (Table 14, entry 1). Furthermore, the coupling of the zinc compound **91d** bearing an ester function with (3-bromophenyl)-acetonitrile (**96b**) afforded the desired product **97c** in 89% yield (Table 14, entry 2). The reaction of the dichlorophenylzinc reagent **91f** and (4-bromophenyl)acetic acid ethyl ester (**96c**) in the presence of *i*PrI provided chemoselectively the dichlorobiaryl **97d** in 83% yield (Table 14, entry 3). The coupling of the zinc compounds **91b** and **91c** with the arylbromide **96c** furnished the esters **97e** and **97f** in yields of 94% and 85%, respectively (Table 14, entries 4-5).

Table 14: Cross-coupling of diarylzinc reagents of type **91** with various aryl bromides bearing acidic benzylic protons.

entry	substrate	time[a]	electrophile	product	yield, %[b]
1	 **91g**	5 min	 **96a**	 **97b**	97[c]
2	 **91d**	5 min	 **96b**	 **97c**	89[c]
3	 **91f**	5 min	 **96c**	 **97d**	83[d]
4	 **91b**	5 min	 **96c**	 **97e**	94[c]
5	 **91c**	5 min	 **96c**	 **97f**	85[c]

[a] Reaction time for the cross-coupling reaction. [b] Yield of isolated, analytically pure product. [c] Zinc reagent obtained after I/Mg-exchange and subsequent transmetalation with $ZnCl_2 \cdot 2LiCl$ (0.55 equiv). [d] Zinc reagent obtained after Br/Mg-exchange and subsequent transmetalation with $ZnCl_2 \cdot 2LiCl$ (0.55 equiv) and addition of *i*PrI (1.1 equiv).

This protocol can be extended from arylzinc reagents towards the reaction of alkylzinc reagents with arylbromides. Thus, octylmagnesium bromide (**98**) can be smoothly transmetalated with $ZnCl_2 \cdot 2LiCl$ (0.55 equiv) giving the corresponding zinc species **91h** (Scheme 38). Subsequent Pd(0)-catalyzed cross-coupling in the presence of *i*PrI with various bromoanilines provided within 10 min the amines **93k** and **93l** in 79% and 67% yield. In a similar manner, the reaction of **91h** with 3-bromoacetophenone (**94a**) furnished within 10 min the ketone **95i** in 72% yield.

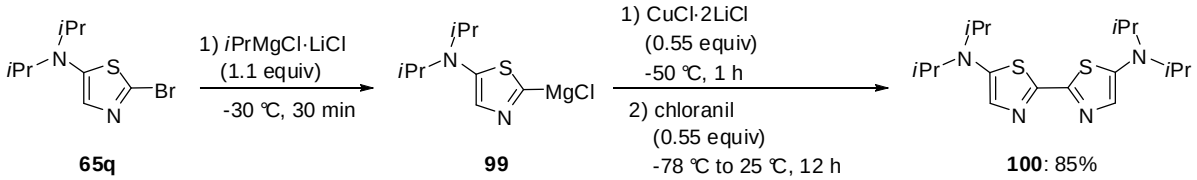


Scheme 38: Cross-coupling of an alkylzinc reagent with various aryl bromides bearing acidic protons.

6. Preparation of Small Oligomers for the Use as Donors in Blended Organic Solar Cells

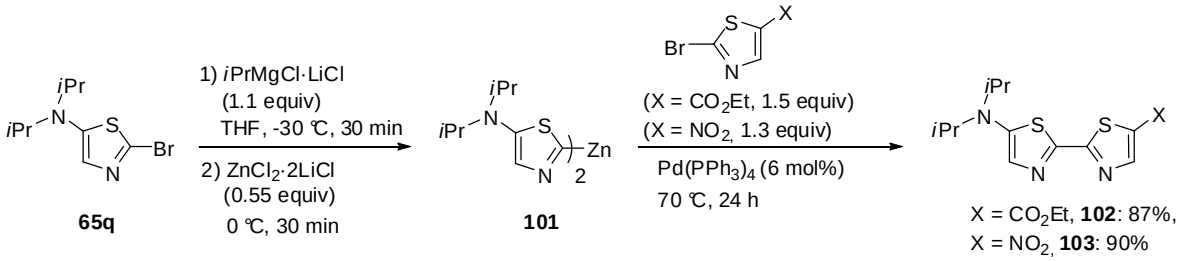
6.1 Preparation of thiazole and thiophene-thiazole dimers

For initial studies several thiazole dimers with various functional groups were prepared. Thus, the symmetrical dimer **100** was prepared from the amine **65q**: After a Br/Mg-exchange on thiazole **65q** at –30 °C for 30 min, the magnesium reagent **99** was transmetalated to the corresponding copper reagent (Scheme 39). This compound was smoothly homocoupled using chloranil as oxidation reagent affording the dimer **100** in 85% yield.



Scheme 39: Preparation of the dimer **100** via an oxidative homocoupling.

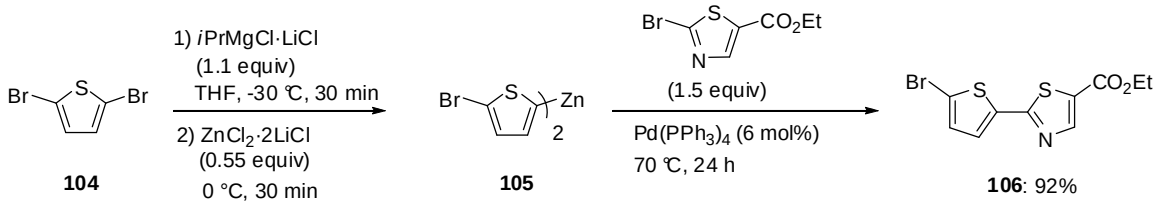
The dimers **102** and **103** possessing both an electron-donating and electron-withdrawing group were prepared by a Negishi cross-coupling reaction. After a Br/Mg-exchange of the thiazole **65q**, the corresponding magnesium reagent was transmetalated to the zinc reagent **101** (Scheme 40). Subsequent Pd-catalyzed cross-coupling reactions with different 2-bromothiazole derivatives gave the dimers **102** and **103** in 87% and 90% yield, respectively.



Scheme 40: Cross-coupling reaction for the synthesis of the dimers **102** and **103**.

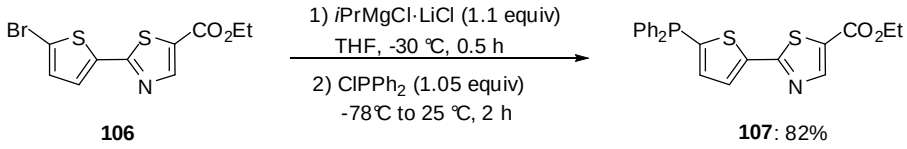
Beside an amine as electron-donating group also a phosphine function was introduced. Such dimers were easily prepared in a two-step synthesis starting from 2,5-dibromothiophene

(**104**). A selective Br/Mg-exchange on 2,5-dibromothiophene at 25 °C for 30 min gave the corresponding magnesium reagent (Scheme 41). Subsequent transmetalation with $ZnCl_2 \cdot 2LiCl$ gave the bisaryl zinc reagent **105**. The following Pd-catalyzed cross-coupling reaction afforded the mixed thiophene-thiazole dimer **106** in 92% yield.



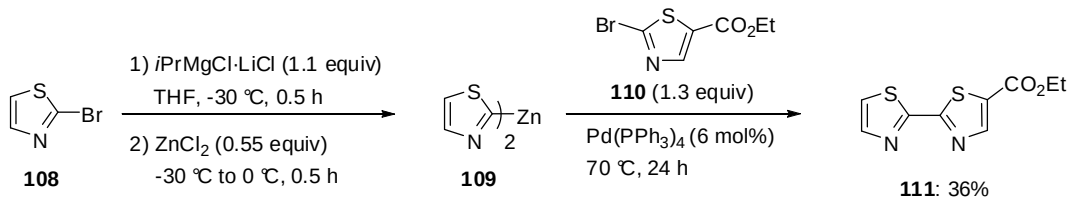
Scheme 41: Synthesis of a mixed thiophene-thiazole dimer as precursor for subsequent transformations.

A Br/Mg-exchange on the dimer **106** furnished the corresponding magnesium reagent, which was trapped by the reaction with $ClPPh_2$ (–78 °C to 25 °C, 2 h) yielding the desired dimer **107** in 82% (Scheme 42).



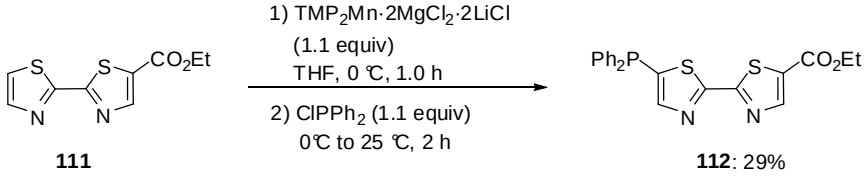
Scheme 42: Preparation of the phosphine containing dimer **107**.

Another dimer containing a phosphino group was prepared starting from 2-bromothiazole **108** (Scheme 43). Hence, 2-bromothiazole was smoothly converted to the corresponding zinc reagent **109** by treatment with *i*PrMgCl·LiCl (–30 °C, 30 min) and subsequent transmetalation using $ZnCl_2$ (–30 °C to 25 °C, 30 min). A Pd(0)-catalyzed cross-coupling of **109** with the thiazole derivative **110** furnished the dimer **111** in 36%. The reason for the low yield is the formation of large amounts of the corresponding homo-coupling product derived from **109**.



Scheme 43: Synthesis of the thiazole dimer **111** via a Negishi cross-coupling reaction.

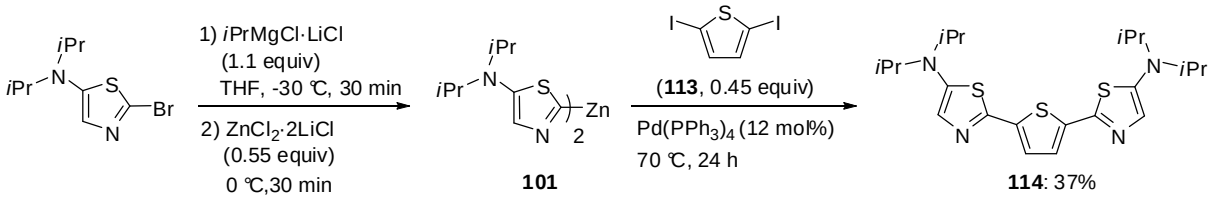
Manganese reagents proved to be good nucleophiles for the reaction with chlorophosphines.[68] Thus, the manganation of **111** with $TMP_2Mn{\cdot}2MgCl_2{\cdot}2LiCl$ (0 °C, 1 h) afforded the corresponding manganese compound which reacted with $ClPPh_2$ (0 °C to 25 °C, 2 h) yielding the thiazole dimer **112** in 29% (Scheme 44).



Scheme 44: Metalation of **111** and subsequent reaction with $ClPPh_2$.

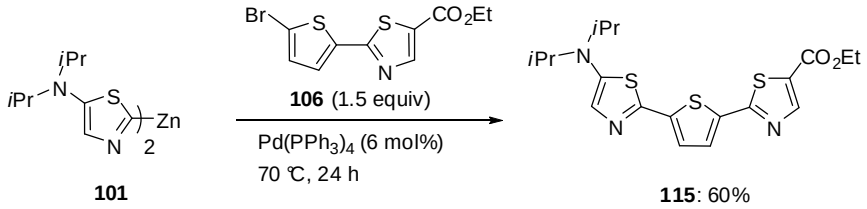
6.2 Synthesis of trimers and tetramers

For the synthesis of a trimer possessing two electron-donating groups the zinc-reagent **101** was coupled with 2,5-diiodothiophene (**113**) in the presence of $Pd(PPh_3)_4$ providing the desired trimer **114** in 37% yield (Scheme 45).



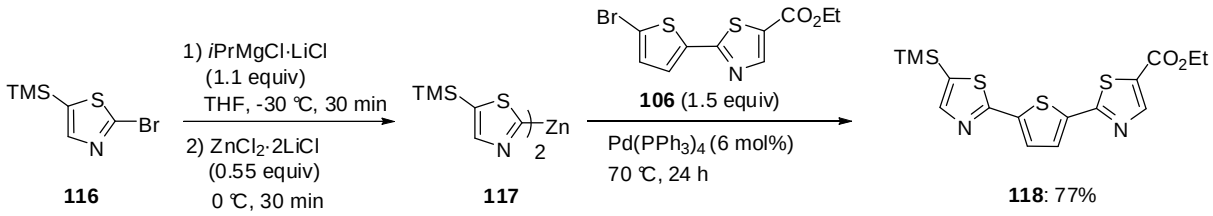
Scheme 45: Synthesis of the trimer **114** containing two electron donating groups.

The previously described dimer **106** was used in a Negishi cross-coupling reaction with the zinc-reagent **101** yielding the trimer **115** in 60% (Scheme 46).



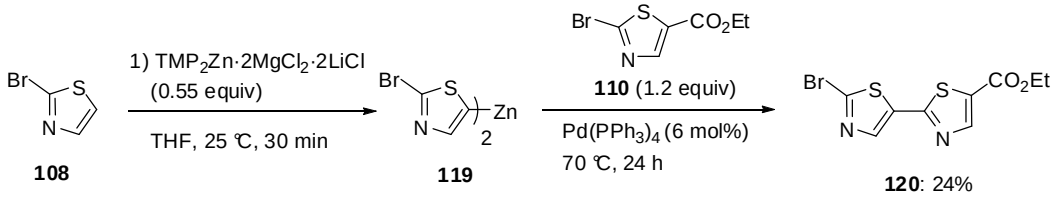
Scheme 46: Synthesis of the trimer **115** containing both an electron-donating and electron-withdrawing group.

In a similar manner, the thiazole derivative **116** bearing a TMS-group was converted to the corresponding zinc reagent **117** by the reaction with *i*PrMgCl·LiCl (–30 °C, 30 min) and transmetalation with $ZnCl_2$·2LiCl (0 °C, 30 min) (Scheme 47). After a Pd(0)-catalyzed cross-coupling reaction of **117** with the dimer **106** the desired trimer **118** was obtained in 77% yield.



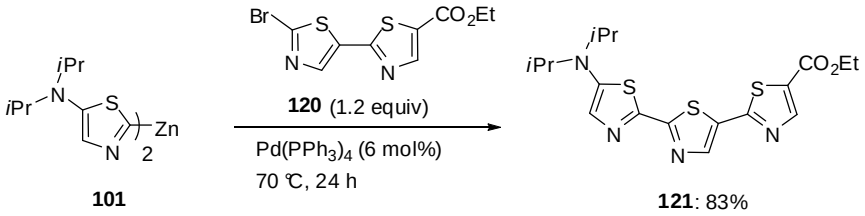
Scheme 47: Preparation of the trimer **118** via Pd(0)-catalyzed cross-coupling reaction.

In order to vary the electronic properties of the scaffold of these small oligomers, it was of interest to prepare trimers containing three thiazole subunits. Therefore, 2-bromothiazole (**108**) was smoothly metalated using TMP_2Zn·2$MgCl_2$·2LiCl furnishing the zinc reagent **119** (Scheme 48). Subsequent Pd-catalyzed cross-coupling reaction with thiazole **110** gave the dimer **120** in only 24%. The reason for the low yield is propably a complexation of the palladium catalyst by TMPH.



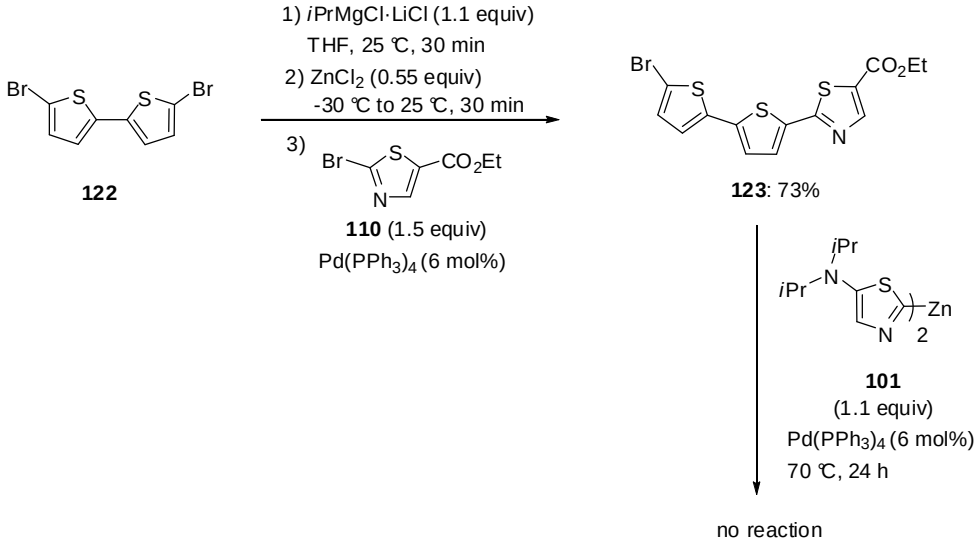
Scheme 48: Synthesis of the precursor **120**.

Nonetheless, the compound **120** was successfully coupled in a second Negishi cross-coupling reaction with the zinc reagent **101** giving the trimer **121** in 83% yield (Scheme 49).



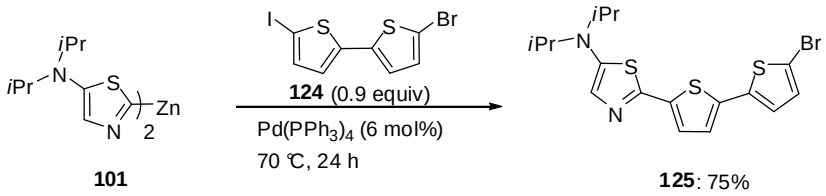
Scheme 49: Synthesis of the thiazole trimer **121**.

For the synthesis of tetramers a first approach started with a selective exchange on 5,5'-dibromo-2,2'-bithiophene (**122**) using *i*PrMgCl·LiCl (1.1 equiv, 25 °C, 30 min). Subsequent transmetalation afforded the corresponding zinc species which underwent a Pd(0)-catalyzed cross-coupling reaction with **110** furnishing the trimer **123** in 73% yield (Scheme 50). However, the cross-coupling of **101** with the trimer **123** as an electrophile did not yield the desired product.



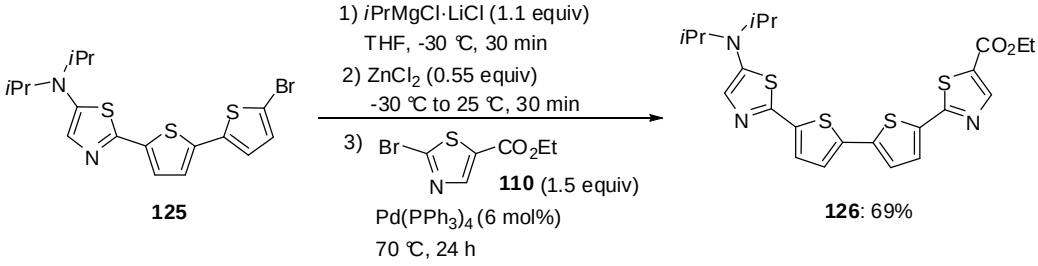
Scheme 50: Approach for the synthesis of a mixed thiophene thiazole tetramer.

Therefore, a second approach was carried out and accomplished: Cross-coupling of the zinc-species **101** with the thiophene-dimer **124**[73] gave the expected precursor **125** in 75% yield (Scheme 51).



Scheme 51: Preparation of the trimer **125** containing an amine.

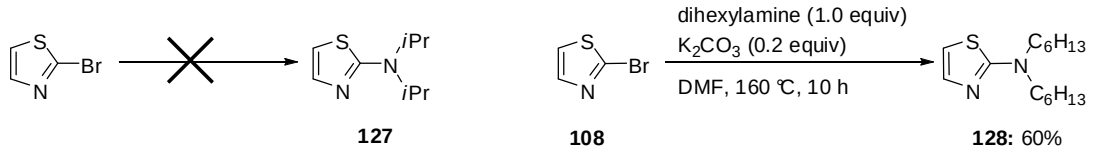
In the second step of this synthesis, the previously formed trimer **125** was converted to the corresponding zinc reagent using a Br/Mg-exchange and subsequent transmetalation (Scheme 52). Then, this zinc reagent reacted with the thiazole derivative **110** using Pd(0)-catalysis, affording the tetramer **126** in 69% yield.



Scheme 52: Synthesis of the tetramer **126**.

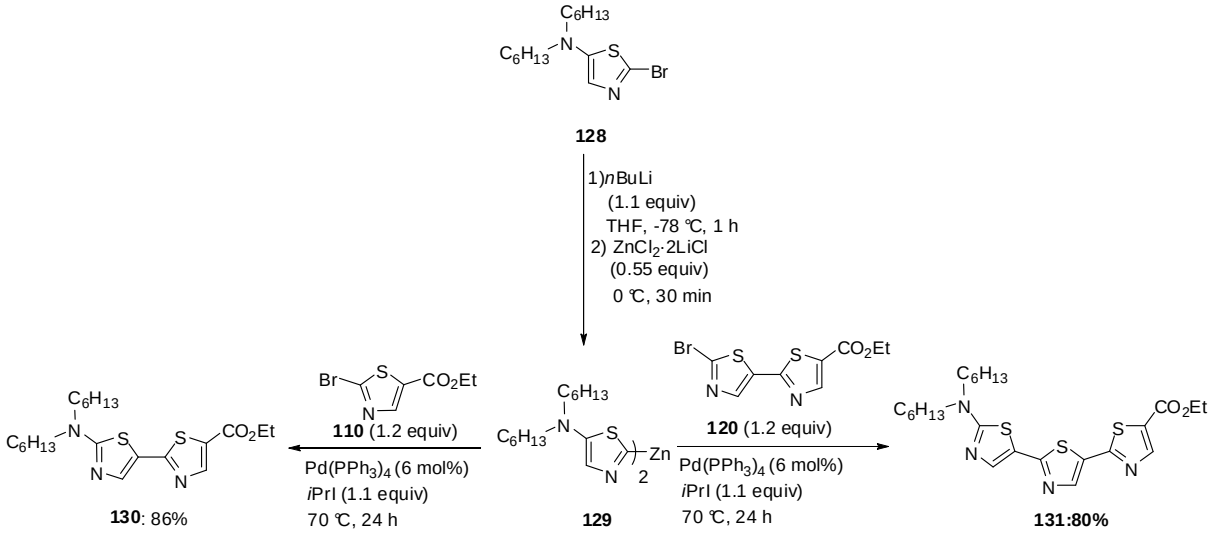
Since first results[74] showed a great influence of the dipole moment of these oligomers on their behaviour as donors in blended organic solar cells, it was of special interest to synthesize oligomers with a larger dipole moment. As the preparation of the amine **127** failed for the oxidative amination as well as for the Pd-catalyzed amination due to the instant decomposition of **127** (Scheme 53), the more stable *N*,*N*-dihexyl-1,3-thiazol-2-amine (**128**) was prepared starting from 2-bromothiazole (**108**).[75]

[73] For the synthesis of **124**, see Experimental Part.
[74] The corresponding experiments were performed in the group of Dr. E. Da Como, Physics Department, LMU, Munich.
[75] H. Meier, F. Nicklas, R. Petermann, *Z. Naturforsch., B: Chem. Sci.* **2007**, *62*, 1525.



Scheme 53: Preparation of the 2-aminothiazole **128**.

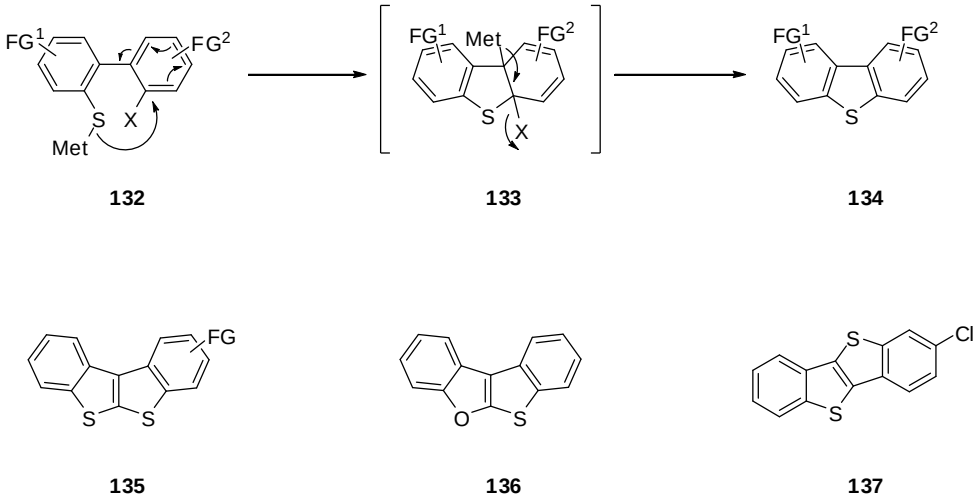
The thiazole derivative **128** was selectively deprotonated using *n*BuLi and the resulting lithium reagent was transmetalated furnishing the bisaryl-zinc compound **129**. Since the addition of *i*PrI accelerated various Negishi cross-coupling reactions (see Chapter 5), the following cross-coupling reactions were performed in the presence of 1.1 equivalents of *i*PrI (Scheme 54). The reaction of the zinc species **129** with the thiazole **110** as well as with the dimer **120** afforded oligomers **130** and **131** in yields of 86% and 80%, respectively.



Scheme 54: Preparation of small thiazole oligomers containing an ester and an amine.

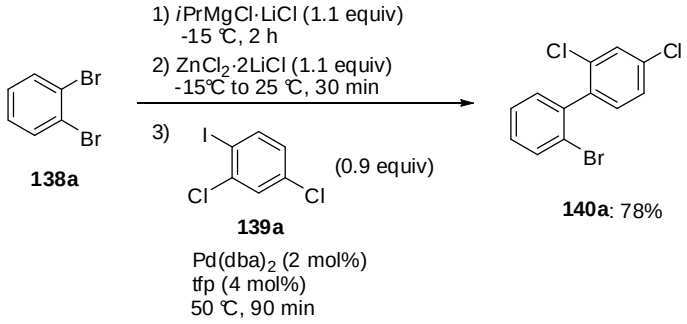
7. Synthesis of Dibenzothiophenes and Related Classes of S-Heterocycles via an Anionic Electrocyclization

As mentioned above, Palladium-catalyzed ring closures are difficult due to the deactivating effect of sulfur on transition metal catalysts. In order to avoid this poison effect of thiols and thiolates on transition metals, we have envisioned a ring closure procedure involving main-group thiophenolates such as **132** as precursors which by an addition elimination reaction will afford an intermediate such as **133** which after the elimination of Met-X will provide various dibenzothiophenes of type **134** (Scheme 55). This part of the work will deal with a practical preparation of compounds of type **132** from readily available precursors as well as the application of this method for the preparation of various other classes of S-heterocycles such as substituted [1]benzothieno[2,3-*b*][1] benzothiophenes of type (**135**), the unknown [1]-benzothieno[2,3-*b*][1]benzofuran (**136**), and a substituted [1]benzothieno[3,2-*b*][1]benzothiophene (**137**).



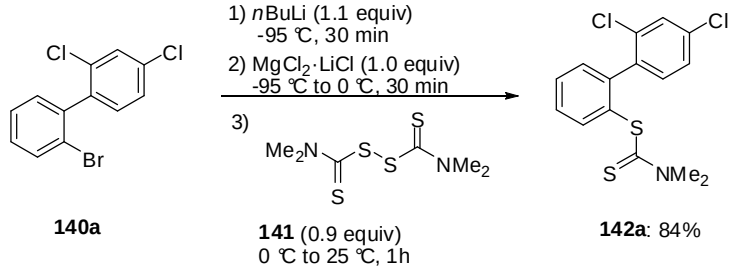
Scheme 55: Preparation of S-heterocyclces via an addition-elimination reaction.

The first step of the synthesis of functionalized dibenzothiophenes on at 1,2-dibromobenzene (**138a**) with *i*PrMgCl·LiCl (–15 °C, 2 h) furnished exclusively the monomagnesium reagent. Subsequent transmetalation with $ZnCl_2$·2LiCl, followed by a cross-coupling with 2,4-dichloroiodobenzene (**139a**) catalyzed by $Pd(dba)_2$ and tfp provided the desired biaryl **140a** in 78% yield (Scheme 56).



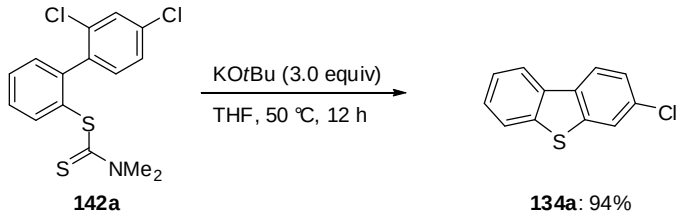
Scheme 56: Pd-catalyzed cross-coupling furnishing a polyfunctionalized biaryl.

Biphenyls of type **140** did not undergo complete Br/Mg-exchange due to steric hindrance and the performance of a Br/Li-exchange proved to be advantageous (*n*BuLi (1.1 equiv), –95 °C, 30 min). After transmetalation with the THF soluble magnesium complex $MgCl_2 \cdot 2LiCl$ the resulting arylmagnesium species was treated with tetramethylthiuram disulfide (**141**; 0 °C to 25 °C, 1 h) providing the dithiocarbamate **142a** in 84% yield (Scheme 57).



Scheme 57: Preparation of the dithiocarbamate **142a**.

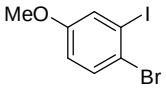
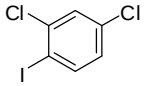
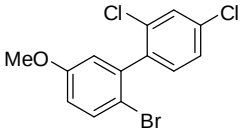
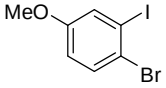
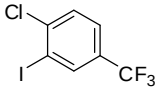
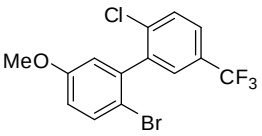
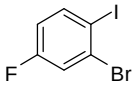
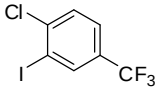
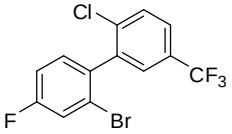
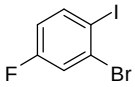
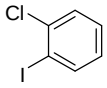
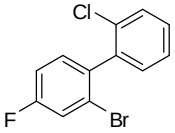
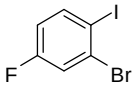
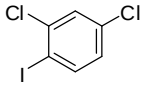
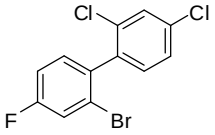
The final ring closing reaction was performed using KO*t*Bu (50 °C, 12 h) giving the functionalized dibenzothiophene **134a** in 94% (Scheme 58).



Scheme 58: Addition-elimination reaction leading to the dibenzothiophene **134a**.

Following the above decribed protocol various functionalized biaryls were synthesized. Thus, the reaction of aryl zinc reagents obtained from the corresponding aryl bromide or aryl iodides **138a**-**138c**[76] with the polyfunctionalized aryl iodides **139a** – **139c** afforded the biaryls **140b**-**140f** in 74-92% yield (Table 15, entries 1-5).

Table 15: Preparation of biphenyls of type **140** via Negishi cross-coupling reaction.

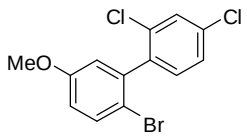
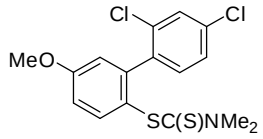
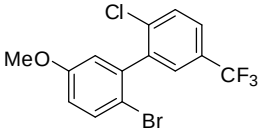
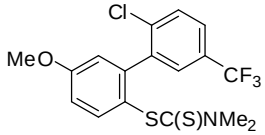
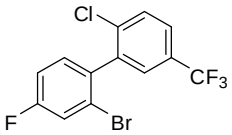
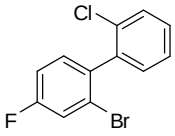
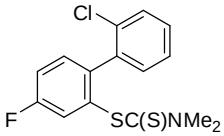
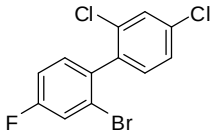
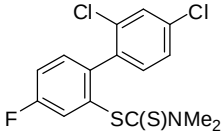
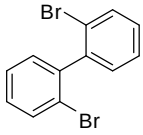
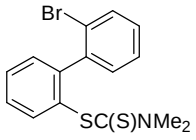
entry	substrate	electrophile	product	yield, %[a]
1	 **138b**	 **139a**	 **140b**	76
2	 **138b**	 **139b**	 **140c**	92
3	 **138c**	 **139b**	 **140d**	75
4	 **138c**	 **139c**	 **140e**	80
5	 **138c**	 **139a**	 **140f**	74

[a] Yield of isolated, analytically pure product.

A smooth Br/Li-exchange of the compounds **140b**-**140g**,[77] followed by the transmetalation using the soluble complex $MgCl_2 \cdot LiCl$ afforded the corresponding Mg-reagents. Then, these reagents were treated with TMTD (**141**) affording the desired dithiocarbamates **142b**-**142g** in 76-94% yield (Table 16, entries 1-6).

[76] For the synthesis of 4-bromo-3-iodoanisole (**138b**), see: S. Bhunia, K.-C. Wang, R.-S. Liu, *Angew. Chem. Int. Ed.* **2008**, *47*, 5063.
[77] For the preparation of 2,2'-dibromobiphenyl, see: H. Gilman, B. J. Gaj, *J. Org. Chem.* **1957**, *22*, 447.

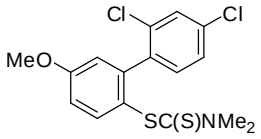
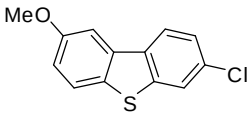
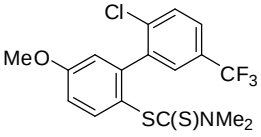
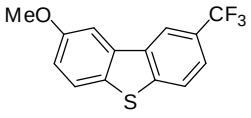
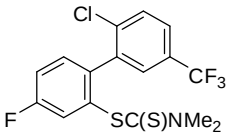
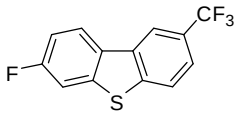
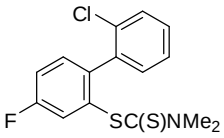
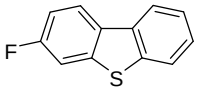
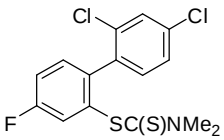
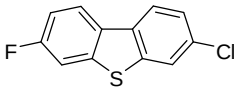
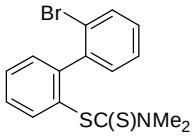
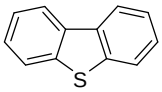
Table 16: Synthesis of various dithiocarbamates of type **142**.

entry	substrate	product	yield, %[a]
1	 **140b**	 **142b**	81
2	 **140c**	 **142c**	80
3	 **140d**	 **142d**	84
4	 **140e**	 **142e**	94
5	 **140f**	 **142f**	85
6	 **140g**	 **142g**	76

[a] Yield of isolated, analytically pure product.

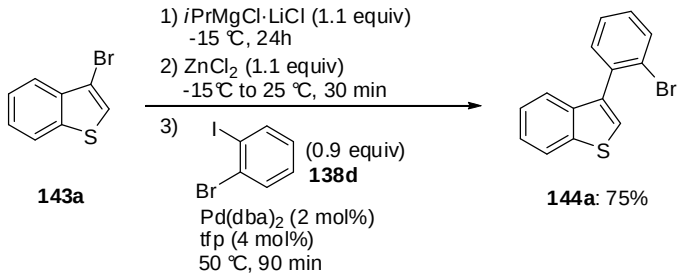
The compounds **142b**-**142d** having a chloride as leaving group were treated with KO*t*Bu and gave the desired dibenzothiophenes **134b** – **134d** within 4 – 18 h at 50 °C (Table 17 entries 1-3). The dithiocarbamates **142e** and **142f** bearing a fluoride were reacted with KO*t*Bu as well (Table 17, entries 4-5). However, in order to obtain full conversion these compounds were heated to 90 °C for 45 min using microwave irradation giving **134e** and **134f** in yields of 71% and 78%, respectively. Finally, the ring closing of **142g** was performed by treatment with *n*BuLi (–20 °C, 30 min) yielding the desired dibenzothiophene **134g** in 89% (Table 17, entry 6).

Table 17: Addition-elimination reaction leading to dibenzothiophenes **134**.

entry	substrate	conditions	product	yield, %[a]
1	 **142b**	50 °C, 18h	 **134b**	81
2	 **142c**	50 °C, 4h	 **134c**	96
3	 **142d**	50 °C, 4h	 **134d**	81
4	 **142e**	90 °C, 0.75h MW	 **134e**	71
5	 **142f**	90 °C, 0.75h MW	 **134f**	78
6	 **142g**	–20 °C, 0.5h[b]	 **134g**	89

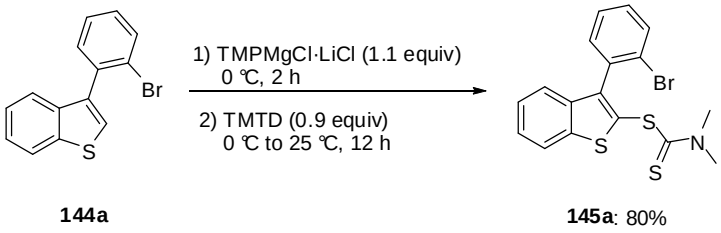
[a] Yield of isolated, analytically pure product. [b] *n*BuLi was used as base.

The synthesis of benzothienobenzothiophenes and related structures started with a cross-coupling reaction furnishing functionalized 3-arylbenzothiophenes. Thus, treatment of 3-bromobenzothiophene **143a** with *i*PrMgCl·LiCl (–15 °C, 24 h) and transmetalation with $ZnCl_2$·2LiCl afforded the corresponding zinc reagent (Scheme 59). This zinc reagent reacted with 1-bromo-2-iodobenzene **138d** using $Pd(dba)_2$ and tfp as catalyst-ligand-system. This reaction smoothly provided the desired product **144a** in 75%.



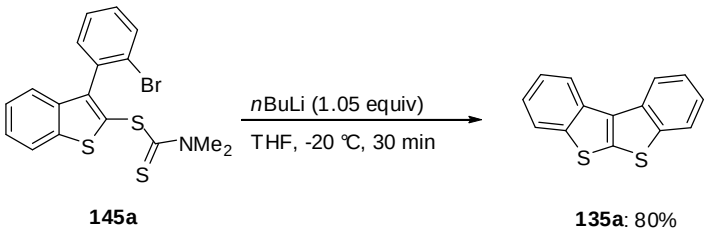
Scheme 59: Negishi cross-coupling leading to the 3-arylated benzothiophene **144a**.

The compound **144a** was easily deprotonated in position 2 using TMPMgCl·LiCl (0 °C, 2 h) furnishing the corresponding magnesiated reagent (Scheme 60). Subsequent addition of TMTD to the generated magnesium reagent gave the dithiocarbamate **145a** in 80%.



Scheme 60: Metalation of **144a** and subsequent reaction with tetramethylthiuram disulfide.

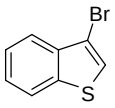
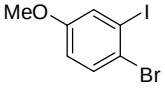
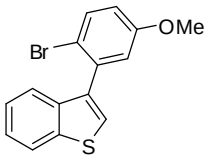
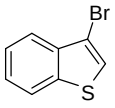
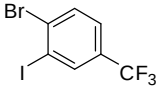
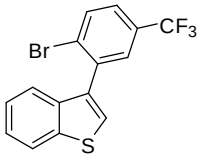
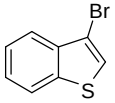
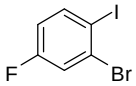
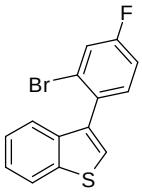
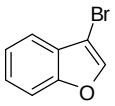
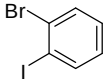
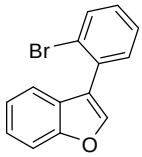
Finally, the ring closing was carried out by the addition of *n*BuLi to a solution of the dithiocarbamate **145a** in THF (–20 °C, 30 min) providing [1]benzothieno[2,3-*b*][1]benzothiophene **135a** in 80% yield (Scheme 61). Beside bromides as a leaving group, the reaction can also be performed using chlorides. Furthermore, the addition of KO*t*Bu to **145a** afforded within 2 h also the desired product **135a**.



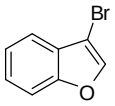
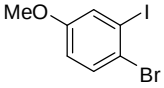
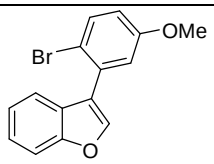
Scheme 61: Preparation of [1]benzothieno[2,3-*b*][1]benzothiophene (**135a**).

Following the above described protocol, several [1]benzothieno[2,3-*b*][1]benzothiophenes and related compounds bearing various functional groups were prepared. Thus, the Br/Mg-exchange of 3-bromobenzothiophene (**143a**) and 3-bromobenzofuran (**143b**) with *i*PrMgCl·LiCl and subsequent transmetalation using $ZnCl_2$·2LiCl gave the corresponding zinc reagents. These intermediates were reacted with various polyfunctional aryl iodides **138b**-**138c** and **138e**[78] in the presence of $Pd(dba)_2$ and tfp affording the compounds **144b**-**144f** in 63-80% yield (Table 18, entries 1-5).

Table 18: Negishi cross-coupling furnishing 3-arylated benzothiophenes of type **144**.

entry	substrate	conditions[a]	electrophile	product	yield, %[b]
1	 **143a**	–15, 24	 **138b**	 **144b**	74
2	 **143a**	–15, 24	 **138e**	 **144c**	71
3	 **143a**	–15, 24	 **138c**	 **144d**	63
4	 **143b**	–55, 24	 **138e**	 **144e**	76

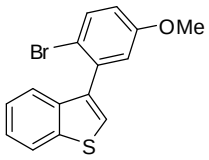
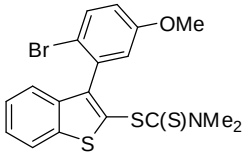
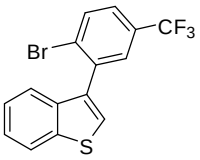
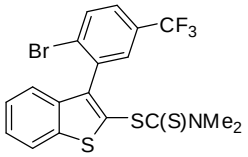
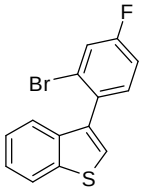
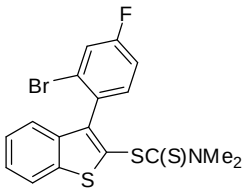
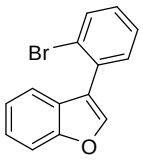
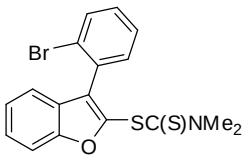
[78] For the synthesis of 4-bromo-3-iodobenzotrifluoride, see: J. Garcia-Fortanet, S. L. Buchwald, *Angew. Chem. Int. Ed*. **2008**, *47*, 8108.

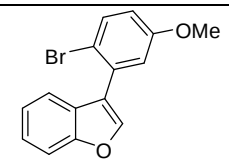
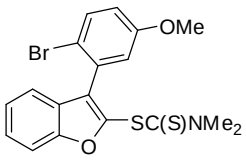
5	 **143b**	–55, 24	 **138b**	 **144f**	80

[a] Reaction conditions for the Br/Mg-exchange using *i*PrMgCl·LiCl (°C, h). [b] Yield of isolated, analytically pure product.

Then, the generated compounds **144b**-**144f** were metalated using TMPMgCl·LiCl (0 °C, 2–2.5 h) furnishing the corresponding magnesium reagents. These reagents reacted smoothly with TMTD within 12 h to the desired dithiocarbamates **145b** – **145f** in yields of 80-90% (Table 19, entries 1-5).

Table 19: Metalation of compounds using TMPMgCl·LiCl and subsequent trapping with $(Me_2N(S)CS)_2$).

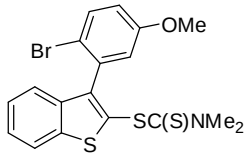
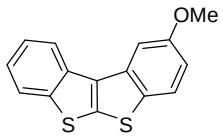
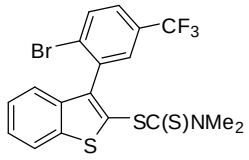
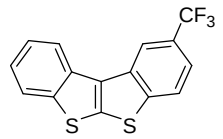
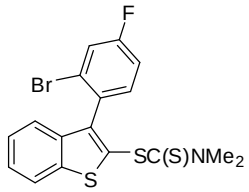
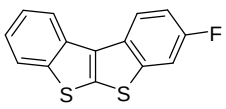
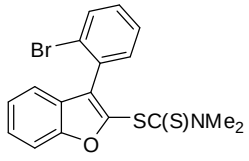
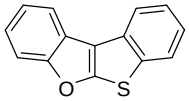
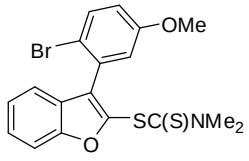
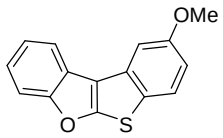
entry	substrate	product	yield, %[a]
1	 **144b**	 **145b**	90
2	 **144c**	 **145c**	86
3	 **144d**	 **145d**	80
4	 **144e**	 **145e**	87

5	 **144f**	 **145f**	81

[a] Yield of isolated, analytically pure product.

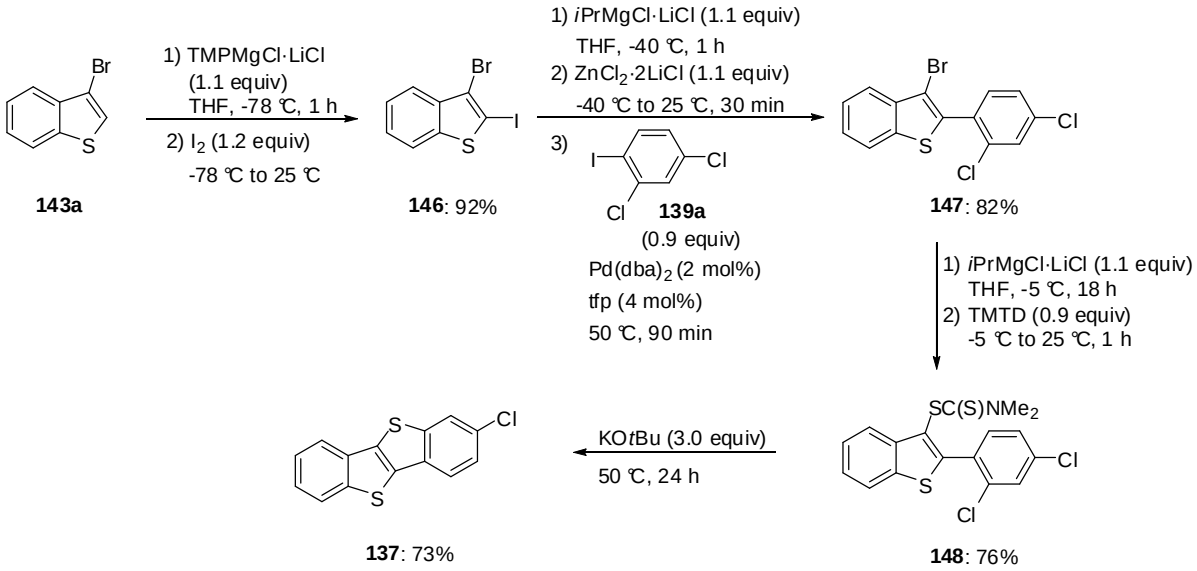
The ring closure was performed as described above using *n*BuLi (–20 °C, 30 min) affording the functionalized [1]benzothieno[2,3-*b*][1]benzothiophenes **135b** – **135d** in 78% - 90 % yield (Table 20, entries 1-3) as well as the [1]-benzothieno[2,3-*b*][1]benzofurans **136a** and **136b** in yields of 72% and 76%, respectively (Table 20, entries 4-5).

Table 20: Ring closing reaction leading to compounds of type **135**.

entry	substrate	product	yield, %[a]
1	 **145b**	 **135b**	90
2	 **145c**	 **135c**	78
3	 **145d**	 **135d**	83
4	 **145e**	 **136a**	72
5	 **145f**	 **136b**	76

[a] Yield of isolated, analytically pure product.

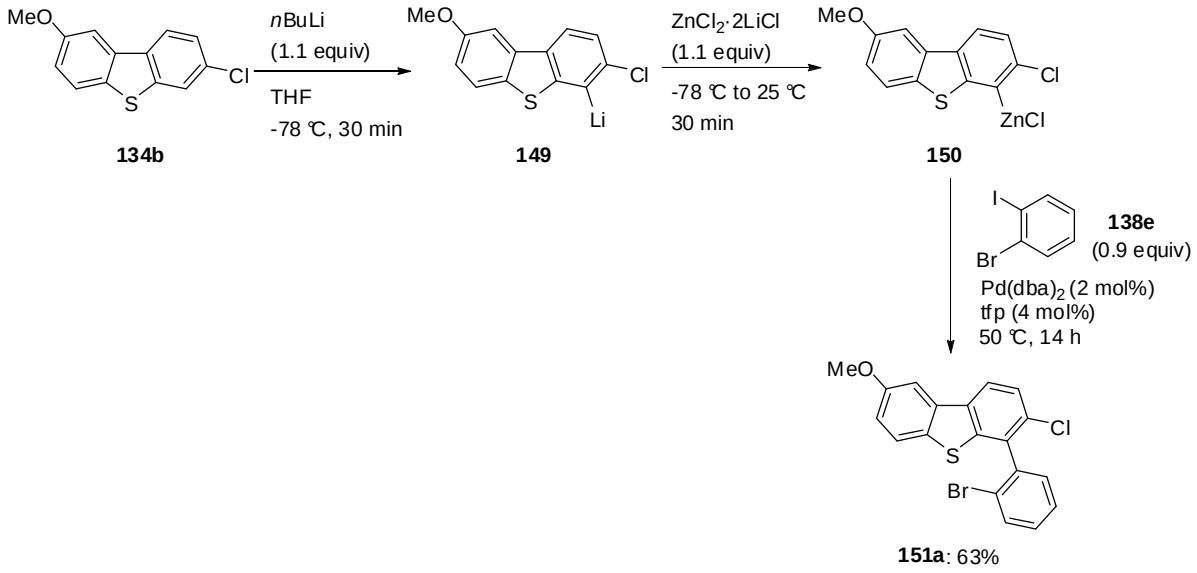
The preparation of 2-chloro[1]benzothieno[3,2-*b*][1]benzothiophene (**137**) started with the metalation of 3-bromobenzothiophene (**143a**) and subsequent iodolysis to afford 3-bromo-2-iodobenzothiophene (**146**) in 92% yield (Scheme 62). The metalation of **143a** with TMPMgCl·LiCl, transmetalation with $ZnCl_2$ and Pd-catalyzed cross-coupling with various aryl iodides gave only unsatisfactory yields. Therefore, treatment of **146** with *i*PrMgCl·LiCl (–40 °C, 1 h) and transmetalation with $ZnCl_2$·2LiCl gave the corresponding zinc reagent which was coupled with the aryl iodide **139a** in the presence of $Pd(dba)_2$ and tfp to provide the intermediate **147** in 82% yield. Further treatment with *i*PrMgCl·LiCl (–5 °C, 18 h) resulted in a smooth Br/Mg-exchange affording the corresponding magnesium reagent which reacted with TMTD yielding the dithiocarbamate **148** in 76%. At last, reaction of the generated dithiocarbamate **148** with KO*t*Bu (50 °C, 24 h) gave the expected 2-chloro[1]benzothieno[3,2-*b*][1]benzothiophene **137** in 73% yield.



Scheme 62: Synthesis of 2-chloro[1]benzothieno[3,2-*b*][1]benzothiophene (**137**).

The so obtained polyfunctional dibenzothiophenes can be metalated and further functionalized. Thus, treatment of the functionalized dibenzothiophene **134b** with *n*BuLi (–78 °C, 30 min)[79] furnished the lithium reagent **149** which was transmetalated to the corresponding zinc reagent **150** (Scheme 63). This zinc reagent was suitable to undergo a Pd-catalyzed cross-coupling (50 °C, 14 h) with 1-bromo-2-iodobenzene (**138e**) in the presence of $Pd(dba)_2$ and tfp affording compound **151** in 63% yield.

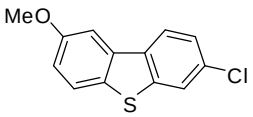
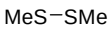
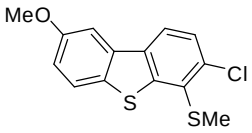
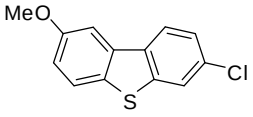
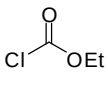
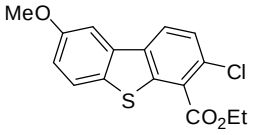
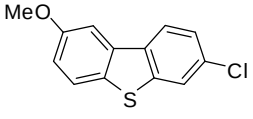
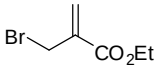
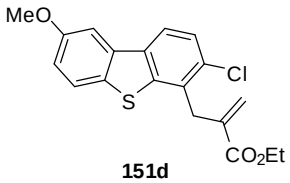
[79] For the lithiation of dibenzothiophene, see: R. Rossi, F. Bellina, D. Ciucci, A. Carpita, C. Fanelli, *Tetrahedron*, **1998**, *54*, 7595.



Scheme 63: Metalation and subsequent Negishi cross-coupling of dibenzothiazole **134b**.

The accessable lithium reagent **149** was treated with various electrophiles. Thus, reaction with dimethyldisulfide (**152a**) or ethyl chloroformate (**152b**) furnished **151b** and **151c** in 81% and 83% yield (Table 21, entries 1-2). The zinc reagent **150** reacted in the presence of CuCN·2LiCl (10 mol%) with ethyl 2-(bromomethyl)acrylate (**152c**) to the ester **151d** in 94% yield (Table 21, entry 3).

Table 21: Functionalization of **134b** leading to compounds of type **151**.

entry	substrate	electrophile	product	yield, %[a]
1	 **134b**	 **152a**	 **151b**	81
2	 **134b**	 **152b**	 **151c**	83
3	 **134b**	 **152c**	 **151d**	94

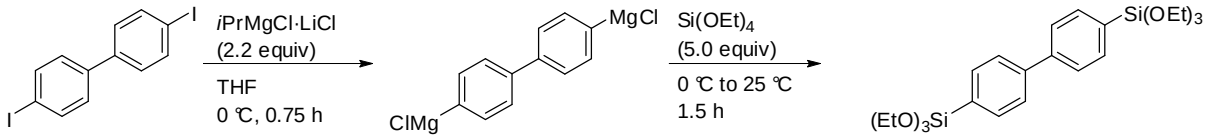
[a] Yield of isolated, analytically pure product.

8. Synthesis of Bis(trialkoxysilyl)biphenyls as Precursors for Periodic Mesoporous Silica

The synthesis of periodic mesoporous silica (PMO) has gained much interest in recent years.[80] These materials can be synthesized from bis(alkoxysilyl) precursors $(RO)_3Si\text{-}R'\text{-}Si(OR)_3$ in the presence of surfactants such tetraalkylammonium halides or nonionic triblock-copolymers as structure directing agents. These kinds of materials exhibit various new and interesting properties, which can be tuned by choosing appropriate linker groups R. Recently, the synthesis of optically active PMO materials has been reported.[81] Furthermore, they can be used as pH sensors, catalysts or fluorescent materials.[82] In particular, thin films of PMO material with biphenyl bridges showed exceptionally high fluorescence quantum yields. The confinement of such a material within the pores of anodic alumina membranes could offer new features such as high aspects ratios of the pore system and unusual optical properties.

This part of the thesis describes the synthesis of various 4,4'-bis(trialkoxysilyl)biphenyls which will be used as starting materials in the synthesis of PMOs.

Starting from 4,4'-diiodobiphenyl (**153**), the desired 4,4'-bis(triethoxysilyl)biphenyl (**155a**) was synthesized by a modified procedure published by *Webster*.[83] Treatment of 4,4'-diiodobiphenyl with *i*PrMgCl·LiCl (0 °C, 45 min) provided the bis-magnesium species **154** (Scheme 64). Then, **154** was treated with an excess of $Si(OEt)_4$ to afford **155a** in 41% yield. This method proved to be superior to the method described by *Webster*, nonetheless, the still low yield results from polymerization side-products.

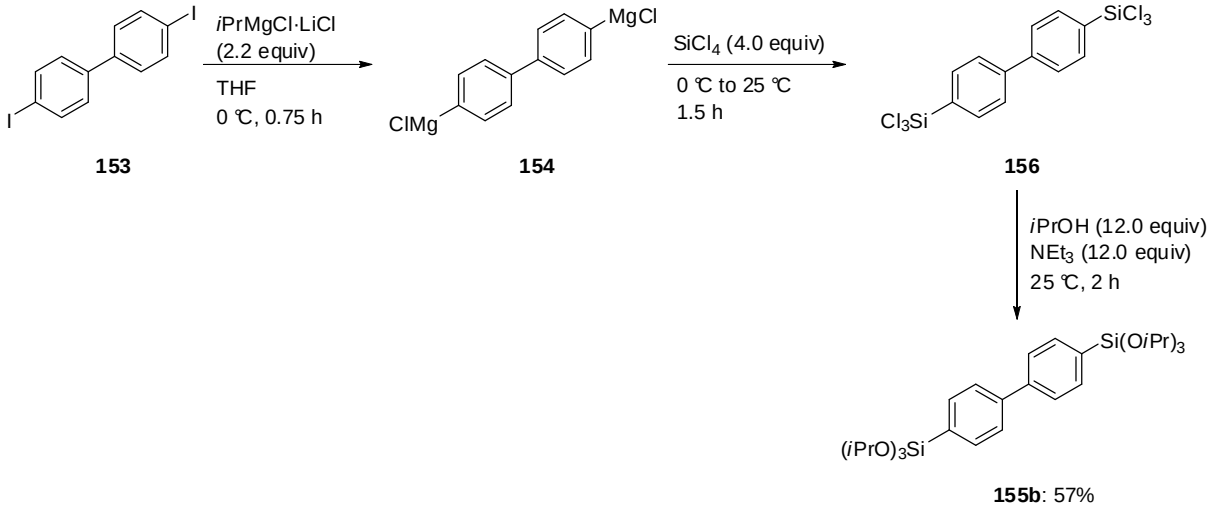


153 **154** **155a**: 42%

Scheme 64: Synthesis of 4,4'-bis(trietoxysilyl)biphenyl (**155a**).

[80] a) F. Hoffmann, M. Cornelius, J. Morell, M. Froeba, *Angew. Chem. Int. Ed.* **2006**, *45*, 3216; b) B. Halton, K. Whitnall, D. Perovic, G. A. Ozin, *Acc. Chem. Res.* **2005**, *38*, 305.
[81] Y. Goto, N. Mizoshita, O. Ohtani, T. Okada, T. Shimada, T. Tani, S. Inagaki, *Chem. Mater*. **2008**, *20*, 4495.
[82] a) G. Wirnsberger, B. J. Scott, G. D. Stucky, *Chem. Commun*. **2001**, 119; b) Q. Yang, J. Liu, J. Yang, M. P. Kapoor, S. Inagaki, C. Li, *J. Catal.* **2004**, *228*, 265; c) Y. Goto, N. Mizoshita, O. Ohtani, T. Okada, T. Shimata, T. Tani, S. Inagaki, *Chem. Mater.* **2008**, *20*, 4495; d) E. M. Wong, M. A. Markowitz, S. B. Quadri, S. Golledge, D. G. Castner, B. P. Gaber, *J. Phys. Chem. B* **2002**, *106*, 6652.
[83] K. J. Shea, D. A. Loy, O.Webster, *J. Am. Chem. Soc.* **1992**, *114*, 6700.

For the synthesis of other siloxanes a new method based on the results of *Reyé* et al.[84] was developed, since beside $Si(OEt)_4$ no reagents of the type $Si(OR)_4$ are available. Thus, treatment of 4,4'-diiodophenyl (**153**) with *i*PrMgCl·LiCl furnished **154** which was trapped with $SiCl_4$ (4.0 equiv) yielding the chlorosilane derivative **156** (Scheme 65). Addition of a large excess of *i*PrOH (12.0 equiv) and NEt_3 (12.0 equiv) gave the desired siloxane **155b** in 57% yield.



153 **154** **156**

155b: 57%

Scheme 65: Preparation of the siloxane **155b**.

Since various alcohols can be used in this reaction procedure, this protocol should give access to a variety of alkoxysilylarenes.

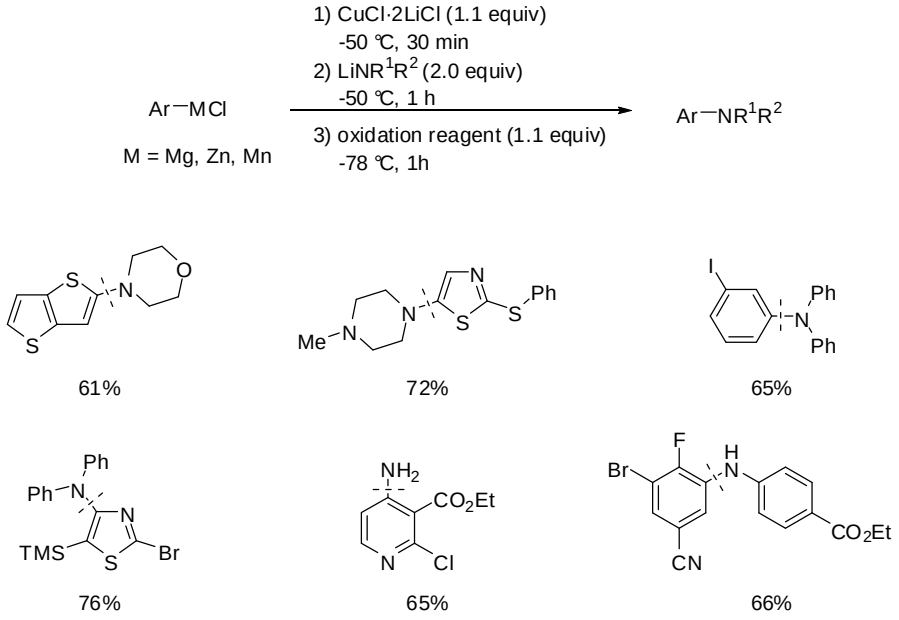
[84] R. J. P. Corriu, E. Lancelle-Beltran, A. Mehdi, C.Reyé, S. Brandès, R. Guilard, *Chem. Mater.* **2003**, *15*, 3152.

9. Summary and Outlook

This work was focused on the development of oxidative cross-coupling reactions employing readily available organometallics. Furthermore, the improvement and the application of the Negishi cross-coupling were studied in detail. This allows the synthesis of small oligomers which may find application as donors in blended organic solar cells. Finally, a new ring closure for the preparation of S-heterocycles was developed.

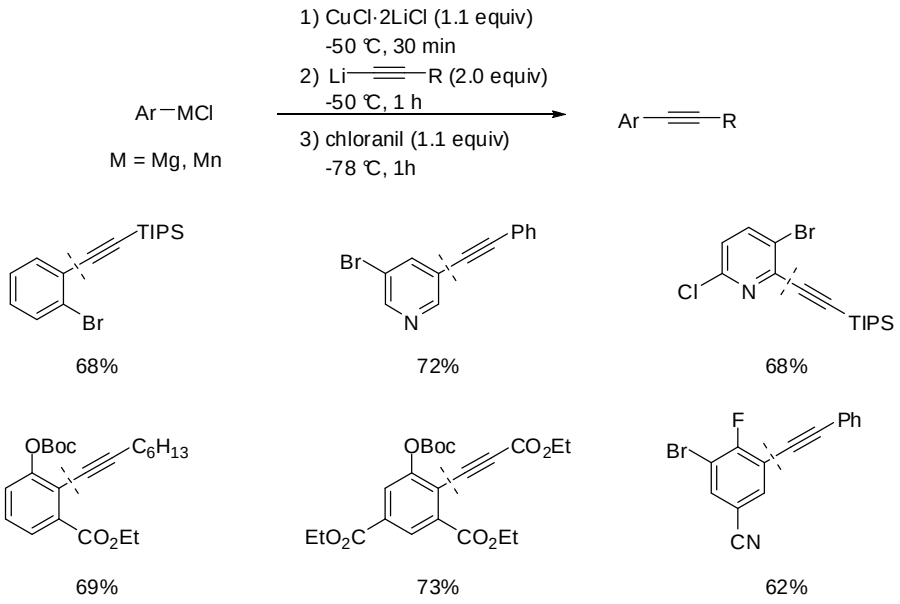
9.1 Oxidative Cross-Coupling Reactions

The Cu(I)-mediated oxidative amination reaction was extended from functionalized organomagnesium reagents towards organozinc and organomanganese compounds (Scheme 66). In general, organocopper reagents obtained from the corresponding organozinc and manganese compounds gave higher yields compared to the corresponding magnesium reagents. Aromatics and heteroaromatics bearing acidic protons were smoothly directly metalated using different new amide bases furnishing the required organometallics. Additionally, we found that these amination reactions can be easily scaled up when $ZnCl_2$ is present in the reaction mixture.



Scheme 66: Oxidative amination reaction.

Furthermore, this procedure was employed for an oxidative Sonogashira-type reaction (Scheme 67). This reaction allowed the selective monofunctionalization of dihaloarenes and the coupling of sterically hindered arenes. Beside organomagnesium reagent various organomanganese compounds, obtained by manganation with $TMP_2Mn{\cdot}2MgCl_2{\cdot}4LiCl$, were successfully coupled.

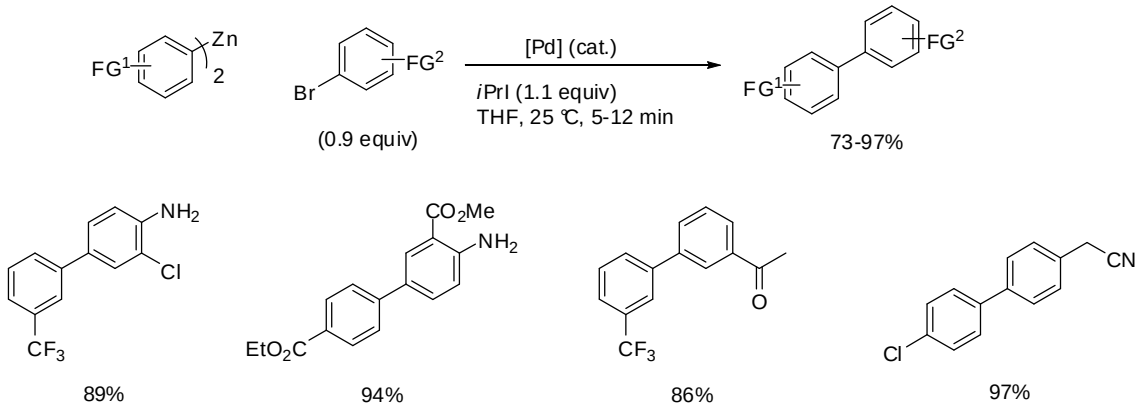


Scheme 67: Oxidative Sonogashira-type reaction.

The Cu(I)-mediated oxidative amination reaction and the oxidative Sonogashira-type reaction of organomanganese compounds are remarkable, since they allow for the first time an oxidative cross-coupling of organomanganese reagents.
A useful extension would be the development of further oxidation reagents, since we have shown that the choice of oxidation reagents influences the outcome of the reaction dramatically.

9.2 Negishi Cross-Coupling Reaction in the Presence of *i*PrI

A remarkably fast and efficient Pd-catalyzed cross-coupling of a wide range of arylzinc reagents with aryl bromides bearing various acidic protons in the presence of *i*PrI was described. The reaction scope is broad and the cross-couplings are finished within 5-12 min at 25 °C (Scheme 68). This reaction gives an easy access to functionalized biaryls bearing acidic protons without the need of protection.



Scheme 68: Negishi cross-coupling in the presence of *i*PrI.

An extension to zinc reagents obtained by direct metalation might be challenging, as in this case the cross-couplings proceed quite slowly due to the presence of an amide base.

9.3 Preparation of Small Oligomers for the Use as Donors in Blended Organic Solar Cells

The synthesis of small oligomers using functionalized thiazoles and thiophenes as building blocks was elaborated. The preparation of various dimers, trimers and a tetramer containing both electron-donating and electron-withdrawing groups was achieved (Figure 5). The properties of these compounds are currently tested in the Department of Physics, LMU, Munich.

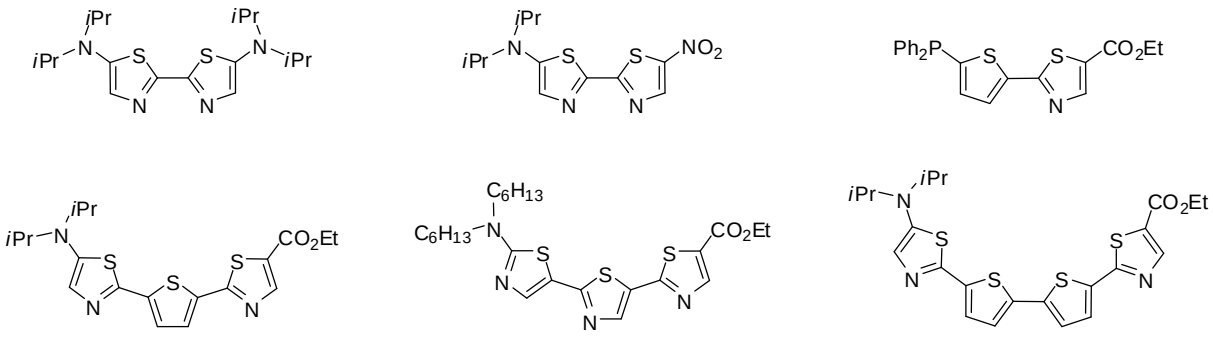
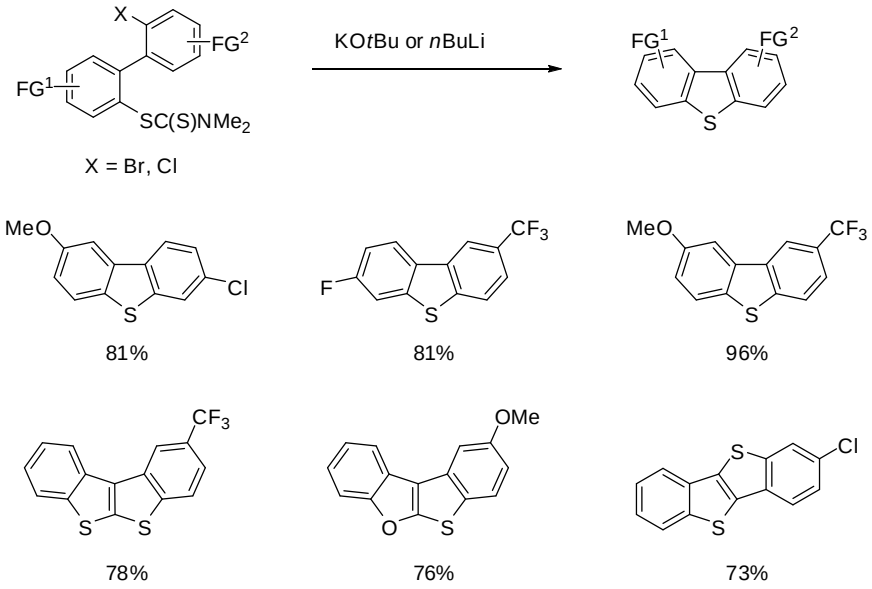


Figure 5: Examples of various prepared small oligomers.

Further extensions of this project could be directed to the synthesis of related oligomers based on thienothiophenes as scaffold and the introduction of various new electron-donating and electron-withdrawing groups.

9.4 Synthesis of Dibenzothiophenes and Related Classes of S-Heterocycles via an Anionic Electrocyclization

Finally, a new cyclization reaction involving an intramolecular addition-elimination of a lithium or potassium thiolate was developed. This protocol allows the preparation of new classes of S-heterocycles as well as the synthesis of polyfunctionalized dibenzothiophenes (Scheme 69).



Scheme 69: Intramolecular ring closing leading to S-heterocycles.

Further extensions of this methodology could be directed towards the synthesis of functionalized thienothiophenes and related S-heterocycles starting from readily available dithiocarbamates.

C

EXPERIMENTAL SECTION

1. General Considerations

All reactions employing air or moisture sensitive reagents were performed in flame-dried glassware under argon. Syringes which were used for the transfer of such reagents or anhydrous solvents were purged with argon prior to use.

Solvents

Solvents were dried according to standard methods by distillation over drying agents as stated below and stored under argon.
The solvents used for workups and flash chromatography were distilled at the rotavapor prior to use.
***Bis*[2-(*N*,*N*dimethylamino)ethyl]ether** was distilled from CaH_2 under nitrogen atmosphere.
CH_2Cl_2 was predried over calcium chloride and was distilled from calcium hydride.
Diethyl ether (Et_2O) was predried over calcium hydride and then dried using a solvent-purification device of type SPS-400-2 (Innovative Technologies Inc.).
Diisopropylamine was distilled from CaH_2 under nitrogen atmosphere.
Ethanol was treated with phthalic anhydride (25 g/L) and sodium, heated to reflux for 6 h and distilled.
Tetrahydrofuran (THF) was continuously refluxed and freshly distilled from sodium benzophenone ketyl.

Reagents

As not otherwise stated, all reagents were obtained from commercial sources. Reagents of >97 % purity were used as obtained.

The following substances were prepared according to literature procedures:

N,*N*-Dihexyl-1,3-thiazol-2-amine,[73] 1-bromo-2-iodo-4-methoxybenzene,[75] 1-bromo-2-iodo-4-(trifluoromethyl)benzene,[77] 2,2'-dibromobiphenyl,[76] 5,5'-dibromo-2,2'-bithiophene.[85]

[85] For the preaparation of 5,5'-dibromo-2,2'-bithiophene, see: A. Krasovskiy, A. Tishkov, V. del Amo, H. Mayr, P. Knochel, *Angew. Chem. Int. Ed.* **2006**, *45*, 5010.

***i*-PrMgCl·LiCl** in THF was either used as solution (1.30 M) purchased from *Chemetall* or prepared according to the following procedure:

Magnesium turnings (2.64 g, 110 mmol, 1.10 equiv) and anhydrous LiCl (4.20 g, 100 mmol, 1.00 equiv) were placed in an Ar-flushed flask and were flame dried in high vacuum. After cooling to 25 °C and purging with argon, THF (50 mL) was added. A solution of *i*-PrCl (7.85 g, 100 mmol, 1.00 equiv) in THF (50 mL) was slowly added at 25 °C. After addition, the reaction mixture was stirred for 12 h at rt. The grey solution of *i*-PrMgCl·LiCl was cannulated to another flask under Ar and removed in this way from excess of magnesium. A yield of ca. 95-98% of *i*PrMgCl·LiCl was obtained. The reagent was titrated prior to use by the method of Paquette,[86] or the method developed in our laboratory.[87]

Preparation of $ZnCl_2$·2LiCl in THF (1.0 M)

$ZnCl_2$ (27.3 g, 200 mmol) and LiCl (17.0 g, 400 mmol) were placed in a 500 mL Schenk flask equipped with a magnetic stirring bar and a septum. The salts were heated at 150 °C in an oil bath for 4 h under high vacuum. Then, after cooling to 25 °C absolute THF (200 mL) was added. Afterwards, the septum was replaced by a glass stopper and the suspension was left stirring over night at 25 °C. After 12 h, the salts had completely dissolved, the stirring was stopped and the solution was left for some more time to become completely clear (little particles and insoluble impurities were allowed to settle down by that way). The solution was stored under argon upon use.

Preparation of CuCl·2LiCl (1 M in THF):

A dry and argon-flushed 50 mL *Schlenk*-flask, equipped with a magnetic stirring bar and a glass stopper, was charged with LiCl (1.7 g, 40 mmol) and heated up to 130 °C under high vacuum for 1-2 h. After cooling to room temperature under argon, CuCl (1.98 g, 20 mmol, 99.5% Cu) was added under inert atmosphere inside a glove-box. The *Schlenk*-flask was further heated to 130 °C for 5 h under high vacuum, cooled to room temperature, charged with freshly distilled THF (20 mL) under argon and wrapped in aluminium foil to protect it from light. The mixture was vigorously stirred until all solid went in solution (ca. 6 h). The reagent CuCl·2LiCl (1 M in THF) appears as a colourless or slightly pink solution.

[86] Lin, H.-S.; Paquette, L. A. *Synth. Commun.* **1994**, *24*, 2503.
[87] A. Krasovskiy, P. Knochel, *Synthesis* **2006**, 890.

Preparation of $MnCl_2$·2LiCl (1 M in THF):

A dry and argon-flushed 250 mL Schlenk-tube, equipped with a magnetic stirring bar and a glass stopper, was charged with LiCl (6.8 g, 160 mmol) and heated up to 150 °C under high vacuum for 3 h. After cooling to room temperature under argon, $MnCl_2$ (10.1 g, 80 mmol, 99% pure) was added under inert atmosphere inside a glove-box. The Schlenk-flask was further heated to 130 °C for 3 h under high vacuum, cooled to room temperature, charged with freshly distilled THF (80 mL) under argon with vigorous stirring. The mixture was stirred for at least 24 h at 25 °C. The reagent $MnCl_2$·2LiCl (1.0 M in THF) appears as a yellow solution.

Preparation of $MgCl_2$·LiCl in THF (0.50 M)

LiCl (424 mg, 10 mmol) was placed in a 50 mL Schenk tube equipped with a magnetic stirring bar and a septum. The salt is heated at 650 °C using a heatgun for 15 min under high vacuum. Then, Mg turnings (243 mg, 10 mmol) were added, followed by absolute THF (5 mL). Afterwards, 1,2-dichloroethane (0.79 mL, 10 mmol) was added in one portion. The reaction was started by gentle warming of the reaction mixture. Once the reaction is started the mixture is cooled by the further addition of THF (15 ml). After complete dissolving of LiCl the stirring was stopped and the solution was was left for some more time to become completely clear (little particles and insoluble impurities are allowed to settle down by that way). The solution was stored under argon upon use.

Determination of the Concentration of the Organometallic Reagents:

Organomagnesium reagents were directly titrated by adding the respective reagent to a known amount of I_2 in a LiCl-solution in THF (0.50 M). The decolourization of the solution was observed.[87]

Preparation of the reagent TMPMgCl·LiCl:

A dry and nitrogen-flushed 250 mL *Schlenk*-flask, equipped with a magnetic stirring bar and a septum, was charged with freshly titrated *i*-PrMgCl·LiCl (1.2 M in THF) (100 mL, 120 mmol). 2,2,6,6-Tetramethylpiperidine (TMPH) (19.8 g, 126 mmol, 1.05 equiv) was added dropwise at room temperature. The reaction mixture was stirred at room temperature until gas evolution was completed (*ca*. 24 h). The reagent was titrated prior to use (benzoic acid and 4-(phenylazo)diphenylamine as indicator).

Preparation of the reagent $TMP_2Zn{\cdot}2MgCl_2{\cdot}2LiCl$:

In an argon-flushed Schlenk-flask, $ZnCl_2$ (53.0 mmol, 7.22 g) was dried *in vacuo* at 140 °C for 4 h. After cooling to 25 °C, freshly titrated TMPMgCl·LiCl (100 mmol, 1.00 M, 100 mL) was added dropwise. The resulting mixture was stirred for 15 h at 25 °C. The freshly prepared $TMP_2Zn{\cdot}2MgCl_2{\cdot}2LiCl$ solution was titrated prior to use at 0°C with benzoic acid using 4-(phenylazo)diphenylamine as indicator. A concentration of 1.60-1.70 M in THF (concentration of Zn) was obtained.

Preparation of the reagent $TMP_2Mn{\cdot}2MgCl_2{\cdot}4LiCl$:

A dry and nitrogen-flushed 100 mL *Schlenk*-flask, equipped with a magnetic stirring bar and a septum, was charged with freshly titrated TMPMgCl·LiCl (50.0 mmol, 1.11 M, 36.0 mL). $MnCl_2{\cdot}2LiCl$ (1.0 M in THF) was added dropwise at 0 °C. The resulting mixture was stirred for 30 min at 0 °C and at 25 °C for additional 2.5 h. The reagent was titrated prior to use (benzoic acid and 4-(phenylazo)diphenylamine as indicator).

Preparation of Grignard-reagents like 58b-d and 98:

Magnesium turnings (150 mmol) and anhydrous LiCl (100 mmol) were placed in an argon-flushed 3 necks round-bottomed flask, equipped with a magnetic stirring bar, a condenser and an addition funnel, and THF (50 mL) was added. A solution of the corresponding chloroarene or bromoarene (100 mmol) in dry THF (50 mL) was added dropwise at 50-60 °C through the addition funnel. If the reaction did not start spontaneously, DIBAH (20 % solution in hexane, 10 mmol) was added to the reaction mixture. After two hours of vigorous stirring the desired Grignard reagent was formed, as determined by GC analysis after iodolysis of a reaction aliquot. The grey solution of the Grignard reagent was cannulated under argon to a Schlenk flask and removed in this way from the excess of magnesium. The reagent was titrated prior to use by the method developed by our laboratory.[87]

Chromatography

Thin layer chromatography (TLC) was performed using aluminium plates covered with SiO_2 (Merck 60, F-254). Spots were visualized under UV light and/or by staining of the TLC plate with one of the solutions below followed by heating with a heat gun:

1. $KMnO_4$ (0.3 g), K_2CO_3 (20 g), KOH (0.3 g) in water (300 mL).

2. Phosphormolybdic acid (5.0 g), $Ce(SO_4)_2$ (2.0 g), conc. H_2SO_4 (12.0 mL) in water (230 mL).

Flash column chromatography was performed using SiO_2 60 (0.040-0.063 mm, 230-400 mesh ASTM) from *Merck* or Al_2O_3 (reactivity grade III) from *Merck*.

Analytical Data

NMR-spectra were recorded on *Bruker* ARX 200, AC 300, WH 400 or AMX 600 instruments. Chemical shifts are reported as δ–values in ppm relative to the deuterated solvent peak: $CDCl_3$(δ_H = 7.25; δ_C= 77.0), DMSO-d_6(δ_H = 2.49; δ_C= 39.5), C_6D_6 (δ_H = 7.16; δ_C= 128.0), THF-d_8 (δ_H = 1.73; 3.58; δ_C= 25.3; 67.4).

For the characterization of the observed signal multiplicities, the following abbreviations were used: s (singlet), d (doublet), dd (doublet of doublets), t (triplet), q (quartet), quint (quintet), sext (sextet), sept (septet), br (broad). If not otherwise noted, the coupling constants given are (CH)-coupling constants.

Melting points are uncorrected and were measured on a *Büchi* B.540 apparatus.

Infrared spectra were recorded from 4000-400 cm^{-1} on a *Nicolet* 510 FT-IR or a *Perkin-Elmer* 281 IR spectrometer. Samples wer measured either as film between potassium bromide plates (film), as potassium bromide tablets (KBr), or neat (*Smiths Detection* DuraSampl *IR* II Diamond ATR).

The absorption bands are reported in wavenumbers (cm^{-1}). For the band characterization, the following abbreviations were used: br (broad), vs (very strong), s (strong), m (medium), w (weak) vw (very weak).

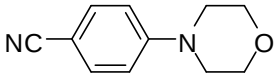
Gas chromatography (GC) was performed machines of the types *Hewlett-Packard* 6890 or 5890 Series II, using a column of the type HP 5 (*Hewlett-Packard*, 5% phenylmethylpolysiloxane; length: 10 m, diameter: 0.25 mm; film thickness: 0.25 μm). The detection was accomplished using a flame ionization detector. Depending on the retention time of the substrate, decane or tetradecane were used as internal standards.

Mass Spectra were recorded on a *Finnigan* MAT 95Q or *Finnigan* MAT90 instrument for electron impact ionization (EI). High resolution mass spectra (HRMS) were recorded on the same instrument.

For the combination of gas chromatography with mass spectroscopic detection, a GC-MS of the type *Hewlett-Packard* 6890 / MSD 5793 networking was used (column: HP 5-MS, *Hewlett-Packard*; 5% phenylmethylpolysiloxane; length: 15 m, diameter 0.25 mm; film thickness: 0.25 μm).

2. Typical Procedures (TP)

2.1 Typical procedure for the preparation of N-(4-cyanophenyl)morpholine (56b) (TP1)

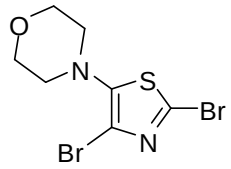


A dry and argon-flushed Schlenk-flask, equipped with a magnetic stirring bar and a septum, was charged with *i*PrMgCl·LiCl (1.39 M in THF; 0.79 mL, 1.1 mmol) and cooled to 0 °C. 4-bromobenzonitrile (182 mg, 1.0 mmol) was added and the mixture was stirred at 0 °C for 2 h to afford the the corresponding magnesium reagent. This reagent was added dropwise to the mixture of CuCl·2LiCl (1.0 M in THF; 1.2 mL, 1.2 equiv) and *bis*[2-(*N*,*N*-dimethylamino)ethyl]ether (192 mg, 1.2 mmol) at –50 °C and the mixture was stirred for 45 min. To the so formed aryl cuprate, lithium morpholide (2 mmol; prepared by adding *n*BuLi (2 mmol) to a 0.5 M solution (174 mg, 2 mmol) of morpholine in THF at 0 °C and stirring for 30 min) was added dropwise and the mixture was further stirred for 1 h at –50 °C. The reaction mixture was cooled to –78 °C, then chloranil (295 mg, 1.2 mmol), in dry THF (7 mL), was added slowly over a period of 45 min. The reaction mixture was allowed to reach –50 °C and was further stirred for 12 h. Diethyl ether (10 mL) was added to the crude reaction mixture and it was filtered through Celite, washed with diethyl ether thoroughly, and the filtrate was washed with 2 x 10 mL portions of NH_4OH (aq., 2.0 M). The organic extract was dried over $MgSO_4$, filtered and concentrated under reduced pressure. Purification by flash chromatography (pentane/Et_2O; 1:1) afforded **56b** (147 mg, 78 %) as an off-white solid. The spectroscopic data match with the literature. [88]

^{1}H-NMR (300 MHz, $CDCl_3$): δ = 7.53 (d, *J* = 9.1 Hz, 2 H, Ar*H*), 6.88 (d, *J* = 9.1 Hz, 2 H, Ar*H*), 3.87 (t, *J* = 5.0 Hz, 4 H, 2 x CH_2), 3.30 (t, *J* = 5.0 Hz, 4 H, 2 x CH_2).
^{13}C-NMR (75 MHz, $CDCl_3$): δ = 153.8, 133.8, 120.1, 114.3, 101.2, 66.7, 47.6.

[88] N.Kataoka, Q. Shelby, J. P. Stambuli, J. F. Hartwig, *J. Org. Chem.* **2002**, *67*, 5553.

2.2 Typical procedure for the preparation of 4-(2,4-dibromo-1,3-thiazol-5-yl)morpholine (65b) (TP2)



A dry and argon-flushed Schlenk-flask, equipped with a magnetic stirring bar and a septum, was charged with 2,4-dibromo-1,3-thiazole (243 mg, 1.0 mmol) and THF (1 mL). To the resulting mixture was added dropwise $TMP_2Zn \cdot 2MgCl_2 \cdot 2LiCl$ (1.30 mL, 1.68 M in THF, 0.55 mmol) and stirred for 45 min. CuCl·2LiCl (1.1 mL, 1.0 M in THF, 1.1 mmol) was added dropwise to the reaction mixture at –50 °C under argon and the resulting solution was stirred for 30 min. Lithium morpholide (2.0 mmol; prepared by adding *n*BuLi (2 mmol) to a 0.5 M solution of morpholine in THF (174 mg, 2 mmol) at 0 °C and stirring for 30 min) was added dropwise to the resulting cuprate, and the mixture was stirred for 1 h at –50 °C. The reaction mixture was cooled to –78 °C, then, a solution of $PhI(OAc)_2$ (354 mg, 1.1 mmol) in dry THF (10 mL) was added slowly over a period of 60 min. The reaction mixture was then warmed to –50 °C and stirred for 3 h. Et_2O (100 mL) was poured into the crude reaction mixture. The organic phase was washed with 2 x 10 mL portions of aqueous NH_4OH (2.0 M) and extracted with Et_2O. The combined organic layers were dried (Na_2SO_4), filtered, and concentrated under reduced pressure. Purification by flash chromatography (pentane/ether; 9:1) yielded **65b** (230 mg, 70 %) as a colourless solid.

mp: 80.6 – 81.8 °C.

IR (ATR) $\tilde{\nu}$ (cm^{-1}): 2854, 2832, 1521, 1450, 1410, 1377, 1293, 1266, 1208, 1195, 1152, 1110, 1071, 1030, 1016, 926, 887, 853, 835, 818, 702, 666.

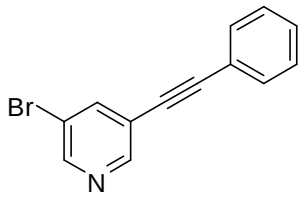
^{1}H-NMR (400 MHz, C_6D_6): δ = 3.35 (t, *J* = 4.7 Hz, 4H, 2 x C*H*$_2$), 2.33 (t, *J* = 4.6 Hz, 4H, 2 x C*H*$_2$).

^{13}C-NMR (100 MHz, C_6D_6): δ = 150.2, 127.4, 114.6, 66.3, 53.2.

MS (70 eV, EI): *m/z* (%) = 330 (34), 328 (65), 326 (35), 272 (25), 270 (41), 125 (21), 111 (40), 109 (24), 99 (26), 97 (67), 95 (36), 85 (58), 83 (65), 81 (41), 71 (67), 69 (65), 57 (100).

HRMS (EI): *m/z* calc. for [$C_7H_8Br_2N_2OS$] 325.8724, found: 325.8713.

2.3 Typical procedure for the preparation of 3-bromo-5-phenylethynylpyridine (73a) (TP3)



A dry and argon-flushed Schlenk-flask, equipped with a magnetic stirring bar and a septum, was charged with 3,5-dibromopyridine (237 mg, 1.0 mmol). After cooling to 0 °C, *i*PrMgCl·LiCl (0.92 mL, 1.20 M in THF, 1.1 mmol) was added dropwise and stirred for 0.5 h and then at 25 °C for further 0.5 h affording 5-bromo-3-pyridylmagnesium chloride. CuCl·2LiCl (1.2 mL, 1.0 M in THF, 1.2 mmol) was added dropwise to the magnesium reagent at –50 °C under argon and the mixture was stirred for 25 min. Phenylethynyllithium (2.0 mmol; prepared by adding *n*BuLi (2 mmol) to a 0.5 M solution of phenyl acetylene (204 mg, 2.0 mmol) at 0 °C and stirring for 30 min) was added dropwise to the resulting cuprate, and the mixture was stirred for 1 h at –50 °C. The reaction mixture was cooled to –78 °C, then, a solution of chloranil (320 mg, 1.3 mmol) in dry THF (7 mL) was added slowly over a period of 45 min. The reaction mixture was then warmed to –50 °C and stirred for 3 h. Et_2O (10 mL) was poured into the crude reaction mixture and the reaction mixture was then filtered through celite and the residue washed with Et_2O (ca. 100 mL). The organic phase was washed with 2 x 10 mL portions of aqueous NH_4OH (2.0 M) and extracted with Et_2O. The combined organic layers were dried ($MgSO_4$), filtered, and concentrated in vacuo. Purification by flash chromatography (pentane/Et_2O; 9:1) yielded **73a** (186 mg, 72 %) as a colourless solid.

mp.: 99.1 – 100.2 °C.

IR (ATR) $\tilde{\nu}$ (cm^{-1}): 3032, 2219, 1597, 1572, 1489, 1429, 1406, 1101, 1013, 941, 916, 879, 755, 687, 659, 611.

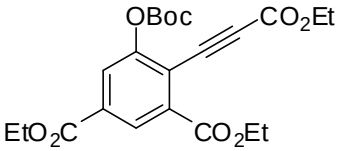
^{1}H-NMR (300 MHz, $CDCl_3$): δ = 8.65 (d, 1H, *J* = 1.8 Hz, Ar*H*), 8.6d (d, 1H, *J* = 2.2 Hz, Ar*H*), 7.95 (dd, *J* = 2.2 Hz, *J* = 1.8 Hz, 1H, Ar*H*), 7.53 (m, 2H, Ar*H*). 7.37 (m, 3H, Ar*H*).

^{13}C-NMR (75 MHz, $CDCl_3$): δ = 150.2, 149.7, 140.6, 131.7, 129.1, 128.5, 122.0, 121.9, 120.1, 94.0, 84.4.

MS (70 eV, EI): *m/z* (%) = 259 (97), 257 (100), 152 (14), 151 (26), 150 (12), 75 (5).

HRMS (EI): *m/z* calc. for [$C_{13}H_8N^{79}Br$] 256.9840, found: 256.9850.

2.4 Synthesis of diethyl 5-[(tert-butoxycarbonyl)oxy]-4-(3-ethoxy-3-oxoprop-1-yn-1-yl)isophthalate (73t) (TP4)



A dry and argon-flushed Schlenk-flask, equipped with a magnetic stirring bar and a septum, was charged with a solution of 5-*tert*-butoxycarbonyloxy-isophthalic acid diethyl ester (338 mg, 1.0 mmol) in dry THF (3 mL). After cooling to 0 °C, TMPMgCl·LiCl (1.20 M in THF; 0.92 mL, 1.1 mmol) was added dropwise and stirred for 1 h to afford the corresponding magnesium reagent. CuCl·2LiCl (1.2 mL, 1.0 M in THF, 1.2 mmol) was added dropwise to the reaction mixture at –50 °C under argon and the mixture was stirred for 20 min. Ethynyllithium (2.0 mmol; prepared by adding *n*BuLi (2 mmol) to a 0.5 M solution of 1-ethylpropiolate in THF (196 mg, 2 mmol) at –78 °C and stirring for 60 min) was added dropwise to the resulting cuprate, and the mixture was further stirred for 1 h at –78 °C (the mixture was usually stirred at –50 °C for 60 min). Then a solution of chloranil (320 mg, 1.3 mmol) in dry THF (7 mL) was added slowly over a period of 45 min at –78 °C. The reaction mixture was then stirred for additional 3 h. Et_2O (10 mL) was poured into the crude reaction mixture and the reaction mixture was then filtered through celite and the residue washed with Et_2O (ca. 100 mL). The organic phase was washed with 2 x 10 mL portions of aqueous NH_4OH (2.0 M) and extracted with Et_2O. The combined organic layers were dried ($MgSO_4$), filtered, and concentrated under reduced pressure. Purification by flash chromatography (pentane/Et_2O; 7:1) yielded **73t** (316 mg, 73 %) as yellow solid.

mp.: 77.6 – v78.4 ^{o}C.

IR (ATR) $\tilde{\nu}$ (cm^{-1}): 3437, 3388, 3091, 2980, 2939, 2908, 2875, 2221, 1760, 1724, 1704, 1616, 1592, 1468, 1420, 1395, 1365, 1328, 1286, 1245, 1199, 1177, 1147, 1099, 1052, 1023, 956, 936, 917, 862, 816, 796, 763, 744, 703.

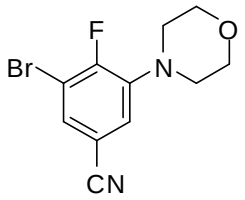
^{1}H-NMR (600 MHz, $CDCl_3$): δ = 8.55 (d, *J* = 1.8 Hz, 1H, Ar*H*), 8.00 (d, *J* = 1.8 Hz, 1H, Ar*H*), 4.44 (q, *J* = 7.1 Hz, 2H, $CO_2CH_2CH_3$), 4.41 (q, *J* = 7.1 Hz, 2H, $CO_2CH_2CH_3$), 4.30 (q, *J* = 7.1 Hz, 2H, $CO_2CH_2CH_3$), 1.57 (s, 9H, $C(CH_3)_3$), 1.43 (t, *J* = 7.1 Hz, 3H, $CO_2CH_2CH_3$), 1.40 (t, *J* = 7.1 Hz, 3H, $CO_2CH_2CH_3$), 1.34 (t, *J* = 7.1 Hz, 3H, $CO_2CH_2CH_3$).

^{13}C-NMR (150 MHz, $CDCl_3$): δ = 164.3, 154.1, 153.4, 150.8, 135.4, 133.0, 129.3, 126.8, 119.4, 92.0, 85.2, 77.9, 62.5, 62.4, 62.2, 27.8, 14.5, 14.3.

MS (70 eV, ESI): *m/z* (%) = 333 [M - Boc]$^+$(100).

HRMS (ESI): *m/z* calc. for [$C_{22}H_{26}O_9$+NH_4] 452.1912, found: 452.1917.

2.5 Typical procedure for the preparation of 3-bromo-4-fluoro-5-morpholin-4-ylbenzonitrile (84d) (TP5)



A dry and argon-flushed Schlenk-flask, equipped with a magnetic stirring bar and a septum, was charged with 3-bromo-4-fluorobenzonitrile (200 mg, 1.0 mmol). After cooling to –4 °C, $TMP_2Mn{\cdot}2MgCl_2{\cdot}4LiCl$ (1.70 mL, 1.32 M in THF, 1.1 mmol) was added dropwise and stirred for 30 min. CuCl·2LiCl (1.1 mL, 1.0 M in THF, 1.1 mmol) was added dropwise to the reaction mixture at –50 °C under argon and the mixture was stirred for 30 min. Lithium morpholide (2.0 mmol; prepared by adding *n*BuLi (2 mmol) to a 0.5 M solution of morpholine in THF (174 mg, 2 mmol) at 0 °C and stirring for 30 min) was added dropwise to the resulting cuprate, and the mixture was stirred for 1 h at –50 °C. The reaction mixture was cooled to –78 °C, then, a solution of chloranil (270 mg, 1.1 mmol) in dry THF (10 mL) was added slowly over a period of 60 min. The reaction mixture was then warmed to –50 °C and stirred for 3 h. Et_2O (10 mL) was poured into the crude reaction mixture and the reaction mixture was then filtered through celite and the residue washed with Et_2O (ca. 100 mL). The organic phase was washed with 2 x 10 mL portions of aqueous NH_4OH (2.0 M) and extracted with Et_2O. The combined organic layers were dried (Na_2SO_4), filtered, and concentrated under reduced pressure. Purification by flash chromatography (pentane/Et_2O; 2:1) yielded **84d** (208 mg, 73 %) as a colourless solid.

mp: 178.6 – 180.4 °C.

IR (ATR) $\tilde{\nu}$ (cm^{-1}): 2868, 2236, 1592, 1566, 1479, 1446, 1417, 1348, 1304, 1267, 1234, 1173, 1119, 1063, 995, 930, 891, 880, 851, 775, 746, 724, 654, 616.

^{1}H-NMR (300 MHz, $CDCl_3$): δ = 7.45 (dd, *J* = 7.5 Hz, *J* = 2.0 Hz, 1H, Ar*H*), 7.10 (dd, *J* = 7.4 Hz, *J* = 2.0 Hz, 1H, Ar*H*), 3.85 (t, *J* = 4.7 Hz, 4H, 2 x CH_2), 3.10 (t, *J* = 4.7 Hz, 4H, 2 x CH_2).

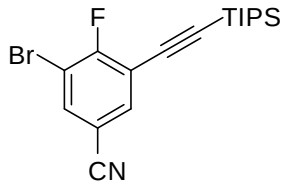
^{13}C-NMR (75 MHz, $CDCl_3$): δ = 154.8 (d, ^{1}J(C,F) = 256 Hz), 141.8 (d, ^{2}J(C,F) = 10 Hz), 129.5 (d, ^{4}J(C,F) = 1 Hz), 121.4 (d, ^{3}J(C,F) = 5 Hz), 117.1 (d, ^{5}J(C,F) = 2 Hz), 111.2 (d, ^{2}J(C,F) = 22 Hz), 109.6 (d, ^{3}J(C,F) = 5 Hz), 66.6, 50.4.

^{19}F-NMR (282 MHz, $CDCl_3$): δ = –105.9.

MS (70 eV, EI): *m/z* (%) = 286 (68), 285 (22), 284 (100), 228 (45), 227 (20), 226 (43), 225 (16).

HRMS (EI): *m/z* calc. for [$C_{11}H_{10}BrFN_2O$] 283.9961, found: 283.9945.

2.6 Typical procedure for the preparation of 3-bromo-4-fluoro-5-[(triisopropylsilyl)ethynyl]benzonitrile (87a) (TP6)



A dry and argon-flushed Schlenk-flask, equipped with a magnetic stirring bar and a septum, was charged with 3-bromo-4-fluorobenzonitrile (200 mg, 1.0 mmol). After cooling to –4 °C, $TMP_2Mn{\cdot}2MgCl_2{\cdot}4LiCl$ (1.70 mL, 1.32 M in THF, 1.1 mmol) was added dropwise and stirred for 30 min. CuCl·2LiCl (1.1 mL, 1.0 M in THF, 1.1 mmol) was added dropwise to the reaction nmixture at –50 °C under argon and the mixture was stirred for 30 min. 1-Triisopropylsilylethynyllithium (2.0 mmol; prepared by adding *n*BuLi (2 mmol) to a 0.5 M solution of triisopropylsilylacetylene in THF (365 mg, 2 mmol) at 0 °C and stirring for 30 min) was added dropwise to the resulting cuprate, and the mixture was stirred for 1 h at –50 °C. The reaction mixture was cooled to –78 °C, then, a solution of chloranil (270 mg, 1.1 mmol) in dry THF (10 mL) was added slowly over a period of 60 min. The reaction mixture

was then warmed to –50 °C and stirred for 3 h. Et_2O (10 mL) was poured into the crude reaction mixture and the reaction mixture was then filtered through celite and the residue washed with Et_2O (ca. 100 mL). The organic phase was washed with 2 x 10 mL portions of aqueous NH_4OH (2.0 M) and extracted with Et_2O. The combined organic layers were dried ($MgSO_4$), filtered, and concentrated under reduced pressure. Purification by flash chromatography (pentane/Et_2O; 20:1) yielded **87a** (251 mg, 66 %) as a light yellow oil.

IR (ATR) $\tilde{\nu}$ (cm^{-1}): 2944, 2892, 2866, 2236, 1594, 1563, 1461, 1454, 1398, 1384, 1368, 1289, 1268, 1238, 1072, 1018, 997, 968, 920, 880, 847, 751, 727, 670, 632, 615.

^{1}H-NMR (300 MHz, $CDCl_3$): δ = 7.78 (dd, *J* = 5.8 Hz, 1H, Ar*H*), 7.69 (dd, *J* = 5.8 Hz, 1H, Ar*H*), 1.12 (s, 21H, Si(*i*Pr)$_3$).

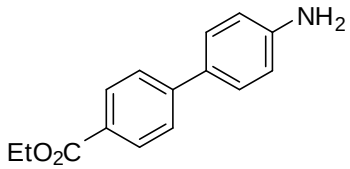
^{13}C-NMR (75 MHz, $CDCl_3$): δ = 162.2 (d, ^1J(C,F) = 261 Hz), 136.5 (d, ^4J(C,F) = 2 Hz), 136.4 (d, ^4J(C,F) = 2 Hz), 116.1 (d, ^5J(C,F) = 1 Hz), 115.2 (d, ^2J(C,F) = 19Hz), 110.6 (d, ^2J(C,F) = 23 Hz), 109.7 (d, ^3J(C,F) = 5 Hz), 102.3 (d, ^3J(C,F) = 4 Hz), 96.1, 18.5, 11.1.

^{19}F-NMR (282 MHz, $CDCl_3$): δ = –93.2.

MS (70 eV, EI): *m/z* (%) = 381 (7), 379 (6), 339 (20), 338 (95), 337 (23), 336 (100), 309 (35), 308 (36), 296 (14), 294 (15), 282 (47), 280 (52), 269 (14), 268 (81), 267 (16), 266 (85), 252 (12), 140 (19), 77 (17), 47 (22).

HRMS (EI): *m/z* calc. for [$C_{18}H_{23}BrFNSi$] 379.0767, found: 379.0770.

2.7 Typical procedure for the Negishi cross-coupling of zinc reagents obtained via an I/Mg-exchange. Preparation of ethyl 4'-aminobiphenyl-4-carboxylate (93f) (TP7)



A dry and argon flushed Schlenk-flask equipped with a magnetic stirring bar was charged with ethyl 4-iodbenzoate (552 mg, 2.0 mmol) and THF (2 mL). The mixture was cooled to –20 °C and *i*PrMgCl·LiCl (1.7 mL, 2.2 mmol, 0.84 M in THF) was added dropwise and stirring was continued for 20 min. The resulting Mg-reagent was transmetalated by the addition of $ZnCl_2$·2LiCl (1.1 mL, 1.1 mmol, 1.0 M in THF) and the resulting mixture was

warmed up to 25 °C within 30 min. To this mixture was added $Pd(dba)_2$ (11.6mg, 0.02 mmol), Ru-Phos (18.7 mg, 0.04 mmol) and 4-bromoaniline (310 mg, 1.8 mmol) in one portion followed by 2 mL THF. The resulting mixture was stirred for 15 min at 25 °C. Then, the reaction mixture was quenched with sat. aq. NH_4Cl solution and extracted with ether (3 x 50 mL). The combined organic phases were washed with sat. thiourea solution (2 x 5 mL) and dried over Na_2SO_4. After evaporation of the solvents the crude residue was purified by flash chromatography (pentane/ether; 3:2) yielding ethyl 4'-aminobiphenyl-4-carboxylate as a colourless solid (400 mg, 88 %).

mp: 96.1 – 97.8 °C

IR (ATR) $\tilde{\nu}$ (cm^{-1}): 3421, 3335, 1694, 1629, 1595, 1564, 1532, 1495, 1474, 1406, 1364, 1310, 1294, 1276, 1198, 1182, 1132, 1116, 1023, 1002, 858, 828, 769, 720.

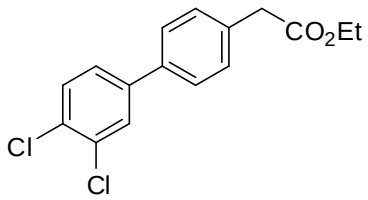
^{1}H-NMR (300 MHz, $CDCl_3$): δ = 8.06 (d, *J* = 8.8 Hz, 2H, Ar*H*), 7.59 (d, *J* = 8.5 Hz, 2H, Ar*H*), 7.45 (d, *J* = 8.5 Hz, 2H, Ar*H*), 6.75 (d, *J* = 8.5 Hz, 2H, Ar*H*), 4.39 (q, *J* = 8.3 Hz, 2H, C*H*$_2$CH$_3$), 3.80 (br, 2*H*, NH_2), 1.40 (t, *J* = 8.3 Hz, 3H, CH_2CH_3).

^{13}C-NMR (75 MHz, $CDCl_3$): δ = 166.6, 146.7, 145.4, 130.0, 128.2, 125.9, 115.3, 60.8, 14.3.

MS (70 eV, EI): *m/z* (%) = 242 (14), 241 (100), 213 (34), 196 (41), 168 (15), 167 (15), 84 (14).

HRMS (EI): *m/z* calc. for [$C_{15}H_{15}NO_2$] 241.1103, found: 241.1098.

2.8 Typical procedure for the Negishi cross-coupling of zinc reagents obtained via a Br/Mg-exchange and addition of *i*PrI. Preparation of ethyl (3',4'-dichlorobiphenyl-4-yl)acetate (97d) (TP8)



In a dry and argon flushed Schlenk-flask equipped with a magnetic stirring bar was added to a solution of 1,2-dichloro-4-bromobenzene (452 mg, 2.0 mmol, 1.0 M in THF) *i*PrMgCl·LiCl (1.7 mL, 2.2 mmol, 0.84 M in THF) and the resulting mixture was stirred at 25 °C for 1 h. The resulting Mg-reagent was transmetallated by the addition of $ZnCl_2$·2LiCl (1.1 mL, 1.1 mmol,

1.0 M in THF) and stirred for 30 min at 25 °C, followed by *i*PrI (340 mg, 2.0 mmol) and further stirring for 5 min at 25 °C. To this mixture was added $Pd(dba)_2$ (11.6mg, 0.02 mmol), Ru-Phos (18.7 mg, 0.04 mmol) and ethyl (4-bromophenyl)acetate (438 mg, 1.8 mmol) in one portion followed by 2 mL THF. The resulting mixture was stirred for 10 min at 25 °C. Then, the reaction mixture was quenched with sat. aq. NH_4Cl solution and extracted with ether (3 x 50 mL). The combined organic phases were washed with sat. thiourea solution (2 x 5 mL) and dried over Na_2SO_4. After evaporation of the solvents the crude residue was purified by flash chromatography (pentane/ether; 9:1) yielding ethyl (3',4'-dichlorobiphenyl-4-yl)acetate (**97d**) as a colourless oil (461 mg, 83 %).

IR (ATR) $\tilde{\nu}$ (cm^{-1}): 1731, 1550, 1465, 1368, 1333, 1299, 1248, 1222, 1153, 1134, 1096, 1027, 1018, 930, 881, 817, 800, 749, 679.

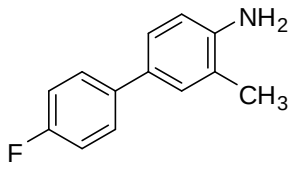
^{1}H-NMR (300 MHz, $CDCl_3$): δ = 7.64 (d, *J* = 1.9 Hz, 1H, Ar*H*), 7.52-7.45 (m, 3H, Ar*H*), 7.40-7.33 (m, 3H, Ar*H*), 4.18 (q, *J* = 7.2 Hz, 2H, C*H*$_2$CH$_3$), 3.65 (s, 2H, C*H*$_2$), 1.27 (t, *J* = 7.2 Hz, 3H, CH$_2$C*H*$_3$).

^{13}C-NMR (75 MHz, $CDCl_3$): δ = 171.3, 140.7, 137.4, 134.1, 132.7, 131.3, 130.6, 129.9, 128.7, 127.0, 126.2, 60.9, 40.9, 14.1.

MS (70 eV, EI): *m/z* (%) = 310 (24), 308 (38), 237 (66), 236 (13), 235 (100), 165 (25).

HRMS (EI): *m/z* calc. for [$C_{16}H_{14}Cl_2O$] 308.0371, found: 308.0359.

2.9 Typical procedure for the Negishi cross-coupling Coupling of zinc reagents obtained via magnesium insertion and addition of *i*PrI. Preparation of 3-chloro-4'-fluorobiphenyl-4-amine (93i) (TP9)



In a dry and argon flushed Schlenk-flask equipped with a magnetic stirring bar was added to a solution of 4-fluorophenylmagnesium bromide (2.35 mL, 2.0 mmol, 0.85 M in THF) $ZnCl_2 \cdot 2LiCl$ (1.1 mL, 1.1 mmol, 1.0 M in THF), and stirred for 30 min at 25 °C. Then, *i*PrI (340 mg, 2.0 mmol) was added and stirring was continued for 5 min at 25 °C. To this mixture

was added $Pd(dba)_2$ (11.6mg, 0.02 mmol), Ru-Phos (18.7 mg, 0.04 mmol) and 4-bromo-2-methylaniline (335 mg, 1.8 mmol) in one portion followed by 2 mL THF. The resulting mixture was stirred for 10 min at 25 °C. Then, the reaction mixture was quenched with sat. aq. NH_4Cl solution and extracted with ether (3 x 50 mL). The combined organic phases were washed with sat. thiourea solution (2 x 5 mL) and dried over Na_2SO_4. After evaporation of the solvents the crude residue was purified by flash chromatography (pentane/ether; 4:1) yielding 3-chloro-4'-fluorobiphenyl-4-amine (**93i**) as a colourless solid (339 mg, 94 %).

mp: 120.6 – 122.3 °C.

IR (ATR) $\tilde{\nu}$ (cm^{-1}): 3428, 3307, 3204, 1635, 1607, 1595, 1578, 1490, 1458, 1427, 1392, 1377, 1287, 1267, 1230, 1213, 1186, 1157, 1101, 1080, 841, 809, 741, 670.

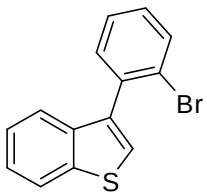
^{1}H-NMR (300 MHz, $CDCl_3$): δ = 7.56-7.47 (m, 2H, Ar*H*), 7.32-7.25 (m, 2H, Ar*H*), 7.11 (t, *J* = 8.8 Hz, 2H), 6.80 (d, *J* = 8.0 Hz, 1H), 3.97 (br, 2H, NH_2), 2.28 (s, 3H, CH_3).

^{13}C-NMR (75 MHz, $CDCl_3$): δ = 161.8 (d, ^1J(C,F) = 245 Hz), 143.4, 137.4 (d, ^4J(C,F) = 3 Hz), 131.1, 129.1, 127.9 (d, ^3J(C,F) = 8 Hz), 125.5, 122.9,115.5, 115.3 (d, ^2J(C,F) = 21 Hz), 17.5.

MS (70 eV, EI): *m/z* (%) = 202 (8), 201 (100), 200 (24), 183 (9), 100 (7).

HRMS (EI): *m/z* calc. for [$C_{13}H_{12}FN$] 201.0954, found: 201.0944.

2.10 Typical procedure for the Negishi cross-coupling. Synthesis of 3-(2-bromophenyl)-1-benzothiophene (144a) (TP10)



A dry and argon-flushed Schlenk-flask, equipped with a magnetic stirring bar and a septum, was charged with 3-bromobenzothiophene (2.13 g, 10.0 mmol) and 5 mL THF. After cooling to –15 °C, *i*PrMgCl·LiCl (8.5 mL, 1.30 M in THF, 11.0 mmol) was added dropwise and stirred for 24 h. Then, a solution of $ZnCl_2$·2LiCl (11.0 mL, 1.0 M in THF, 11.0 mmol) was added and the mixture was warmed up to 25 °C and stirred for 30 min. A dry and argon flushed Schlenk-flask, equipped with a magnetic stirrer and septum was charged with 1-bromo-2-iodobenzene

(2.69 g, 9.5 mmol), $Pd(dba)_2$ (115 mg, 0.20 mmol) and tfp (93 mg, 0.40 mmol) in 9.5 mL THF. The zinc reagent was added dropwise over 90 min at 50 °C and the resulting mixture was stirred for additional 15 min. The crude reaction mixture was cooled to 25 °C, diluted with Et_2O (200 mL) and washed with water (40 mL) and sat. NaCl solution (2 x 40 mL). The combined organic layers were dried ($MgSO_4$), filtered, and concentrated under reduced pressure. Purification by flash chromatography (pentane) yielded **144a** (2.16 g, 75 %) as a colourless oil.

mp: 52.6 – 54.1 °C.

IR (ATR) $\tilde{\nu}$ (cm^{-1}): 1462, 1455, 1435, 1426, 1421, 1343, 1259, 1055, 1044, 1027, 1019, 942, 822, 789, 761, 755, 737, 732, 703, 671, 632, 627.

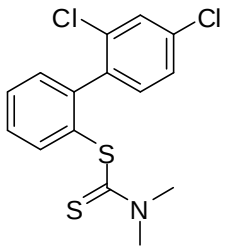
^{1}H-NMR (300 MHz, $CDCl_3$): δ = 7.97-7.90 (m, 1H, Ar*H*), 7.75 (dt, *J* = 7.8 Hz, *J* = 0.9 Hz, 1H, Ar*H*), 7.56-7.49 (m, 1H, Ar*H*), 7.46-7.35 (m, 5H, Ar*H*), 7.33-7.26 (m, 1H, Ar*H*).

^{13}C-NMR (75 MHz, $CDCl_3$): δ = 139.8, 138.4, 136.8, 136.6, 133.2, 132.0, 129.4, 127.3, 125.3, 124.5, 124.2, 124.1, 123.3, 122.7.

MS (70 eV, EI): *m/z* (%) = 291 (15), 290 (100), 289 (16), 288 (97), 209 (15), 208 (28), 166 (13), 165 (89), 164 (10), 163 (14), 105 (21), 104 (25), 83 (10).

HRMS (EI): *m/z* calc. for [$C_{14}H_9BrS$] 287.9608, found: 287.9591.

2.11 Typical procedure for the preparation of a dithiocarbamate using a Br/Li-exchange. Synthesis of 2',4'-dichlorobiphenyl-2-yl dimethyldithiocarbamate (142a) (TP11)



A dry and argon-flushed Schlenk-flask, equipped with a magnetic stirring bar and a septum, was charged with 2'-bromo-2,4-dichlorobiphenyl (1.54 g, 5.09 mmol) and 20 mL THF. After cooling to –95 °C, *n*BuLi (2.15 mL, 2.48 M in hexane, 5.34 mmol) was added dropwise and stirred for 30 min. Then, $MgCl_2$·LiCl (10.2 mL, 0.50 M in THF, 5.09 mmol) was added

dropwise and the resulting solution was warmed up to 0 °C and stirred for 30 min. Then, a solution of tetramethylthiuram disulfide (1.16 g, 4.84 mmol) in CH_2Cl_2 (10 mL) was added and the mixture was gradually warmed up to 25 °C within 1 h. The crude reaction mixture was quenched by the addition of sat. NH_4Cl solution (10 mL) and extracted with CH_2Cl_2 (3 x 40 mL). The combined organic layers were dried ($MgSO_4$), filtered, and concentrated under reduced pressure. Purification by flash chromatography (pentane/EtOAc; 9:1) yielded **142a** (1.39 g, 84 %) as a yellow solid.

mp: 90.0 – 90.9 °C.

IR (ATR) $\tilde{\nu}$ (cm^{-1}): 1489, 1455, 1442, 1404, 1368, 1246, 1142, 1127, 1098, 1058, 985, 869, 827, 810, 763, 732.

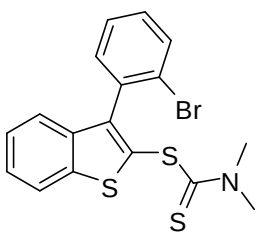
^{1}H-NMR (600 MHz, $CDCl_3$): δ = 7.58 (ddd, *J* = 7.8 Hz, *J* = 1.5 Hz, *J* = 0.4 Hz, 1H, Ar*H*), 7.55 (dt, *J* = 7.6 Hz, *J* = 1.5 Hz, 1H, Ar*H*), 7.48 (dt, *J* = 7.6 Hz, *J* = 1.5 Hz, 1H, Ar*H*), 7.43 (d, *J* = 2.1 Hz, 1H, Ar*H*), 7.38 (d, *J* = 8.2 Hz, 1H, Ar*H*), 7.30 (ddd, *J* = 7.6 Hz, *J* = 1.5 Hz, *J* = 0.4 Hz, 1H, Ar*H*), 7.21(dd, *J* = 8.2 Hz, *J* = 2.1 Hz, 1H, Ar*H*), 3.43 (br. s, 3H, CH_3), 3.29 (br. s, 3H, CH_3).

^{13}C-NMR (150 MHz, $CDCl_3$): δ = 196.9, 143.9, 138.6, 138.0, 134.0, 133.9, 132.1, 131.3, 130.7, 130.4, 129.1, 128.6, 126.5, 45.5, 42.1.

MS (70 eV, EI): *m/z* (%) = 308 (11), 306 (25), 220 (11), 218 (27), 139 (10), 88 (100), 72 (61), 61 (11), 44 (14).

HRMS (EI): *m/z* calc. for [$C_{15}H_{13}Cl_2NS_2$] 340.9866, found: 340.9851.

2.12 Typical procedure for the preparation of a dithiocarbamate using a metalation. Synthesis of 3-(2-bromophenyl)-1-benzothien-2-yl dimethyldithiocarbamate (145a) (TP12)



A dry and argon-flushed Schlenk-flask, equipped with a magnetic stirring bar and a septum, was charged with 3-(2-bromophenyl)-1-benzothiophene (911 mg, 3.15 mmol) and 3 mL THF. After cooling to 0 °C, TMPMgCl·LiCl (3.01 mL, 1.15 M in THF, 3.47 mmol) was added dropwise and stirred for 2 h. Then, a solution of tetramethylthiuram disulfide (719 mg, 2.99 mmol) in CH_2Cl_2 (4 mL) was added and the mixture was gradually warmed up to 25 °C within 12 h. The crude reaction mixture was quenched by the addition of sat. NH_4Cl solution (10 mL) and extracted with CH_2Cl_2 (3 x 40 mL). The combined organic layers were dried ($MgSO_4$), filtered, and concentrated under reduced pressure. Purification by flash chromatography (pentane/Et_2O; 2:1) yielded **145a** (982 mg, 80 %) as a light yellow solid.

mp: 174.1 – 175.0 °C.

IR (ATR) $\tilde{\nu}$ (cm^{-1}): 1501, 1464, 1420, 1381, 1340, 1315, 1242, 1186, 1150, 1074, 1050, 1028, 1018, 966, 905, 854, 812, 771, 752, 736, 702, 680, 653.

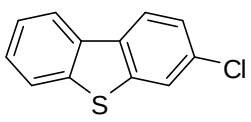
^{1}H-NMR (300 MHz, $CDCl_3$): δ = 7.86 (dt, *J* = 8.1 Hz, *J* = 0.9 Hz, 1H, Ar*H*), 7.70 (dd, *J* = 7.9 Hz, *J* = 1.3 Hz, 1H, Ar*H*), 7.54 (dd, *J* = 7.6 Hz, *J* = 1.9 Hz, 1H, Ar*H*), 7.44-7.26 (m, 5H, Ar*H*), 3.47 (s, 3H, CH_3), 3.36 (s, 3H, CH_3).

^{13}C-NMR (75 MHz, $CDCl_3$): δ = 195.1, 145.3, 142.6, 138.7, 135.4, 132.5, 132.2, 129.8, 128.4, 127.2, 125.9, 124.4, 124.4, 124.3, 122.3, 45.6, 42.0.

MS (70 eV, EI): *m/z* (%) = 329 (15), 241 (16), 240 (90), 195 (11), 164 (10), 163 (11), 88 (100).

HRMS (EI): *m/z* calc. for [$C_{17}H_{14}BrNS_3$] 406.9472, found: 406.9468.

2.13 Typical procedure for the ring-closing reaction using chlorides as leaving group. Synthesis of 3-chlorodibenzo[b,d]thiophene (134a) (TP13)



A dry and argon-flushed Schlenk-flask, equipped with a magnetic stirring bar and a septum, was charged with 2',4'-dichlorobiphenyl-2-yl dimethyldithiocarbamate (342 mg, 1.00 mmol) and KO*t*Bu (337 mg, 3.00 mmol) in 10 mL THF. The reaction mixture was heated to 50 °C for 12 h. The crude reaction was stopped by the addition of sat. NH_4Cl solution (20 mL) and

extracted with Et_2O (3 x 50 mL). The combined organic layers were dried (Na_2SO_4), filtered, and concentrated under reduced pressure. Purification by flash chromatography (pentane/Et_2O; 9:1) yielded **134a** (206 mg, 94 %) as a colourless solid.

mp: 74.5 – 76.0 °C.

IR (ATR) $\tilde{\nu}$ (cm^{-1}): 1580, 1428, 1387, 1317, 1311, 1229, 1099, 1059, 1003, 935, 863, 858, 818, 808, 756, 729, 702.

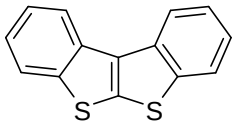
^{1}H-NMR (300 MHz, $CDCl_3$): δ = 8.13-8.07 (m, 1H, Ar*H*), 8.04 (dd, *J* = 8.5 Hz, *J* = 0.5 Hz, 1H, Ar*H*), 7.87-7.80 (m, 2H, Ar*H*), 7.50-7.44 (m, 2H, Ar*H*), 7.41 (dd, *J* = 8.5 Hz, *J* = 1.9 Hz, 1H, Ar*H*).

^{13}C-NMR (75 MHz, $CDCl_3$): δ = 140.6, 139.4, 134.7, 134.1, 132.5, 126.9, 125.0, 124.7, 122.8, 122.5, 122.3, 121.5.

MS (70 eV, EI): *m/z* (%) = 220 (35), 219 (15), 218 (100), 183 (16), 139 (16), 109 (11), 91 (10), 83 (12), 69 (14), 57 (19), 55 (13), 43 (12),

HRMS (EI): *m/z* calc. for [$C_{12}H_7ClS$] 217.9957, found: 217.9948.

2.14 Typical procedure for the ring-closing reaction using bromides as leaving group. Synthesis of [1]benzothieno[2,3-b][1]benzothiophene (135a) (TP14)



A dry and argon-flushed Schlenk-flask, equipped with a magnetic stirring bar and a septum, was charged with 3-(2-bromophenyl)-1-benzothien-2-yl dimethyldithiocarbamate (408 mg, 1.00 mmol) and 10 mL THF. After cooling to –20 °C, *n*BuLi (0.49 mL, 2.14 M in hexane, 1.05 mmol) was added dropwise and stirred for 0.5 h. Then, the reaction was stopped by the addition of MeOH (5 drops) and the crude reaction mixture was concentrated under reduced pressure. Purification by flash chromatography (pentane) yielded **135a** (201 mg, 84 %) as a colourless solid.

mp: 141.4 – 142.1 °C.

IR (ATR) $\tilde{\nu}$ (cm^{-1}): 1478, 1452, 1398, 1306, 1273, 1187, 1161, 1121, 1049, 1026, 1014, 928, 756, 731, 717, 700, 630, 615.

^{1}H-NMR (600 MHz, $CDCl_3$): δ = 8.31 (d, *J* = 8.0 Hz, 2H), 7.88 (d, *J* = 8.0 Hz, 2H), 7.52 (dt, *J* = 7.1 Hz, *J* = 1.2 Hz, 2H), 7.39 (dt, *J* = 7.1 Hz, *J* = 1.2 Hz, 2H).

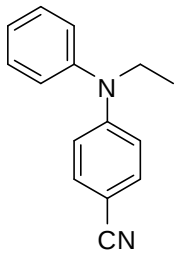
^{13}C-NMR (150 MHz, $CDCl_3$): δ = 143.5, 139.9, 135.0, 133.4, 124.9, 123.9, 123.3, 121.2.

MS (70 eV, EI): *m/z* (%) = 242 (9), 241 (16), 240 (100), 120 (8).

HRMS (EI): *m/z* calc. for [$C_{14}H_8S_2$] 240.0067, found: 240.0060.

3. Oxidative Amination Using Organo Magnesium Reagents

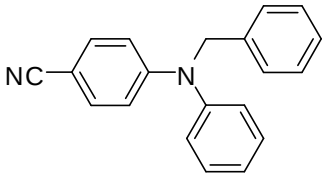
Synthesis of *N*-(4-cyanophenyl)-*N*-ethylaniline (56a)



Prepared according to **TP1** from 4-bromobenzonitrile (182 mg, 1.0 mmol) and lithium *N*-ethylanilide (2.0 mmol, prepared by adding *n*BuLi to a 1.0 M of *N*-ethylaniline (242 mg, 2 mmol) in THF at –40 °C and stirring for 30 min, then the mixture was allowed to reach 0 °C and was stirred for additional 15 min). Purification by flash chromatography (pentane/Et_2O; 9:1) yielded **56a** (153 mg, 69 %) as a yellow oil. The spectroscopic data match with the literature.[89]

^{1}H-NMR (300 MHz, $CDCl_3$): δ = 7.50-6.91 (m, 7H, Ar*H*), 6.66 (d, *J* = 9.0 Hz, 2H, Ar*H*), 3.78 (q, *J* = 7.2 Hz, 2H, CH_2), 1.24 (t, *J* = 7.2 Hz, 3H, CH_3).

Synthesis of *N*-(4-cyanophenyl)-*N*-benzylaniline (56c)



Prepared according to **TP1** from 4-bromobenzonitrile (182 mg, 1.0 mmol) and lithium *N*-benzylanilide (2.0 mmol, prepared by adding *n*BuLi to a 1.0 M solution of *N*-benzylaniline (367 mg, 2 mmol) in THF at –40 °C and stirring for 30 min before the mixture was allowed to reach 0 °C and was then further stirred for additional 15 min). Purification by flash chromatography (pentane/Et_2O; 5:1) yielded **56c** (202 mg, 71 %) as a brown oil.

[89] M. C. Harris, O. Geis, S. L. Buchwald, *J. Org. Chem*. **1999**, *64*, 6019.

IR (ATR) $\tilde{\nu}$ (cm^{-1}): 3059, 3028, 2924, 2853, 2215, 1603, 1591, 1509, 1495, 1452, 1378, 1350, 1259, 1222, 1176, 823, 730, 699.

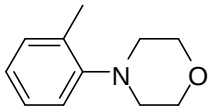
^{1}H-NMR (300 MHz, $CDCl_3$): δ = 7.50-7.21 (m, 12H, Ar*H*), 6.77 (d, *J* = 9.1 Hz, 2H, Ar*H*), 5.02 (s, 2H, CH_2).

^{13}C-NMR (75 MHz, $CDCl_3$): δ = 151.6, 146.4, 137.7, 133.5, 130.4, 129.1, 127.6, 126.8, 126.6, 126.5, 120.4, 114.8, 100.2, 56.7.

MS (70 eV, EI): *m/z* (%) = 284 (61), 281 (14), 207 (55), 91 (100), 69 (13), 44 (13).

HRMS (EI): *m/z* calc. for [$C_{20}H_{16}N_2$] 284.1313, found: 284.1275.

Synthesis of *N*-(2-tolyl)morpholine (56d)

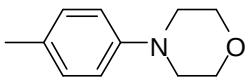


Prepared according to the **TP1** from 2-tolylmagnesium chloride·LiCl (1.0 mL, 1.0 M in THF, 1.0 mmol) and lithium morpholide (2 mmol; prepared by adding *n*BuLi (2 mmol) to a 0.5 M solution of morpholine (174 mg, 2 mmol) in THF at 0 °C and stirring for 30 min). Purification by flash chromatography (pentane/Et_2O; 9:1) yielded **56d** (103 mg, 58 %) as colourless oil. The spectroscopic data match with the literature.[88]

^{1}H-NMR (300 MHz, $CDCl_3$): δ = 7.27-6.96 (m, 4H, Ar*H*), 3.86 (t, *J* = 4.6 Hz, 4H, 2 x CH_2), 2.92 (t, *J* = 4.6 Hz, 4H, 2 x CH_2), 2.33 (s, 3H, CH_3).

^{13}C-NMR (75 MHz, $CDCl_3$): δ = 151.6, 132.9, 131.4, 126.9, 123.7, 119.2, 67.7, 52.5, 18.1.

Synthesis of *N*-(4-tolyl)morpholine (56e)

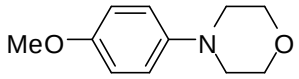


Prepared according to **TP1** from 4-tolylmagnesium chloride·LiCl (0.9 mL, 1.11 M in THF, 1.0 mmol) and lithium morpholide (2 mmol; prepared by adding *n*BuLi (2 mmol) to a 0.5 M solution of morpholine (174 mg, 2 mmol) in THF at 0 °C and stirring for 30 min). Purification

by flash chromatography (pentane/Et_2O; 5:1) yielded **56e** (125 mg, 71 %) as a colourless solid. The spectroscopic data match with the literature.[88]

^{1}H-NMR (300 MHz, $CDCl_3$): δ = 7.10 (d, *J* = 8.5 Hz, 2H, Ar*H*), 6.84 (d, *J* = 8.5 Hz, 2H, Ar*H*), 3.86 (t, *J* = 4.8 Hz, 4H, 2 x CH_2), 3.11 (t, *J* = 4.8 Hz, 4H, 2 x CH_2), 2.28 (s, 3H, CH_3).
^{13}C-NMR (75 MHz, $CDCl_3$): δ = 149.5, 130.0, 129.8, 116.3, 67.2, 50.2, 20.7.

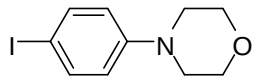
Synthesis of *N*-(4-methoxyphenyl)morpholine (56f)



Prepared according to **TP1** from 4-iodoanisole (234 mg, 1.0 mmol) (I/Mg-exchange conditions: *i*PrMgCl·LiCl at 25 °C for 1 h) and lithium morpholide (2 mmol; prepared by adding *n*BuLi (2 mmol) to a 0.5 M solution of morpholine (174 mg, 2 mmol) in THF at 0 °C and stirring for 30 min). Purification by flash chromatography (pentane/Et_2O; 5:1) yielded **56f** (107 mg, 55 %) as a colourless solid. The spectroscopic data match with the literature. [88]

^{1}H-NMR (300 MHz, $CDCl_3$): δ = 6.99-6.85 (m, 4H, Ar*H*), 3.90 (t, *J* = 4.7 Hz, 4H, 2 x CH_2), 3.80 (s, 3H, CH_3), 3.10 (t, *J* = 4.7 Hz, 4H, 2 x CH_2).
^{13}C-NMR (75 MHz, $CDCl_3$): δ = 154.3, 145.8, 118.1, 114.8, 67.3, 55.8, 51.1.

Synthesis of *N*-(4-iodophenyl)morpholine (56g)

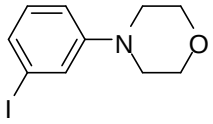


Prepared according to **TP1** from 1,4-diiodobenzene (330 mg, 1.0 mmol) (I/Mg-exchange conditions: *i*PrMgCl·LiCl at –20 °C for 2 h) and lithium morpholide (2 mmol; prepared by adding *n*BuLi (2 mmol) to a 0.5 M solution of morpholine (174 mg, 2 mmol) in THF at 0 °C

and stirring for 30 min). Purification by flash chromatography (pentane/Et_2O; 5:1) yielded **56g** (188 mg, 65 %) as a colourless solid. The spectroscopic data match with the literature.[90]

^{1}H -NMR (300 MHz, $CDCl_3$): δ = 7.56 (d, *J* = 8.2 Hz, 2H, Ar*H*), 6.70 (d, *J* = 8.2 Hz, 2H, Ar*H*), 3.88 (t, *J* = 4.7 Hz, 4H, 2 x CH_2), 3.15 (t, *J* = 4.7 Hz, 4H, 2 x CH_2).
^{13}C-NMR (75 MHz, $CDCl_3$): δ = 151.2, 138.1, 118.0, 82.1, 67.0, 49.1.

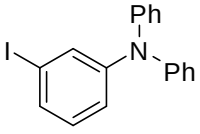
Synthesis of *N*-(3-iodophenyl)morpholine (56h)



Prepared according to **TP1** from 1,3-diiodobenzene (330 mg, 1.0 mmol) (I/Mg-exchange conditions: *i*PrMgCl·LiCl at 0 °C for 15 min) and lithium morpholide (2 mmol; prepared by adding *n*BuLi (2 mmol) to a 0.5 M solution of morpholine (174 mg, 2 mmol) in THF at 0 °C and stirring for 30 min). Purification by flash chromatography (pentane/Et_2O; 5:1) yielded **56h** (170 mg, 59 %) as yellow oil.

IR (ATR) $\tilde{\nu}$ (cm^{-1}): 2961, 2853, 2822, 1585, 1555, 1479, 1448, 1262, 1234, 1121, 982, 937, 768.
^{1}H-NMR (300 MHz, $CDCl_3$): δ = 7.27-6.86 (m, 4H, Ar*H*), 3.87 (t, *J* = 4.8 Hz, 4H, 2 x CH_2), 3.17 (t, *J* = 4.8 Hz, 4H, 2 x CH_2).
^{13}C-NMR (75 MHz, $CDCl_3$): δ = 152.7, 130.8, 129.0, 124.8, 115.1, 95.5, 67.0, 49.2.
MS (70 eV, EI): *m/z* (%) = 289 (100), 231 (79), 104 (15), 77 (17), 76 (10).
HRMS (EI): *m/z* calc. for [$C_{10}H_{12}INO$] 288.9964, found: 288.9936.

Synthesis of (3-iodophenyl)diphenylamine (56i)



[90] G. Xu, Y.-G. Wang, *Org. Lett.* **2004**, *6*, 985.

Prepared according to **TP1** from 1,3-diiodobenzene (330 mg, 1.0 mmol) (I/Mg-exchange conditions: *i*PrMgCl·LiCl at 0 °C for 15 min) and lithium diphenylamide (2.0 mmol; prepared by adding *n*BuLi (2 mmol) to a 1.0 M solution of diphenylamine in THF (338 mg, 2.0 mmol) at –20 °C and stirring for 5 min and further stirring at 0 °C for 30 min). Purification by flash chromatography (pentane/Et_2O; 95:5) yielded **56i** (243 mg, 65 %) as a colourless solid.

mp: 69.1 – 69.7 °C.

IR (ATR) $\tilde{\nu}$ (cm^{-1}): 3035, 1938, 1576, 1557, 1488, 1468, 1456, 1416, 1307, 1296, 1270, 1249, 1171, 1079, 1058, 1026, 992, 934, 890, 871, 777, 747.

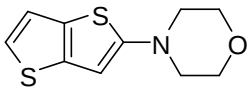
^{1}H-NMR (300 MHz, $CDCl_3$): δ = 7.42 (t, *J* = 1.8 Hz, 1H, Ar*H*), 7.34-7.28 (m, 5H, Ar*H*), 7.14-6.92 (m, 8H, Ar*H*).

^{13}C-NMR (75 MHz, $CDCl_3$): δ = 149.5, 147.5, 132.0, 131.3, 130.8, 129.7, 124.9, 123.7, 122.7, 94.7.

MS (70 eV, EI): *m/z* (%) = 372 (21), 371 (100), 244 (17), 243 (19).

HRMS (EI): *m/z* calc. for [$C_{18}H_{14}IN$] 371.0171, found: 371.0148.

Synthesis of 4-thieno[3,2-*b*]thien-2-ylmorpholine (56j)



A dry and argon-flushed Schlenk-flask, equipped with a magnetic stirring bar and a septum, was charged with thienothiophene (140 mg, 1.0 mmol) and 2 mL THF. TMPMgCl·LiCl (0.92 mL, 1.19 M in THF, 1.1 mmol) was added dropwise at 25 °C and stirred for 45 min to afford the corresponding magnesium reagent. CuCl·2LiCl (1.1 mL, 1.0 M in THF, 1.1 mmol) was added dropwise to this magnesium reagent at –50 °C under argon and the mixture was stirred for 30 min. To the so formed aryl cuprate, lithium morpholide (2 mmol; prepared by adding *n*BuLi (2 mmol) to a 0.5 M solution of morpholine (174 mg, 2 mmol) in THF at 0 °C and stirring for 30 min) was added dropwise and the mixture was further stirred for 1 h at –50 °C. The reaction mixture was cooled to –78 °C, then chloranil (270 mg, 1.1 mmol), in dry THF (10 mL), was added slowly over a period of 1 h. The reaction mixture was then warmed to –50 °C and stirred for 3 h. Et_2O (100 mL) was poured into the crude reaction mixture and the mixture was washed with 2 x 10 mL portions of aqueous NH_4OH (2.0 M). The organic layer

was dried ($MgSO_4$), filtered, and concentrated under reduced pressure. Purification by flash chromatography (pentane/Et_2O; 9:1) yielded the amine **56j** (138 mg, 61 %) as a yellow solid.

mp: 140.8 – 141.8 °C.

IR (neat): υ_{max} (cm^{-1}) = 3089, 3069, 2970, 2886, 2854, 2832, 2323, 1739, 1509, 1465, 1455, 1443, 1426, 1375, 1352, 1308, 1295, 1262, 1217, 1167, 1114, 1064, 1031, 1025, 934, 925, 879, 853, 806, 764, 756, 708, 646, 629.

^{1}H-NMR (300 MHz, $CDCl_3$): δ = 7.14-7.08 (m, 2H, Ar*H*), 6.36 (s, 1H, Ar*H*), 3.85 (t, *J* = 4.9 Hz, 4H, 2 x CH_2), 3.15 (t, *J* = 5.0 Hz, 4H, 2 x CH_2).

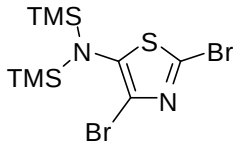
^{13}C-NMR (75 MHz, $CDCl_3$): δ = 160.6, 138.0, 128.2, 122.4, 119.5, 98.8, 66.3, 51.8.

MS (70 eV, EI): *m/z* (%) = 227 (8), 226 (11), 225 (100), 167 (39), 140 (9).

HRMS (EI): *m/z* calc. for [$C_{10}H_{11}NOS_2$] 225.0282, found: 225.0285.

4. Oxidative Amination Using Organo Zinc Reagents

Synthesis of 2,4-dibromo-*N*,*N*-bis(trimethylsilyl)-1,3-thiazol-5-amine (65a)



Prepared according to **TP2** from 2,4-dibromo-1,3-thiazole (243 mg, 1.0 mmol) and $LiN(SiMe_3)_2$ (2mmol, 2 mL, 1 M in THF). Purification by flash-chromatography (pentane; Al_2O_3 III) yielded **65a** (331 mg, 82 %) as a colourless oil.

IR (ATR) $\tilde{\nu}$ (cm^{-1}): 2950, 1499, 1412, 1251, 1204, 1154, 1009, 909, 869, 837, 816, 790, 753, 684, 666, 632.

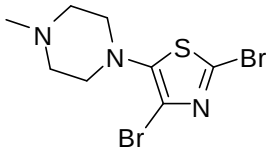
^{1}H-NMR (300 MHz, $CDCl_3$): δ = 0.17 (s, 18H).

^{13}C-NMR (150 MHz, $CDCl_3$): δ = 147.3, 127.7, 119.8, 1.5.

MS (70 eV, EI): *m/z* (%) = 402 (18), 399 (18), 387 (32), 385 (14), 323 (15), 321 (14), 125 (12), 123 (11), 97 (11), 83 (11), 73 (100).

HRMS (EI): *m/z* calc. for [$C_9H_{18}{}^{79}Br_2N_2SSi_2$] 399.9096, found: 399.9086.

Synthesis of 1-(2,4-dibromo-1,3-thiazol-5-yl)-4-methylpiperazine (65c)



Prepared according to **TP2** from 2,4-dibromo-1,3-thiazole (243 mg, 1.0 mmol) and lithium *N*-methylpiperazide (2.0 mmol, prepared by adding *n*BuLi to a 1.0 M solution of *N*-methylpiperazine (200 mg, 2 mmol) in THF at 0 °C and stirring for 30 min). Purification by flash-chromatography (pentane/ether; 2:1) yielded **65c** (209 mg, 61 %) as a yellow oil.

IR (ATR) $\tilde{\nu}$ (cm^{-1}): 2938, 2877, 2838, 2796, 2744, 2690, 2359, 1680, 1524, 1448, 1413, 1371, 1316, 1288, 1235, 1209, 1193, 1140, 1075, 1050, 1037, 1008, 939, 880, 806, 784, 699, 666.

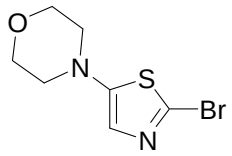
^{1}H-NMR (400 MHz, C_6D_6): δ = 2.58 (t, *J* = 4.7 Hz, 4H, 2 x C*H*$_2$), 2.09 (t, *J* = 4.7 Hz, 4H, 2 x C*H*$_2$), 1.97 (s, 3H, C*H*$_3$).

^{13}C-NMR (100 MHz, C_6D_6): δ = 150.7, 127.0, 114.4, 54.5, 53.2, 45.9.

MS (70 eV, EI): *m/z* (%) = 343 (23), 341 (46), 340 (12), 339 (23), 262 (45), 260 (46), 256 (12), 181 (12), 71 (51), 70 (37), 57 (33), 56 (19), 44 (12), 42 (100), 41 (65).

HRMS (EI): *m/z* calc. for [$C_8H_{11}Br_2N_3S$] 338.9040, found: 338.9040.

Synthesis of 4-(2-bromo-1,3-thiazol-5-yl)morpholine (65d)



Prepared according to **TP2** from 2-bromothiazole (164 mg, 1.0 mmol) [reaction conditions: deprotonation with $TMP_2Zn{\cdot}2MgCl_2{\cdot}2LiCl$ at 25 °C for 60 min] and lithium morpholide (2.0 mmol; prepared by adding *n*BuLi (2 mmol) to a 0.5 M solution of morpholine in THF (174 mg, 2 mmol) at 0 °C and stirring for 30 min). Purification by flash-chromatography (pentane/ether; 9:1; Al_2O_3 III) yielded **65d** (188 mg, 75 %) as a colourless solid.

mp: 145.3 – 147.0 °C.

IR (ATR) $\tilde{\nu}$ (cm^{-1}): 1512, 1448, 1430, 1368, 1336, 1308, 1293, 1272, 1257, 1220, 1211, 1168, 1143, 1112, 1071, 1038, 991, 929, 893, 855, 842, 758, 728.

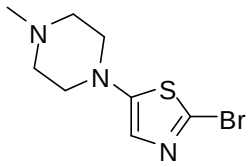
^{1}H-NMR (400 MHz, C_6D_6): δ = 6.51 (s, 1H, Ar*H*), 3.23 (t, *J* = 4.9 Hz, 4H, 2 x C*H*$_2$), 2.31 (t, *J* = 4.9 Hz, 4H, 2 x C*H*$_2$).

^{13}C-NMR (100 MHz, C_6D_6): δ = 157.6, 122.4, 122.3, 65.7, 51.8.

MS (70 eV, EI): *m/z* (%) = 250 (99), 249 (12), 248 (100), 192 (43), 190 (42), 169 (39), 111 (31).

HRMS (EI): *m/z* calc. for [$C_7H_9BrN_2OS$] 247.9619, found: 247.9616.

Synthesis of 1-(2-bromo-1,3-thiazol-5-yl)-4-methylpiperazine (65e)



Prepared according to **TP2** from 2-bromothiazole (164 mg, 1.0 mmol) [reaction conditions: deprotonation with $TMP_2Zn \cdot 2MgCl_2 \cdot 2LiCl$ at 25 °C for 60 min] and lithium *N*-methylpiperazide (2.0 mmol, prepared by adding *n*BuLi to a 1.0 M solution of *N*-methylpiperazine (200 mg, 2 mmol) in THF at 0 °C and stirring for 30 min). Purification by flash-chromatography (pentane/ether; 2:1; Al_2O_3 III) yielded **65e** (186 mg, 71 %) as a light yellow solid.

mp: 60.5 – 61.7 °C.

IR (ATR) $\tilde{\nu}$ (cm^{-1}): 2969, 2938, 2876, 2839, 2803, 2747, 1739, 1515, 1442, 1372, 1343, 1293, 1237, 1217, 1208, 1158, 1141, 1074, 1049, 1005, 984, 943, 885, 793, 773, 726, 701, 665, 656, 635, 618, 611, 604.

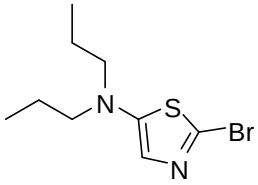
^{1}H-NMR (300 MHz, $CDCl_3$): δ = 6.69 (s, 1H, Ar*H*), 3.08 (t, *J* = 5.0 Hz, 4H, 2 x CH_2), 2.51 (t, *J* = 5.0 Hz, 4H, 2 x CH_2), 2.31 (s, 3H, CH_3).

^{13}C-NMR (75 MHz, $CDCl_3$): δ = 157.3, 122.6, 122.0, 54.1, 51.9, 46.1.

MS (70 eV, EI): *m/z* (%) = 264 (13), 263 (94), 262 (22), 261 (100), 260 (10), 221 (16), 219 (15), 192 (15), 190 (16), 182 (19), 178 (20), 176 (19), 111 (15), 71 (34), 70 (99), 58 (12).

HRMS (EI): *m/z* calc. for [$C_8H_{12}BrN_3S$] 260.9935, found: 260.9935.

Synthesis of 2-bromo-*N*,*N*-dipropyl-1,3-thiazol-5-amine (65f)



Prepared according to **TP2** from 2-bromothiazole (164 mg, 1.0 mmol) [reaction conditions: deprotonation with $TMP_2Zn \cdot 2MgCl_2 \cdot 2LiCl$ at 25 °C for 60 min] and lithium *N*-dipropylamide

prepared by adding *n*BuLi to a 1.0 M solution of dipropylamine (202 mg, 2 mmol) in THF at 0 °C and stirring for 30 min). Purification by flash chromatography (pentane/ether; 19:1; Al_2O_3 III) yielded **65f** (167 mg, 63%) as a light yellow oil.

IR (ATR) $\tilde{\nu}$ (cm^{-1}): 2961, 2932, 2873, 1531, 1439, 1380, 1370, 1350, 1224, 1183, 1134, 1101, 988, 960, 745, 726.

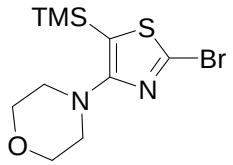
^{1}H-NMR (400 MHz, C_6D_6): δ = 6.50 (s, 1H, Ar*H*), 2.54 (t, *J* = 7.4 Hz, 4H, 2 x CH_2), 1.18 (m, *J* = 7.4 Hz, 4H, 2 x CH_2), 0.58 (t, *J* = 7.4 Hz, 6H, 2 x CH_3),

^{13}C-NMR (100 MHz, C_6D_6): δ = 156.1, 120.2, 118.5, 56.3, 20.2, 11.3.

MS (70 eV, EI): *m/z* (%) = 264 (36), 262 (38), 236 (11), 235 (100), 234 (10), 233 (99), 207 (10), 205 (17), 193 (51), 191 (54), 141 (12), 111 (13), 99 (10), 97 (11), 83 (16), 71 (12), 69 (16), 57 (27), 55 (23), 44 (30), 43 (75), 41 (43).

HRMS (EI): *m/z* calc. for [$C_9H_{15}BrN_2S$] 262.0139, found: 262.0139.

Synthesis of 4-[2-bromo-5-(trimethylsilyl)-1,3-thiazol-4-yl]morpholine (65g)



Prepared according to **TP2** from 2-bromo-5-(trimethylsilyl)-1,3-thiazole (236 mg, 1.0 mmol) [reaction conditions: deprotonation with $TMP_2Zn{\cdot}2MgCl_2{\cdot}2LiCl$ at 25 °C for 8 h] and *N*-lithium morpholide (2.0 mmol; prepared by adding *n*BuLi (2 mmol) to a 0.5 M solution of morpholine in THF (174 mg, 2 mmol) at 0 °C and stirring for 30 min). Purification by flash chromatography (pentane/ether; 9:1; Al_2O_3 III) yielded **65g** (235 mg, 73 %) as a colourless solid.

mp: 115.0 – 120.4 °C.

IR (ATR) $\tilde{\nu}$ (cm^{-1}): 2970, 2924, 2858, 1738, 1669, 1626, 1520, 1471, 1435, 1400, 1365, 1337, 1301, 1267, 1229, 1217, 1163, 1137, 1107, 1064, 1032, 984, 950, 921, 895, 855, 805, 702, 676, 639, 629, 612, 607, 602.

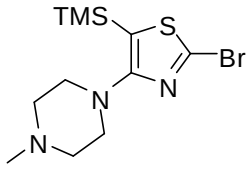
^{1}H-NMR (400 MHz, C_6D_6): δ = 3.55 (t, *J* = 4.7 Hz, 4H, 2 x CH_2), 2.87 (t, *J* = 4.7 Hz, 4H, 2 x CH_2), 0.15 (s, 9H, Si(CH_3)$_3$).

^{13}C-NMR (100 MHz, C_6D_6): δ = 167.5, 137.6, 124.0, 66.8, 53.3, –0.1.

MS (70 eV, EI): *m/z* (%) = 322 (100), 320 (96), 307 (36), 305 (33), 291 (33), 289 (35), 265 (24), 263 (60), 261 (41), 249 (97), 247 (90), 241 (25), 236 (26), 73 (70), 44 (52).

HRMS (EI): *m/z* calc. for [$C_{10}H_{17}BrN_2OSSi$] 320.0014, found: 320.0008.

Synthesis of 1-[2-bromo-5-(trimethylsilyl)-1,3-thiazol-4-yl]-4-methylpiperazine (65h)



Prepared according to **TP2** from 2-bromo-5-(trimethylsilyl)-1,3-thiazole (236 mg, 1.0 mmol) [reaction conditions: deprotonation with $TMP_2Zn{\cdot}2MgCl_2{\cdot}2LiCl$ at 25 °C for 8 h] and lithium *N*-methylpiperazide (2.0 mmol, prepared by adding *n*BuLi to a 1.0 M solution of *N*-methylpiperazine (200 mg, 2 mmol) in THF at 0 °C and stirring for 30 min). Purification by flash chromatography (pentane/ether; 4:1, Al_2O_3 III)) yielded **65h** (218 mg, 76 %) as a colourless solid.

mp: 88.5 – 90.2 °C.

IR (ATR) $\tilde{\nu}$ (cm^{-1}): 2946, 2836, 2783, 2761, 2741, 1505, 1462, 1454, 1423, 1369, 1308, 1288, 1260, 1245, 1232, 1135, 1078, 1071, 1005, 961, 933, 835, 783, 752, 736, 726, 698, 661, 625, 608.

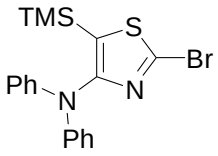
^{1}H-NMR (400 MHz, C_6D_6): δ = 3.07 (t, *J* = 4.9 Hz, 4H, 2 x C*H*$_2$), 2.26 (t, *J* = 4.9 Hz, 4H, 2 x C*H*$_2$), 2.07 (s, 3H, C*H*$_3$), 0.20 (s, 9H, Si(C*H*$_3$)$_3$).

^{13}C-NMR (100 MHz, C_6D_6): δ = 168.0, 137.3, 123.0, 55.3, 53.0, 46.2, 0.0.

MS (70 eV, EI): *m/z* (%) = 335 (42), 333 (43), 320 (32), 318 (32), 278 (22), 276 (17), 265 (24), 263 (27), 254 (37), 249 (35), 247 (41), 97 (15), 73 (27), 71 (69), 70 (100), 44 (99), 43 (32), 41 (34).

HRMS (EI): *m/z* calc. for [$C_{11}H_{20}BrN_3SSi$] 333.0331, found: 333.0330.

Synthesis of 2-bromo-*N*,*N*-diphenyl-5-(trimethylsilyl)-1,3-thiazol-4-amine (65i)



Prepared according to **TP2** from 2-bromo-5-(trimethylsilyl)-1,3-thiazole (236 mg, 1.0 mmol) [reaction conditions: deprotonation with $TMP_2Zn \cdot 2MgCl_2 \cdot 2LiCl$ at 25 °C for 8 h] and lithium diphenylamide (2.0 mmol; prepared by adding *n*BuLi (2 mmol) to a 1.0 M solution of diphenylamine in THF (338 mg, 2 mmol) at –20 °C and stirring for 5 min and further stirring at 0 °C for 30 min). Purification by flash chromatography (pentane/CH_2Cl_2; 10:1 to pentane/ether; 10:1) yielded **65i** (305 mg, 76 %) as a colourless solid.

mp: 98.0 – 99.7 °C.

IR (ATR) $\tilde{\nu}$ (cm^{-1}): 3028, 2970, 1739, 1587, 1492, 1478, 1459, 1449, 1420, 1365, 1330, 1308, 1290, 1275, 1262, 1249, 1230, 1217, 1207, 1177, 1153, 1029, 1001, 840, 826, 747, 716, 699, 691, 647, 627, 616, 609, 602.

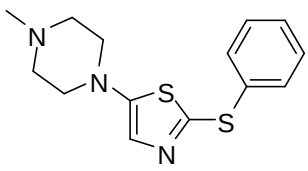
^{1}H-NMR (400 MHz, C_6D_6): δ = 7.03-6.93 (m, 8H, Ar*H*), 6.83-6.76 (m, 2H, Ar*H*), -0.06 (s, 9H, Si(C*H*$_3$)$_3$).

^{13}C-NMR (100 MHz, C_6D_6): δ = 160.3, 147.4, 138.5, 130.2, 129.4, 122.8, 122.3, -0.9.

MS (70 eV, EI): *m/z* (%) = 405 (24), 404 (100), 403 (29), 402 (90), 389 (26), 387 (25), 224 (12), 77 (14), 73 (49).

HRMS (EI): *m/z* calc. for [$C_{18}H_{19}BrN_2SSi$] 402.0222, found: 402.0209.

Synthesis of 1-methyl-4-[2-(phenylthio)-1,3-thiazol-5-yl]piperazine (65j)

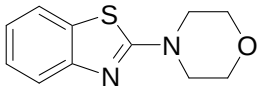


Prepared according to **TP2** from 2-(phenylthio)thiazole (164 mg, 1.0 mmol) [reaction conditions: deprotonation with $TMP_2Zn \cdot 2MgCl_2 \cdot 2LiCl$ at 25 °C for 2 h] and lithium *N*-methylpiperazide (2.0 mmol, prepared by adding *n*BuLi to a 1.0 M solution of *N*-

methylpiperazine (200 mg, 2 mmol) in THF at 0 °C and stirring for 30 min). Purification by flash chromatography (pentane/ether; 2:1; Al_2O_3 III) yielded **65j** (210 mg, 72%) as a yellow oil.

IR (ATR) $\tilde{\nu}$ (cm^{-1}): 2936, 2798, 1716, 1582, 1506, 1478, 1448, 1404, 1375, 1341, 1329, 1292, 1238, 1206, 1143, 1083, 1074, 1023, 1006, 970, 942, 888, 812, 791, 738, 689.
^{1}H-NMR (400 MHz, C_6D_6): δ = 7.50-7.45 (m, 2H, Ar*H*), 6.96-6.86 (m, 4H, Ar*H*), 2.65 (t, *J* = 5.3 Hz, 4H, 2 x CH_2), 1.95 (t, *J* = 5.3 Hz, 4H, 2 x CH_2), 1.93 (s, 3H, CH_3).
^{13}C-NMR (100 MHz, C_6D_6): δ = 158.6, 146.6, 135.9, 130.9, 129.4, 127.7, 123.5, 54.1, 51.6, 46.0.
MS (70 eV, EI): *m/z* (%) = 293 (9), 292 (17), 291 (100), 206 (21), 70 (22), 43 (10).
HRMS (EI): *m/z* calc. for [$C_{14}H_{17}N_3S_2$] 291.0864, found: 291.0861.

Synthesis of 2-morpholin-4-yl-benzothiazole (65k)

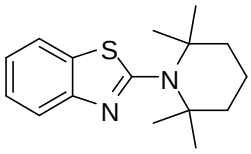


Prepared according to **TP2** from benzothiazole (135 mg, 1.0 mmol) [reaction conditions: deprotonation with $TMP_2Zn{\cdot}2MgCl_2{\cdot}2LiCl$ at 25 °C for 1 h] and lithium morpholide (2.0 mmol; prepared by adding *n*BuLi (2 mmol) to a 0.5 M solution of morpholine in THF (174 mg, 2 mmol) at 0 °C and stirring for 30 min). Purification by flash chromatography (pentane/Et_2O; 2:1; Al_2O_3 III) yielded **65k** (161 mg, 73 %) as colourless solid.

mp: 128.5 – 130.3 °C.
IR (ATR) $\tilde{\nu}$ (cm^{-1}): 2969, 2959, 2914, 2854, 1738, 1593, 1562, 1531, 1455, 1439, 1377, 1341, 1289, 1269, 1241, 1228, 1159, 1111, 1068, 1031, 1016, 945, 911, 858, 754, 727, 698, 656.
^{1}H-NMR (300 MHz, $CDCl_3$): δ = 7.63 – 7.56 (m, 2H, 2 x Ar*H)*, 7.34 – 7.26 (m, 1H, Ar*H*), 7.13 – 7.05 (m, 1H, Ar*H*), 3.81 (t, *J* = 5.2 Hz, 4H, 2 x CH_2), 3.61 (t, *J* = 5.3 Hz, 4H, 2 x CH_2).
^{13}C-NMR (75 MHz, $CDCl_3$): δ = 169.0, 152.5, 130.6, 126.1, 121.7, 120.8, 119.3, 66.3, 48.5.
MS (70 eV, EI): *m/z* (%) = 221 (11), 220 (100), 219 (11), 189 (12), 175 (11), 163 (84), 162 (24), 136 (10), 135 (41), 108 (13), 95 (11).

HRMS (EI): *m/z* calc. for [$C_{11}H_{12}N_2OS$] 220.0670, found: 220.0667.

Synthesis of 2-(2,2,6,6-tetramethylpiperidin-1-yl)-1,3-benzothiazole (65l)



Prepared according to **TP2** from benzothiazole (135 mg, 1.0 mmol) [reaction conditions: deprotonation with $TMP_2Zn{\cdot}2MgCl_2{\cdot}2LiCl$ at 25 °C for 1 h] and LiTMP (2.0 mmol; prepared by adding *n*BuLi (2 mmol) to a 0.5 M solution of 2,2,6,6-tetramethylpiperidine in THF (284 mg, 2 mmol) at 0 °C and stirring for 30 min). Purification by flash chromatography (pentane/Et_2O; 9:1) yielded **65l** (164 mg, 60 %) as a light yellow solid.

mp: 71.7 – 73.4 °C.

IR (ATR) $\tilde{\nu}$ (cm^{-1}): 1503, 1471, 1453, 1435, 1416, 1382, 1367, 1350, 1291, 1257, 1240, 1175, 1152, 1127, 1037, 1027, 1012, 904, 824, 765, 730, 710, 656.

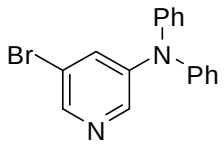
^{1}H-NMR (400 MHz, C_6D_6): δ = 8.05-8.01 (m, 1H, Ar*H*), 7.46-7.42 (m, 1H, Ar*H*), 7.16-7.11 (m, 1H, Ar*H*), 7.06-7.00 (m, 1H, Ar*H*), 1.59-1.51 (m, 2H, CH_2), 1.48-1.41 (m, 4H, 2 x CH_2), 1.32 (s, 12H, 4 x CH_3).

^{13}C-NMR (100 MHz, C_6D_6): δ = 170.4, 151.3, 135.9, 125.6, 124.9, 123.3, 121.1, 56.2, 40.5, 29.2, 17.8.

MS (70 eV, EI): *m/z* (%) = 274 (32), 260 (24), 259 (100), 191 (53), 151 (65), 150 (55), 149 (45), 109 (30), 97 (27), 85 (35), 84 (18), 83 (33), 82 (24), 81 (27), 71 (58), 70 (26), 69 (60), 67 (22), 57 (70), 56 (29), 55 (75).

HRMS (EI): *m/z* calc. for [$C_{16}H_{22}N_2S$] 274.1504, found: 274.1498.

Synthesis of 5-bromo-*N*,*N*-diphenylpyridin-3-amine (65m)



A dry and argon-flushed Schlenk-flask, equipped with a magnetic stirring bar and a septum, was charged with 3,5-dibromopyridine (2.36 g, 10.0 mmol). After cooling to 0 °C, *i*PrMgCl·LiCl (8.9 mL, 1.24 M in THF, 11.0 mmol) was added dropwise and stirred for 30 min at this temperature and for further 30 min at 25 °C. Then, 10 mL THF were added and the resulting solution was stirred for additional 10 min at 25 °C. After cooling to 0 °C $ZnCl_2$ (5.5 mL, 1.0 M in THF, 5.5 mmol) was added and the mixture was stirred for 30 min at this temperature. CuCl·2LiCl (11.0 mL, 1.0 M in THF, 11.0 mmol) was added dropwise at –50 °C and the resulting mixture was stirred for additional 30 min at –50 °C. Lithium diphenylamide (20.0 mmol; prepared by adding *n*BuLi (20 mmol) to a 1.0 M solution of diphenylamine in THF (3.38 g, 20 mmol) at –20 °C and stirring for 5 min and further stirring at 0 °C for 30 min) was added dropwise to the resulting cuprate, and the mixture was stirred for 1 h at –50 °C. The reaction mixture was cooled to –78 °C, then a solution of $PhI(OAc)_2$ (3.54 mg, 11.0 mmol) in dry THF (10 mL) was added slowly over a period of 60 min. The reaction mixture was then warmed to –50 °C and stirred for 3 h. Et_2O (500 mL) was poured into the crude reaction mixture. The organic phase was washed with 3 x 50 mL portions of aqueous NH_4OH (2.0 M) and extracted with Et_2O. The combined organic layers were dried (Na_2SO_4), filtered, and concentrated under reduced pressure. Purification by flash chromatography (pentane/CH_2Cl_2; 1:1 to 1:2) yielded **65m** (2.88 g, 89 %) as a colourless solid.

mp: 118.4 – 119.9 °C.

IR (ATR) $\tilde{\nu}$ (cm^{-1}): 1586, 1570, 1557, 1544, 1485, 1456, 1438, 1424, 1329, 1276, 1270, 1232, 1191, 1098, 1069, 1005, 948, 903, 854, 844, 780, 758, 746, 702, 694, 665, 628, 620.

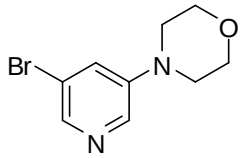
^{1}H-NMR (400 MHz, C_6D_6): δ = 8.36 (dd, *J* = 6.1 Hz, *J* = 2.9 Hz, 2H), 7.37 (t, *J* = 2.2 Hz, 1H), 6.97-6.91 (m, 4H), 6.85-6.76 (m, 6H).

^{13}C-NMR (100 MHz, C_6D_6): δ = 146.5, 145.6, 143.7, 142.9, 130.6, 129.9, 125.0, 124.5, 120.7.

MS (70 eV, EI): *m/z* (%) = 327 (19), 326 (87), 325 (48), 324 (100), 323 (30), 245 (14), 244 (38), 243 (18), 217 (12), 167 (14), 115 (13), 77 (23).

HRMS (EI): *m/z* calc. for [$C_{17}H_{13}BrN_2$] 324.0262, found: 324.0257.

Synthesis of 4-(5-bromopyridin-3-yl)morpholine (65n)



A dry and argon-flushed Schlenk-flask, equipped with a magnetic stirring bar and a septum, was charged with 3,5-dibromopyridine (2.36 g, 10.0 mmol). After cooling to 0 °C, *i*PrMgCl·LiCl (8.9 mL, 1.24 M in THF, 11.0 mmol) was added dropwise and stirred for 30 min at this temperature and for further 30 min at 25 °C. Then, 10 mL THF were added and the resulting solution was stirred for additional 10 min at 25 °C. After cooling to 0 °C $ZnCl_2$ (5.5 mL, 1.0 M in THF, 5.5 mmol) was added and the mixture was stirred for 30 min at this temperature. CuCl·2LiCl (11.0 mL, 1.0 M in THF, 11.0 mmol) was added dropwise at –50 °C and the resulting mixture was stirred for additional 30 min at –50 °C. Lithium morpholide (20.0 mmol; prepared by adding *n*BuLi (20 mmol) to a 0.5 M solution of morpholine in THF (1.74 g, 20 mmol) at 0 °C and stirring for 30 min) was added dropwise to the resulting cuprate, and the mixture was stirred for 1 h at –50 °C. The reaction mixture was cooled to –78 °C, then a solution of $PhI(OAc)_2$ (3.54 mg, 11.0 mmol) in dry THF (10 mL) was added slowly over a period of 60 min. The reaction mixture was then warmed to –50 °C and stirred for 3 h. Et_2O (500 mL) was poured into the crude reaction mixture. The organic phase was washed with 3 x 50 mL portions of aqueous NH_4OH (2.0 M) and extracted with Et_2O. The combined organic layers were dried (Na_2SO_4), filtered, and concentrated under reduced pressure. Purification by flash chromatography (pentane/ether; 2:1) yielded **65n** (1.73 g, 71 %) as a colourless solid.

mp: 87.9 – 89.5 °C.

IR (ATR) $\tilde{\nu}$ (cm^{-1}): 2962, 2877, 2829, 1569, 1539, 1471, 1459, 1442, 1428, 1401, 1365, 1338, 1314, 1272, 1248, 1183, 1154, 1120, 1108, 1074, 1054, 1024, 996, 943, 903, 867, 840, 778, 689, 671, 630.

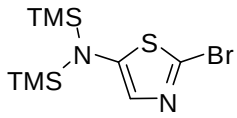
^{1}H-NMR (400 MHz, C_6D_6): δ = 8.32 (d, *J* = 1.7 Hz, 1H, Ar*H*), 8.01 (d, *J* = 2.7 Hz, 1H, Ar*H*), 6.81 (m, 1H, Ar*H*), 3.29 (t, *J* = 4.9 Hz, 4H, 2 x CH_2), 2.33 (t, *J* = 4.9 Hz, 4H, 2 x CH_2).

^{13}C-NMR (100 MHz, C_6D_6): δ = 147.8, 141.4, 136.4, 123.5, 121.1, 66.2, 47.5.

MS (70 eV, EI): *m/z* (%) = 244 (58), 242 (72), 186 (100), 185 (25), 184 (96), 183 (18), 158 (10), 156 (11), 78 (11), 57 (11), 44 (13).

HRMS (EI): *m/z* calc. for [$C_9H_{11}BrN_2O$] 242.0055, found: 242.0047.

Synthesis of 2-bromo-*N*,*N*-bis(trimethylsilyl)-1,3-thiazol-5-amine (65o)



Prepared according to **TP2** from 2-bromothiazole (1.64 g, 10.0 mmol) [reaction conditions: deprotonation with $TMP_2Zn \cdot 2MgCl_2 \cdot 2LiCl$ at 25 °C for 60 min] and $LiN(SiMe_3)_2$ (20 mmol, 20 mL, 1 M in THF). Purification by flash chromatography (pentane; Al_2O_3 III) yielded **65o** (2.44 mg, 75%) as colourless oil.

IR (ATR) $\tilde{\nu}$ (cm^{-1}): 2956, 1517, 1436, 1412, 1251, 1185, 1148, 1132, 1001, 919, 874, 840, 818, 756, 699, 686.

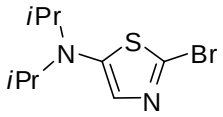
^{1}H-NMR (400 MHz, C_6D_6): δ = 6.76 (s, 1H, Ar*H*), –0.02 (s, 18H).

^{13}C-NMR (100 MHz, C_6D_6): δ = 152.3, 137.1, 128.0, 1.3.

MS (70 eV, EI): *m/z* (%) = 324 (13), 322 (22), 309 (17), 307 (14), 244 (10), 243 (44), 227 (15), 116 (20), 73 (100).

HRMS (EI): *m/z* calc. for [$C_9H_{19}{}^{79}BrN_2SSi_2$] 321.9991, found: 321.9977.

Synthesis of 2-bromo-*N*,*N*-diisopropyl-1,3-thiazol-5-amine (65p)



Prepared according to **TP2** from 2-bromothiazole (1.64 g, 10.0 mmol) [reaction conditions: deprotonation with $TMP_2Zn \cdot 2MgCl_2 \cdot 2LiCl$ at 25 °C for 60 min] and LDA (20 mmol, 20 mL, 0.5 M in THF). Purification by flash-chromatography (pentane/Et_2O; 100:1; Al_2O_3 III) yielded **65p** (1.71 g, 65%) as colourless oil.

IR (ATR) $\tilde{\nu}$ (cm^{-1}): 2968, 2930, 2871, 1538, 1518, 1446, 1416, 1382, 1365, 1328, 1271, 1240, 1204, 1178, 1149, 1122, 1101, 1089, 999, 907, 857, 840, 756, 719, 697, 635.

^{1}H-NMR (300 MHz, C_6D_6): δ = 6.83 (s, 1H, Ar*H*), 3.08 (sept. *J* = 6.8 Hz, 2H, 2 x C*H*(CH_3)$_2$), 0.84 (d, *J* = 6.8 Hz, 12H, 2 x CH(C*H*$_3$)$_2$).

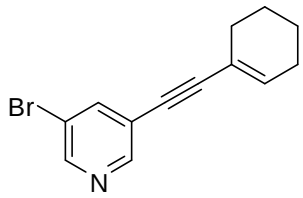
^{13}C-NMR (75 MHz, C_6D_6): δ = 150.6, 133.0, 126.1, 51.1, 20.6.

MS (70 eV, EI): *m/z* (%) = 264 (24), 262 (13), 249 (37), 247 (54), 127 (38), 112 (38), 97 (46), 83 (40), 71 (37), 70 (36), 69 (62), 57 (100), 55 (51), 43 (75).

HRMS (EI): *m/z* calc. for [$C_9H_{15}BrN_2S$] 262.0139, found: 262.0136.

5. Copper(I)-Mediated Oxidative Coupling of Lithium Acetylides and Aryl Magnesium Reagents in the Presence of Chloranil

Synthesis of 3-bromo-5-cyclohex-1-enylethynyl-pyridine (73b)



Prepared according to **TP3** from 3,5-dibromopyridine (237 mg, 1.0 mmol) and corresponding ethynyllithium (2.0 mmol; prepared by adding *n*BuLi (2.0 mmol) to a 0.5 M solution of 1-ethynyl-cyclohexene (212 mg, 2.0 mmol) in THF at –50 °C and stirring for 40 min). Purification by flash chromatography (pentane/Et_2O; 9:1) yielded **73b** (183 mg, 70 %) as a light green solid.

mp: 47.9 – 49.5 °C.

IR (ATR) $\tilde{\nu}$ (cm^{-1}): 3025, 2924, 2857, 2206, 1672, 1567, 1532, 1429, 1402, 1166, 1132, 1097, 1012, 945, 916, 880, 873, 841, 830, 798, 745, 694, 670.

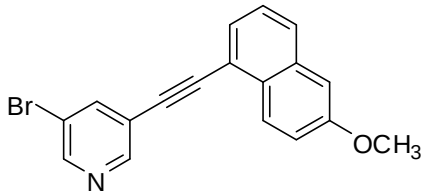
^{1}H-NMR (300 MHz, $CDCl_3$): δ = 8.52 (br.s, 2H, Ar*H*), 7.83 (dd, *J* = 2.2 Hz, *J* = 1.8 Hz, 1H, Ar*H*), 6.26 (m, 1H), 2.18 (m, 4H), 1.64 (s, 4H).

^{13}C-NMR (75 MHz, $CDCl_3$): δ = 150.1, 149.1, 140.4, 137.2, 122.4, 120.1, 120.0, 96.0, 82.0, 28.9, 25.8, 22.2, 21.4.

MS (70 eV, EI): *m/z* (%) = 263 (95), 261 (100), 260 (38), 248 (16), 246 (17), 235 (13), 233 (13), 167 (29), 154 (11), 127 (11).

HRMS (EI): *m/z* calc. for [$C_{13}H_{12}N^{79}Br$] 261.0153, found: 261.0148.

Synthesis of 3-bromo-5-(6-methoxynaphthalen-1-ylethynyl) pyridine (73c)



Prepared according to **TP3** from 3,5-dibromopyridine (237 mg, 1.0 mmol) and 6-methoxynaphthylethynyllithium (2.0 mmol; prepared by adding *n*-BuLi (2.0 mmol) to a 0.3 M solution of 6-methoxynapthnyl acetylene (364 mg, 2.0 mmol) in THF at 0 °C and stirring for 30 min). Purification by flash chromatography (pentane/CH_2Cl_2 1:1) yielded **73c** (230 mg, 72 %) as a colourless solid.

mp: 177.7 – 179.8 °C.

IR (ATR) $\tilde{\nu}$ (cm^{-1}): 3016, 2209, 1623, 1599, 1572, 1538, 1480, 1457, 1427, 1405, 1384, 1257, 1213, 1162, 1098, 1027, 1013, 936, 900, 876, 857, 820, 803, 741, 692, 679, 665, 654, 583, 575, 550, 532.

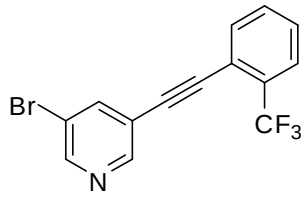
^{1}H-NMR (600 MHz, $CDCl_3$): δ = 8.66 (d, *J* = 1.7 Hz, 1H, Ar*H*), 8.60 (d, *J* = 2.2 Hz, 1H, Ar*H*), 7.98 (br.s, 1H, Ar*H*), 7.97 (dd, *J* = 2.2 Hz, *J* = 1.7 Hz, 1H, Ar*H*), 7.71 (m, 2H, Ar*H*), 7.52 (dd, *J* = 8.5 Hz, *J* = 1.8 Hz, 1H, Ar*H*), 7.17 (dd, *J* = 9.0 Hz, *J* = 2.4 Hz, 1H, Ar*H*), 7.12 (m, 1H, Ar*H*), 3.93 (s, 3H, OCH_3).

^{13}C-NMR (150 MHz, $CDCl_3$): δ = 158.9, 150.4, 149.7, 140.3, 134.8, 132.1, 129.7, 128.9, 128.6, 127.3, 122.4, 120.4, 119.9, 117.0, 106.1, 95.0, 84.4, 55.6.

MS (70 eV, EI): *m/z* (%) = 339 (100), 338 (22), 337 (99), 324 (7), 322 (5), 295 (28), 294 (28), 213 (10), 188 (11), 187 (19), 169 (10), 168 (10), 115 (6), 94 (3).

HRMS (EI): *m/z* calc. for [$C_{18}H_{12}NBrO$] 337.0102, found: 337.0098.

Synthesis of 3-bromo-5-[2-(trifluoromethyl)phenyl]ethynylpyridine (73d)



Prepared according to **TP3** from 3,5-dibromopyridine (237 mg, 1.0 mmol) [reaction conditions: Br/Mg-exchange with *i*PrMgCl·LiCl at 0 °C for 30 min and 25 ° for 30 min] and [2-(trifluoromethyl)phenyl]ethynyllithium (2.0 mmol; prepared by adding *n*BuLi (2.0 mmol) to a 0.5 M solution of 1-ethynyl-2-(trifluoromethyl)benzene (233 mg, 2.0 mmol) in THF at –40 °C for 30 min and 0 ° for 30 min). Purification by flash chromatography (pentane/Et_2O; 40:1) yielded **73d** (137 mg, 42 %) as a colourless solid.

mp: 58.3 – 58.6 °C.

IR (ATR) $\tilde{\nu}$ (cm^{-1}): 3040, 2225, 1944, 1837, 1603, 1572, 1537, 1491, 1451, 1429, 1404, 1378, 1344, 1312, 1290, 1262, 1181, 1170, 1165, 1138, 1114, 1106, 1057, 1030, 1016, 988, 958, 908, 886, 877, 783, 761, 748, 736, 689, 659, 647.

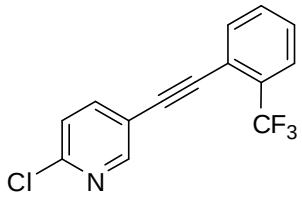
^{1}H-NMR (600 MHz, $CDCl_3$): δ = 8.68 (s, 1H, Ar*H*), 8.65 (s, 1H, Ar*H*), 7.99 (t, *J* = 2.0 Hz, 1H, Ar*H*), 7.72 (d, *J* = 7.9 Hz, 1H, Ar*H*), 7.68 (d, *J* = 7.7 Hz, 1H, Ar*H*), 7.56 (t, *J* = 7.7 Hz, 1H, Ar*H*), 7.49 (t, *J* = 7.9 Hz, 1H, Ar*H*).

^{13}C-NMR (150 MHz, $CDCl_3$): δ = 149.9, 149.8, 141.0, 133.9, 131.9 (q, ^2J(C,F) = 31 Hz), 131.5, (q, ^4J(C,F) = 1 Hz), 129.0, 126.0 (q, ^3J(C,F) = 5 Hz), 123.4 (q, ^1J(C,F) = 273 Hz), 121.4, 120.2, 120.1 (q, ^3J(C,F) = 2 Hz), 89.9, 89.5 (q, ^4J(C,F) = 1 Hz).

MS (70 eV, EI): *m/z* (%) = 328 (14), 327 (88), 326 (18), 325 (100), 247 (23), 228 (11), 227 (63), 220 (15), 199 (30), 110 (19).

HRMS (EI): *m/z* calc. for [$C_{14}H_7BrF_3N$] 324.9714, found: 324.9717.

Synthesis of 2-chloro-5-[2-(trifluoromethyl)phenyl]ethynylpyridine (73e)



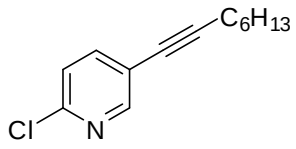
Prepared according to **TP3** from 5-bromo-2-chloropyridine (193 mg, 1.0 mmol) [reaction conditions: Br/Mg-exchange with *i*PrMgCl·LiCl at 0 °C for 30 min and 25 ° for 30 min] and [2-(trifluoromethyl)phenyl]ethynyllithium (2.0 mmol; prepared by adding *n*BuLi (2.0 mmol) to a 0.5 M solution of 1-ethynyl-2-(trifluoromethyl)benzene (233 mg, 2.0 mmol) in THF at –40 °C for 30 min and 0 ° for 30 min). Purification by flash chromatography (pentane/Et_2O; 40:1) yielded **73e** (176 mg, 62 %) as a colourless solid.

mp: 83.4 – 85.3 °C.

IR (ATR) $\tilde{\nu}$ (cm^{-1}): 2916, 2848, 1602, 1574, 1547, 1489, 1455, 1356, 1314, 1282, 1260, 1228, 1166, 1131, 1124, 1107, 1097, 1056, 1032, 1020, 957, 829, 777, 762, 746, 737, 732, 652, 637.

^{1}H-NMR (600 MHz, $CDCl_3$): δ = 8.55 (d, *J* = 2.2 Hz, 1H, Ar*H*), 7.77 (dd, *J* = 8.2 Hz, *J* = 2.2 Hz, 1H, Ar*H*), 7.71 (d, *J* = 7.7 Hz, 1H, Ar*H*), 7.68 (d, *J* = 7.7 Hz, 1H, Ar*H*), 7.55 (t, *J* = 7.7 Hz, 1H, Ar*H*), 7.47 (t, *J* = 7.7 Hz, 1H, Ar*H*), 7.35 (d, *J* = 7.7 Hz, 1H, Ar*H*).
^{13}C-NMR (150 MHz, $CDCl_3$): δ = 152.0, 151.0, 141.0, 133.8, 131.7 (q, ^2J(C,F) = 30 Hz), 131.5 (q, ^4J(C,F) = 1 Hz), 128.8, 126.1 (q, ^3J(C,F) = 5 Hz), 124.0, 123.4 (q, ^1J(C,F) = 273 Hz), 120.4 (q, ^3J(C,F) = 2 Hz), 118.8, 90.0 (q, ^4J(C,F) = 1 Hz), 89.6.
MS (70 eV, EI): *m/z* (%) = 283 (35), 282 (14), 281 (100), 262 (15), 246 (14), 226 (47), 207 (14), 193 (12), 168 (10).
HRMS (EI): *m/z* calc. for [$C_{14}H_7ClF_3N$] 281.0219, found: 281.0216.

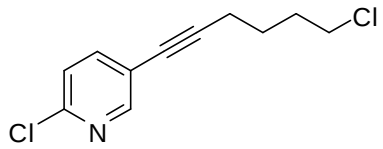
Synthesis of 2-chloro-5-(oct-1-ynyl)pyridine (73f)



Prepared according to **TP3** from 5-bromo-2-chloropyridine (193 mg, 1.0 mmol) [reaction conditions: Br/Mg-exchange with *i*PrMgCl·LiCl at 0 °C for 30 min and at 25 °C for additional 30 min] and octynyllithium (2.0 mmol; prepared by adding *n*BuLi (2.0 mmol) to a 0.5 M solution of 1-octyne (220 mg, 2.0 mmol) in THF at 0 °C and stirring for 30 min). Purification by flash chromatography (pentane/Et_2O; 40:1)) yielded **73f** (133 mg, 60 %) as a yellow oil.

IR (ATR) $\tilde{\nu}$ (cm^{-1}): 2929, 2857, 2230, 1581, 1544, 1452, 1356, 1132, 1106, 1024, 831, 734.
^{1}H-NMR (600 MHz, $CDCl_3$): δ = 8.39 (d, *J* = 2.2 Hz, 1H, Ar*H*), 7.61 (dd, *J* = 8.2 Hz, *J* = 2.2 Hz, 1H, Ar*H*), 7.24 (d, *J* = 8.2 Hz, 1H, Ar*H*), 2.41 (t, *J* = 7.2 Hz, 2H, CH_2), 1.63-1.57 (m, 2H, CH_2), 1.46-1.41 (m, 2H, CH_2), 1.35-1.30 (m, 2H, CH_2), 0.90 (t, *J* = 7.2 Hz, 3H, CH_3).
^{13}C-NMR (75 MHz, $CDCl_3$): δ = 152.1, 149.6, 141.0, 123.7, 120.1, 95.4, 76.1, 31.3, 28.6, 28.4, 22.5, 19.4, 14.0.
MS (70 eV, EI): *m/z* (%) = 221 (35), 194 (11), 192 (42), 180 (32), 179 (23), 178 (100), 166 (12), 165 (19), 164 (37), 154 (12), 153 (15), 152 (48), 151 (17), 150 (29), 143 (12), 142 (15), 137 (19), 130 (18), 128 (10), 126 (25), 117 (11), 116 (15), 115 (17).
HRMS (EI): *m/z* calc. for [$C_{13}H_{16}{}^{35}ClN$] 221.0971, found: 221.0961.

Synthesis of 2-chloro-5-(6-chlorohex-1-yn-1-yl)pyridine (73g)



Prepared according to **TP3** from 5-bromo-2-chloropyridine (193 mg, 1.0 mmol) [reaction conditions: Br/Mg-exchange with *i*PrMgCl·LiCl at 0 °C for 30 min and 25 ° for 30 min] and 6-chlorohexynyllithium (2.0 mmol; prepared by adding *n*BuLi (2.0 mmol) to a 0.5 M solution of 6-chloro-1-hexyne (233 mg, 2.0 mmol) in THF at –40 °C and stirring for 1 h). Purification by flash chromatography (pentane/Et_2O; 20:1) yielded **73g** (132 mg, 58 %) as yellow oil.

IR (ATR) $\tilde{\nu}$ (cm^{-1}): 2954, 2867, 2233, 1580, 1544, 1452, 1356, 1133, 1106, 1023, 926, 832, 774, 734, 652.

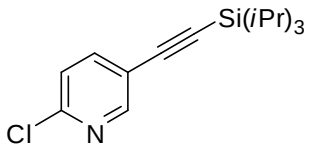
^{1}H-NMR (600 MHz, $CDCl_3$): δ = 8.39 (d, *J* = 2.2 Hz, 1H, Ar*H*), 7.61 (dd, *J* = 8.2 Hz, *J* = 2.2 Hz, 1H, Ar*H*), 7.25 (d, *J* = 8.2 Hz, 1H, Ar*H*), 3.60 (t, *J* = 6.4 Hz, 2H, CH_2), 2.47 (t, *J* = 7.0 Hz, 2H, CH_2), 1.97-1.92 (m, 2H, CH_2), 1.80-1.75 (m, 2H, CH_2).

^{13}C-NMR (150 MHz, $CDCl_3$): δ = 152.1, 150.0, 141.0, 123.7, 119.8, 94.2, 76.8, 44.4, 31.6, 25.6, 18.8.

MS (70 eV, EI): *m/z* (%) = 227 (16), 178 (37), 164 (37), 152 (72), 150 (82), 128 (45), 126 (60), 63 (100).

HRMS (EI): *m/z* calc. for [$C_{11}H_{11}Cl_2N$] 227.0269, found: 227.0273.

Synthesis of 2-chloro-5-[(triisopropylsilyl)ethynyl]pyridine (73h)



Prepared according to **TP3** from 5-bromo-2-chloropyridine (193 mg, 1.0 mmol) [reaction conditions: Br/Mg-exchange with *i*PrMgCl·LiCl at 0 °C for 30 min and at 25 °C for additional 30 min] and triisopropylsilylethynyllithium (2.0 mmol; prepared by adding *n*BuLi (2.0 mmol) to a 0.5 M solution of triisopropylsilylacetylene (365 mg, 2.0 mmol) in THF at

0 °C and stirring for 30 min). Purification by flash chromatography (pentane/Et_2O; 25:1) yielded **73h** (206 mg, 70 %) as colourless oil.

IR (ATR) $\tilde{\nu}$ (cm^{-1}): 2942, 2889, 2864, 2161, 1578, 1548, 1452, 1355, 1224, 1133, 1106, 1020, 996, 919, 882, 735, 703, 675.

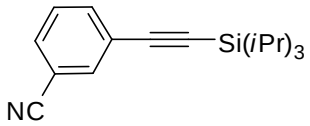
^{1}H-NMR (300 MHz, $CDCl_3$): δ = 8.46 (dd, *J* = 2.3 Hz, *J* = 0.7 Hz, 1H, Ar*H*), 7.69 (dd, *J* = 8.3 Hz, *J* = 2.3 Hz, 1H, Ar*H*), 7.27 (dd, *J* = 8.3 Hz, *J* = 0.7 Hz, 1H, Ar*H*), 1.13 (s, 21H, Si(*i*Pr)$_3$).

^{13}C-NMR (75 MHz, $CDCl_3$): δ = 152.5, 150.4, 141.4, 123.7, 119.5, 102.0, 96.4, 18.6, 11.2.

MS (70 eV, EI): *m/z* (%) = 252 (58), 251 (25), 250 (38), 224 (17), 222 (44), 210 (16), 208 (46), 196 (33), 195 (12), 194 (96), 182 (30), 181 (11), 180 (100), 164 (11).

HRMS (EI): *m/z* calc. for [$C_{16}H_{24}ClNSi$] 293.1367, found: 293.1382.

Synthesis of 3-[(triisopropylsilyl)ethynyl]benzonitrile (73i)



Prepared according to **TP3** from 3-bromobenzonitrile (182 mg, 1.0 mmol) [reaction conditions: Br/Mg-exchange with *i*PrMgCl·LiCl at 0 °C for 3 h] and 1-triisopropylsilylethynyllithium (2.0 mmol; prepared by adding *n*BuLi (2.0 mmol) to a 0.5 M solution of triisopropylsilylacetylene (365 mg, 2.0 mmol) in THF at 0 °C and stirring for 30 min). Purification by flash chromatography (pentane/Et_2O; 30:1) yielded **73i** (204 mg, 72 %) as a light yellow oil.

IR (ATR) $\tilde{\nu}$ (cm^{-1}): 2942, 2889, 2864, 2232, 2150, 1595, 1572, 1476, 1457, 1413, 1250, 996, 922, 882, 797, 734, 680, 663, 643.

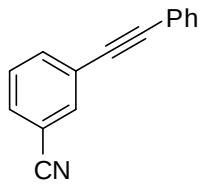
^{1}H-NMR (300 MHz, $CDCl_3$): δ = 7.73 (br.s, 1H, Ar*H*), 7.66 (d, *J* = 7.5 Hz, 1H, Ar*H*), 7.56 (d, *J* = 7.5 Hz, 1H, Ar*H*), 7.40 (t, *J* = 7.5 Hz, 1H, Ar*H*), 1.12 (br. s, 21H, Si(*i*Pr)$_3$).

^{13}C-NMR (75 MHz, $CDCl_3$): δ = 130.0, 135.3, 131.4, 129.1, 125.0, 118.0, 112.8, 104.3, 94.1, 18.6, 11.2.

MS (70 eV, EI): *m/z* (%) = 283 (15), 241 (20), 240 (100), 212 (27), 198 (27), 184 (50), 170 (51), 154 (10), 130(5).

HRMS (EI): *m/z* calc. for [$C_{18}H_{25}NSi$] 283.1756, found: 283.1745.

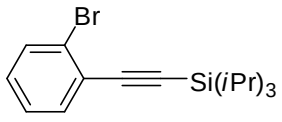
Synthesis of 3-(phenylethynyl)benzonitrile (73j)



Prepared according to **TP3** from 3-bromobenzonitrile (182 mg, 1.0 mmol) [reaction conditions: Br/Mg-exchange with *i*PrMglCl·LiCl at 0 °C for 2 h] and phenylethynyllithium (2.0 mmol; prepared by adding *n*BuLi (2.0 mmol) to a 0.5 M solution of phenyl acetylene (204 mg, 2.0 mmol) in THF at 0 °C and stirring for 30 min). Purification by flash chromatography (pentane/Et_2O; 5:1) yielded **73j** (125 mg, 62 %) as a colourless solid. The spectroscopic data match with the literature.[91]

^{1}H-NMR (600 MHz, $CDCl_3$): δ = 7.80 (m, 1H), 7.74-7.71 (m, 1H), 7.61-7.58 (m, 1H), 7.55-7.51 (m, 2H), 7.46 (t, *J* = 7.9 Hz, 1H), 7.39-7.35 (m, 3H).
^{13}C-NMR (150 MHz, $CDCl_3$): δ = 135.8, 135.1, 132.0, 131.6, 129.5, 129.2, 128.7, 125.2, 122.5, 118.3, 113.1, 92.0, 87.1.

Synthesis of [(2-bromophenyl)ethynyl](triisopropyl)silane (73k)



Prepared according to **TP3** from 1,2-dibromobenzene (236 mg, 1.0 mmol) [reaction conditions: Br/Mg-exchange with *i*PrMglCl·LiCl at 0 °C for 1 h] and 1-triisopropylsilylethynyllithium (2.0 mmol; prepared by adding *n*-BuLi (2.0 mmol) to a 0.5 M solution of triisopropylsilylacetylene (365 mg, 2.0 mmol) in THF at 0 °C and stirring for 30

[91] H. Huang, H. Jiang, K. Chen, H. Liu, *J. Org. Chem.* **2008**, *73*, 9061.

min). Purification by flash chromatography (pentane) yielded **73k** (228 mg, 68 %) as colourless oil.

IR (ATR) $\tilde{\nu}$ (cm^{-1}): 2941, 2889, 2863, 2159, 1467, 1432, 1382, 1256, 1218, 1044, 1024, 992, 882, 851, 750, 679, 637.

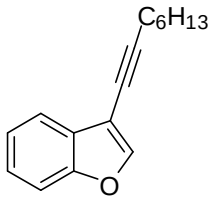
^{1}H-NMR (300 MHz, $CDCl_3$): δ = 7.59 (dd, *J* = 7.9 Hz, *J* = 1.1Hz, 1H, Ar*H*), 7.53 (dd, *J* = 7.5 Hz, *J* = 1.8 Hz, 1H, Ar*H*), 7.26 (ddd, *J* = 7.5 Hz, *J* = 1.3 Hz, 1H, Ar*H*), 7.17 (ddd, *J* = 7.9 Hz, *J* = 1.8 Hz, 1H, Ar*H*), 1.18 (s, 21 H, Si(*i*Pr)$_3$).

^{13}C-NMR (75 MHz, $CDCl_3$): δ = 134.1, 132.6, 129.6, 127.1, 126.0, 125.9, 105.0, 96.4, 18.9, 11.6.

MS (70 eV, EI): *m/z* (%) = 338 (12), 226 (12), 296 (19), 295 (100), 294 (20), 293 (98), 266 (24), 264 (22), 253 (16), 251 (18), 237 (23), 225 (33), 223 (34), 208 (13), 129 (20), 119 (12), 118 (12).

HRMS (EI): *m/z* calc. for [$C_{17}H_{25}{}^{79}BrSi$] 336.0909, found: 336.0909.

Synthesis of 3-oct-1-yn-1-yl-1-benzofuran (74l)



Prepared according to **TP3** from 3-bromobenzofuran (197 mg, 1.0 mmol) [reaction conditions: Br/Mg-exchange with *i*PrMgCl·LiCl at -55 °C for 24 h] and 1-octynyllithium (2.0 mmol; prepared by adding *n*BuLi (2 mmol) to a 0.5 M solution of 1-octyne in THF (220 mg, 2 mmol) at 0 °C and stirring for 30 min). Purification by flash chromatography (pentane) yielded **74l** (144 mg, 62 %) as colourless oil.

IR (ATR) $\tilde{\nu}$ (cm^{-1}): 3061, 2956, 2917, 2858, 1813, 1592, 1452, 1337, 1287, 1201, 1132, 1108, 1088, 1007, 932, 856, 794, 768, 744.

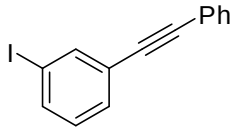
^{1}H NMR (600 MHz, $CDCl_3$): δ = 7.73 (s, 1H, Ar*H*), 7.66 (d, *J* = 7.5 Hz, 1H, Ar*H*), 7.47 (d, *J* = 7.9 Hz, 1H, Ar*H*), 7.34-7.27 (m, 2H, Ar*H*), 2.47 (t, *J* = 7.1 Hz, 2H), 1.68-1.62 (m, 2H), 1.53-1.46 (m, 2H), 1.39-1.30 (m, 4H), 0.92 (t, *J* = 7.1 Hz, 3H).

^{13}C NMR (150 MHz, $CDCl_3$): δ = 154.7, 147.0, 128.3, 125.1, 123.3, 120.6, 111.7, 105.3, 95.3, 69.8, 31.6, 29.0, 28.8, 22.8, 19.9, 14.3.

MS (70 eV, EI): *m/z* (%) = 226 (80), 197 (16), 183 (42), 169 (22), 157 (55), 155 (100), 131 (16), 129 (22), 128 (15), 127 (18), 126 (16), 115 (13).

HRMS (EI): *m/z* calc. for [$C_{16}H_{18}O$] 226.1358, found: 226.1359.

Synthesis of 1-iodo-3-(phenylethynyl)benzene (73m)

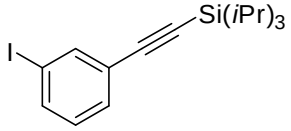


Prepared according to **TP3** from 1,3-diiodobenzene (330 mg, 1.0 mmol) [reaction conditions: I/Mg-exchange with *i*PrMgCl·LiCl at 0 °C for 15 min] and phenylethynyllithium (2.0 mmol; prepared by adding *n*BuLi (2.0 mmol) to a 0.5 M solution of phenyl acetylene (204 mg, 2.0 mmol) in THF at 0 °C and stirring for 30 min). Purification by flash chromatography (pentane) yielded **73m** (178 mg, 59 %) as a colourless solid. The spectroscopic data match with the literature.[92]

^{1}H-NMR (300 MHz, $CDCl_3$): δ = 7.95-7.90 (m, 1H), 7.72-7.66 (m, 1H), 7.59-7.49 (m, 3H), 7.41-7.35 (m, 3H), 7.10 (t, *J* = 7.9 Hz, 1H).

^{13}C-NMR (75 MHz, $CDCl_3$): δ = 140.4, 137.5, 131.9, 131.0, 130.1, 128.9, 128.7, 125.6, 123.0, 93.9, 91.0, 87.9.

Synthesis of [(3-iodophenyl)ethynyl](triisopropyl)silane (73n)



Prepared according to **TP3** from 1,3-diiodobenzene (330 mg, 1.0 mmol) [reaction conditions: I/Mg-exchange with *i*PrMgCl·LiCl at 0 °C for 15 min] and 1-triisopropylsilylethynyl-lithium (**3a,** 2.0 mmol; prepared by adding *n*BuLi (2.0 mmol) to a 0.5 M solution of

[92] A. Orita, H. Taniguchi, J. Otera, *Chem. Asian J.* **2006**, *1*, 430.

triisopropylsilylacetylene (365 mg, 2.0 mmol) in THF at 0 °C and stirring for 30 min). Purification by flash chromatography (pentane) yielded **73n** (295 mg, 77 %) as a colourless oil.

IR (ATR) $\tilde{\nu}$ (cm^{-1}): 2941, 2889, 2858, 2159, 1582, 1552, 1467, 1397, 1382, 1295, 1218, 1070, 1063, 992, 918, 882, 851, 780, 679, 637.

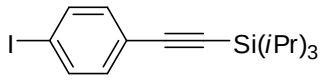
^{1}H-NMR (300 MHz, $CDCl_3$): δ = 7.84 (t, *J* = 1.8 Hz, 1H, Ar*H*), 7.68-7.64 (m, 1H, Ar*H*), 7.45 (dt, *J* = 7.7 Hz, *J* = 1.1 Hz, 1H, Ar*H*), 7.05 (t, *J* = 7.9 Hz, 1H, Ar*H*), 1.14 (s, 21H, Si(*i*Pr)$_3$).

^{13}C-NMR (75 MHz, $CDCl_3$): δ = 140.7, 137.6, 131.4, 129.9, 125.8, 105.4, 93.8, 92.6, 18.9, 11.5.

MS (70 eV, EI): *m/z* (%) = 384 (18), 342 (17), 341 (100), 312 (19), 299 (21), 285 (27), 271 (36), 142 (14).

HRMS (EI): *m/z* calc. for [$C_{17}H_{25}ISi$] 384.0770, found: 384.0751.

Synthesis of [(4-iodophenyl)ethynyl]triisopropylsilane (73o)



Prepared according to **TP3** from 1,4-diiodobenzene (330 mg, 1.0 mmol) [reaction conditions: I/Mg-exchange with *i*PrMgCl·LiCl at –20 °C for 2.5 h] and triisopropylsilylethynyl-lithium (2.0 mmol; prepared by adding *n*BuLi (2.0 mmol) to a 0.5 M solution of triisopropyl-silylacetylene (365 mg, 2.0 mmol) in THF at 0 °C and stirring for 30 min). Purification by flash chromatography (pentane) yielded **73o** (242 mg, 63 %) as a colourless oil.

IR (ATR) $\tilde{\nu}$ (cm^{-1}): 2942, 2891, 2864, 2157, 1644, 1482, 1469, 1390, 1214, 1056, 1006, 996, 919, 882, 819, 666.

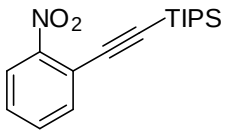
^{1}H-NMR (300 MHz, $CDCl_3$): δ = 7.63 (dt, *J* = 8.4 Hz, *J* = 1.9 Hz, 2H, Ar*H*), 7.19 (dt, *J* = 8.4 Hz, *J* = 1.9 Hz, 2H, Ar*H*), 1.14 (s, 21H, Si(*i*Pr)$_3$).

^{13}C-NMR (75 MHz, $CDCl_3$): δ = 137.3, 133.5, 123.0, 105.9, 94.1, 92.4, 18.6, 11.2.

MS (70 eV, EI): *m/z* (%) = 384 (9), 342 (17), 341 (100), 313 (23), 299 (30), 285 (33), 271 (51), 144 (11), 142 (13), 129 (10).

HRMS (EI): *m/z* calc. for [$C_{17}H_{25}ISi$] 384.0770, found: 384.0758.

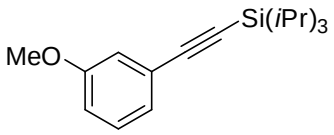
Synthesis of triisopropyl((2-nitrophenyl)ethynyl)silane (73p)



Prepared according to **TP3** from 2-iodonitrobenzene (236 mg, 1.0 mmol) [reaction conditions: I/Mg-exchange with PhMgCl at –40 °C for 30 min] and 1-triisopropylsilylethynyllithium (2.0 mmol; prepared by adding *n*-BuLi (2.0 mmol) to a 0.5 M solution of triisopropylsilylacetylene (365 mg, 2.0 mmol) in THF at 0 °C and stirring for 30 min). Purification by flash chromatography (pentane) yielded **73p** (123 mg, 41 %) as a yellow oil.

IR (ATR) $\tilde{\nu}$ (cm^{-1}): 2943, 2863, 2164, 1606, 1568, 1528, 1463, 1342, 1219, 994, 882, 865.
^{1}H-NMR (300 MHz, $CDCl_3$): δ = 8.06 (dd, *J* = 8.2 Hz, *J* = 1.3 Hz, 1H, Ar*H*), 7.69 (dd, *J* = 7.7 Hz, *J* = 1.3 Hz, 1H, Ar*H*), 7.57 (ddd, *J* = 7.5 Hz, *J* = 1.3 Hz, 1H, Ar*H*), 7.46 (ddd, *J* = 7.3 Hz, *J* = 1.3 Hz, 1H, Ar*H*), 1.17 (t, 21 H, Si(*i*Pr)$_3$).
^{13}C-NMR (75 MHz, $CDCl_3$): δ = 135.7, 132.8, 128.9, 124.7, 119.0, 101.3, 101.1, 18.8, 11.5; quaternary carbon atom could not be detected.
MS (70 eV, EI): *m/z* (%) = 261 (22), 260 (100), 232 (21), 218 (10), 204 (13), 190 (16).
HRMS (EI): *m/z* calc. for [$C_{17}H_{25}NO_2Si$] 303.1655, found: 303.1656.

Synthesis of triisopropyl[(3-methoxyphenyl)ethynyl]silane (73q)



Prepared according to **TP3** from 3-methoxyphenylmagnesium bromide (1.0 ml, 1 M in THF, 1.0 mmol and 1-triisopropylsilylethynyllithium (2.0 mmol; prepared by adding *n*-BuLi (2.0 mmol) to a 0.5 M solution of triisopropylsilylacetylene (365 mg, 2.0 mmol) in THF at 0 °C and stirring for 30 min). Purification by flash chromatography (pentane) yielded **73q** (195 mg, 68 %) as a yellow oil.

IR (ATR) $\tilde{\nu}$ (cm^{-1}): 2941, 2889, 2863, 2155, 1602, 1592, 1574, 1478, 1460, 1421, 1315, 1282, 1266, 1192, 1150, 1047, 993, 933, 915, 882, 851, 783, 776, 750, 680, 662.

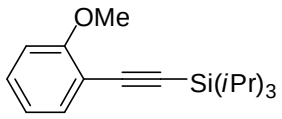
^{1}H-NMR (300 MHz, $CDCl_3$): δ = 7.23 (t, *J* = 7.9 Hz, 1H, Ar*H*), 7.10 (d, *J* = 7.5 Hz, 1H, Ar*H*), 7.01 (s, 1H, Ar*H*), 6.89 (dd, *J* = 8.4 Hz, *J* = 1.5 Hz, 1H, Ar*H*), 3.83 (s, 3H, OCH_3), 1.15 (s, 21H, Si(*i*Pr)$_3$).

^{13}C-NMR (75 MHz, $CDCl_3$): δ = 159.5, 129.5, 124.9, 124.8, 117.1, 115.1, 107.2, 90.6, 55.5, 18.9, 11.6.

MS (70 eV, EI): *m/z* (%) = 288 (22), 246 (17), 245 (100), 217 (20), 203 (31), 189 (33), 175 (55), 95 (27).

HRMS (EI): *m/z* calc. for [$C_{18}H_{28}OSi$] 288.1909, found: 288.1902.

Synthesis of triisopropyl[(2-methoxyphenyl)ethynylsilane (73r)



Prepared according to **TP3** from (2-methoxyphenyl)magnesium bromide·LiCl (1.0 mL, 1.0 M in THF, 1.0 mmol) and triisopropylsilylethynyllithium (2.0 mmol; prepared by adding *n*BuLi (2.0 mmol) to a 0.5 M solution of triisopropylsilylacetylene (365 mg, 2.0 mmol) in THF at 0 °C and stirring for 30 min). Purification by flash chromatography (pentane) yielded **73r** (186 mg, 65 %) as a yellow oil.

IR (ATR) $\tilde{\nu}$ (cm^{-1}): 2941, 2890, 2863, 2155, 1595, 1575, 1490, 1462, 1433, 1382, 1291, 1279, 1255, 1205, 1180, 1161, 1113, 1047, 1027, 996, 882, 844, 769, 748, 676, 661, 638.

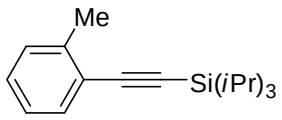
^{1}H-NMR (300 MHz, $CDCl_3$): δ = 7.43 (dd, *J* = 7.5 Hz, *J* = 1.7 Hz, 1H, Ar*H*), 7.29-7.23 (m, 1H, Ar*H*), 6.89 (dd, *J* = 7.5 Hz, *J* = 1.2 Hz, 1H, Ar*H*), 6.87-6.83 (m, 1H, Ar*H*), 3.86 (s, 2H, OCH_3), 1.14 (s, 21H, Si(*i*Pr)$_3$).

^{13}C-NMR (75 MHz, $CDCl_3$): δ = 160.7, 133.9, 129.6, 120.3, 113.1, 111.0, 103.2, 94.9, 55.9, 18.7, 11.4.

MS (70 eV, EI): *m/z* (%) = 288 (14), 246 (43), 245 (100), 230 (18), 217 (41), 203 (66), 202 (21), 289 (37), 188 (70), 187 (49), 175 (60), 173 (15), 161 (28), 159 (24), 147 (15), 145 (15), 115 (30), 95 (64), 88 (13).

HRMS (EI): *m/z* calc. for [$C_{18}H_{28}OSi$] 288.1909, found: 288.1900.

Synthesis of triisopropyl[(2-methylphenyl)ethynylsilane (73s)



Prepared according to **TP3** from (2-methylphenyl)magnesium bromide·LiCl (1.0 mL, 1.0 M in THF, 1.0 mmol) and triisopropylsilylethynyllithium (2.0 mmol; prepared by adding *n*BuLi (2.0 mmol) to a 0.5 M solution of triisopropylsilylacetylene (365 mg, 2.0 mmol) in THF at 0 °C and stirring for 30 min). Purification by flash chromatography (pentane) yielded **73s** (185 mg, 68 %) as a colourless oil.

IR (ATR) $\tilde{\nu}$ (cm^{-1}): 2941, 2890, 2863, 2152, 1483, 1461, 1382, 1225, 1193, 1110, 1072, 995, 882, 848, 754, 715, 676, 662, 640.

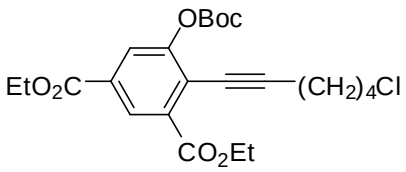
^{1}H-NMR (300 MHz, $CDCl_3$): δ = 7.48-7.43 (m, 1H, Ar*H*), 7.23-7.19 (m, 2H, Ar*H*), 7.19-7.08 (m, 1H, Ar*H*), 2.47 (s, 3H, CH_3), 1.14 (s, 21H, Si(*i*Pr)$_3$).

^{13}C-NMR (75 MHz, $CDCl_3$): δ = 140.5, 132.4, 129.3, 128.3, 125.4, 123.4, 10.8, 94.5, 20.9, 18.7, 11.3.

MS (70 eV, EI): *m/z* (%) = 272 (13), 229 (24), 201 (66), 187 (100), 173 (40), 19 (18), 145 (39).

HRMS (EI): *m/z* calc. for [$C_{18}H_{28}Si$] 272.1960, found: 272.1967.

Synthesis of diethyl 5-[(*tert*-butoxycarbonyl)oxy]-4-(6-chlorohex-1-yn-1-yl)isophthalate (73u)



Prepared according to **TP4** from ethyl 5-*tert*-butoxycarbonyloxy-isophthalic acid diethyl ester **8** (338 mg, 1.0 mmol) [reaction conditions: deprotonation with TMPMgCl·LiCl at 0 °C for 1 h] and 6-chlorohexynyllithium (2.0 mmol; prepared by adding *n*BuLi (2.0 mmol) to a 0.5 M solution of 6-chloro-1-hexyne (233 mg, 2.0 mmol) in THF at –40 °C and stirring for 1 h).

Purification by flash chromatography (pentane/Et_2O; 7:1) yielded **73u** (306 mg, 68 %) as colourless oil.

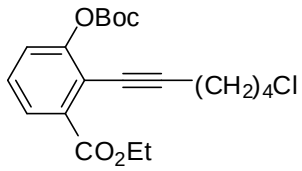
IR (ATR) $\tilde{\nu}$ (cm^{-1}): 2977, 2930, 2217, 1760, 1724, 1610, 1476, 1463, 1367, 1323, 1241, 1176, 1148, 1101, 1057, 1026, 954, 866, 765.

^{1}H-NMR (300 MHz, $CDCl_3$): δ = 8.46 (d, *J* = 1.8 Hz, 1H, Ar*H*), 7.95 (d, *J* = 1.8 Hz, 1H, Ar*H*), 4.42 (q, *J* = 7.1 Hz, 2H, $CO_2CH_2CH_3$), 4.41 (q, *J* = 7.1 Hz, 2H, $CO_2CH_2CH_3$), 3.63 (t, *J* = 6.4 Hz, 2H, CH_2Cl), 2.59 (t, *J* = 7.1 Hz, 2H, CCH_2), 2.07-1.96 (m, 2H, CH_2), 1.90-1.78 (m, 2H, CH_2), 1.58 (s, 9H, $C(CH_3)_3$), 1.43 (t, *J* = 7.1 Hz, 3H, $CO_2CH_2CH_3$), 1.42 (t, *J* = 7.1 Hz, 3H, $CO_2CH_2CH_3$).

^{13}C-NMR (75 MHz, $CDCl_3$): δ = 165.2, 164.8, 153.1, 151.1, 134.4, 130.2, 128.9, 126.2, 104.3, 84.4, 74.3, 61.9, 61.8, 44.8, 31.7, 27.9, 25.8, 19.7, 14.5.

HRMS (ESI): *m/z* calc. for $[C_{23}H_{29}ClO_7+NH_4]$ 470.1946, found: 470.1937.

Synthesis of ethyl 3-[(*tert*-butoxycarbonyl)oxy]-2-(6-chlorohex-1-yn-1-yl)benzoate (73v)



Prepared according to **TP4** from ethyl 3-*tert*-butoxycarbonyloxy-benzoate (266 mg, 1.0 mmol) [reaction conditions: deprotonation with TMPMgCl·LiCl at 0 °C for 3 h] and 6-chlorohexynyllithium (**3c,** 2.0 mmol; prepared by adding *n*BuLi (2.0 mmol) to a 0.5 M solution of 6-chloro-1-hexyne (233 mg, 2.0 mmol) in THF at –40 °C and stirring for 1 h). Purification by flash chromatography (pentane/Et_2O; 9:1) yielded **73v** (265 mg, 70 %) as colourless oil.

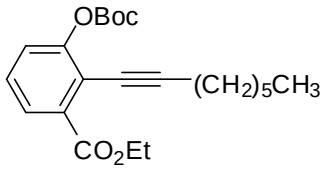
IR (ATR) $\tilde{\nu}$ (cm^{-1}): 2982, 2937, 2872, 2233, 1759, 1728, 1601, 1456, 1395, 1369, 1296, 1248, 1228, 1180, 1144, 1079, 1052, 1031, 942, 876, 823, 773, 749.

^{1}H-NMR (600 MHz, $CDCl_3$): δ = 7.79 (dd, *J* = 7.5 Hz, *J* = 1.3 Hz, 1 H, Ar*H*), 7.34-7.28 (m, 2H), 4.37 (q, *J* = 7.1 Hz, 2H), 3.61 (t, *J* = 7.2 Hz, 2H), 2.54 (t, *J* = 7.1 Hz, 2H), 2.03-1.97 (m, 2H), 1.84-1.78 (m, 2H), 1.55 (s, 9H, $C(CH_3)_3$), 1.39 (t, *J* = 7.1 Hz, 3H).

^{13}C-NMR (150 MHz, $CDCl_3$): δ = 165.8, 153.1, 151.4, 134.2, 128.0, 127.9, 125.6, 118.7, 100.8, 84.0, 61.5, 44.8, 31.7, 27.9, 25.9, 19.5, 14.5.

HRMS (ESI): *m/z* calc. for [$C_{20}H_{25}ClO_5$ + NH_4] 398.1734, found: 398.1727.

Synthesis of ethyl 3-[(*tert*-butoxycarbonyl)oxy]-2-oct-1-yn-1-ylbenzoate (73w)



Prepared according to **TP4** from ethyl 3-*tert*-butoxycarbonyloxy-benzoate (266 mg, 1.0 mmol) [reaction conditions: deprotonation with TMPMgCl·LiCl at 0 °C for 3 h] and corresponding octynyllithium (2.0 mmol; prepared by adding *n*BuLi (2.0 mmol) to a 0.5 M solution of 1-octyne (220 mg, 2.0 mmol) in THF at 0 °C and stirring for 30 min). Purification by flash chromatography (pentane/Et_2O; 9:1) yielded **73w** (257 mg, 69 %) as colourless oil.

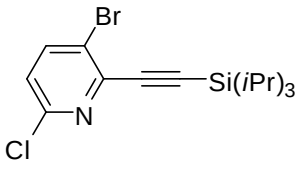
IR (ATR) $\tilde{\nu}$ (cm^{-1}): 2933, 2860, 2227, 1763, 1731, 1460, 1369, 1298, 1250, 1231, 1185, 1152, 1053, 1032, 878.

^{1}H-NMR (600 MHz, $CDCl_3$): δ = 7.79 (dd, *J* = 7.5 Hz, *J* = 1.8 Hz, 1H, Ar*H*), 7.33-7.27 (m, 2H, Ar*H*), 4.37 (q, *J* = 7.1 Hz, 2H, $CO_2CH_2CH_3$), 2.47 (t, *J* = 7.1 Hz, 2H), 1.68-1.61 (m, 2H), 1.55 (s, 9H, $C(CH_3)_3$), 1.49-1.42 (m, 2H), 1.39 (t, *J* = 7.5 Hz, 3H, $CO_2CH_2CH_3$), 1.36-1.28 (m, 2H), 0.90 (t, *J* = 7.1 Hz, 3H, $CO_2CH_2CH_3$).

^{13}C-NMR (150 MHz, $CDCl_3$): δ = 166.0, 153.1, 151.4, 134.3, 128.0, 127.8, 125.6, 119.0, 102.1, 83.9, 73.5, 61.4, 31.6, 28.9, 28.8, 27.9, 22.8, 20.4, 14.5, 14.3.

HRMS (ESI): *m/z* calc. for [$C_{22}H_{30}O_5$ + NH_4] 392.2437, found: 392.2437.

Synthesis of 3-bromo-6-chloro-2-[(triisopropylsilyl)ethynyl]pyridine (73x)



Prepared according to **TP4** from 5-bromo-2-chloropyridine (193 mg, 1.0 mmol) [reaction conditions: deprotonation with TMPMgCl·LiCl at –25 °C for 30 min] and triisopropylsilylethynyllithium (2.0 mmol; prepared by adding *n*BuLi (2.0 mmol) to a 0.5 M solution of triisopropylsilylacetylene (365 mg, 2.0 mmol) in THF at 0 °C and stirring for 30 min). Purification by flash chromatography (pentane/Et_2O; 25:1) yielded **73x** (190 mg, 68%) as a colourless oil.

IR (ATR) $\tilde{\nu}$ (cm^{-1}): 2942, 2890, 1550, 1537, 1462, 1406, 1383, 1354, 1242, 1211, 1139, 1128, 1018, 996, 918, 898, 881, 818, 745, 722, 676, 660, 637, 625.

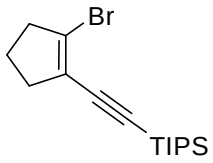
^{1}H-NMR (600 MHz, $CDCl_3$): δ = 7.81 (d, *J* = 8.4 Hz, 1H, Ar*H*), 7.13 (d, *J* = 8.4 Hz, 1H, Ar*H*), 1.18-1.14 (m, 21H, Si(*i*Pr)$_3$).

^{13}C-NMR (150 MHz, $CDCl_3$): δ = 149.6, 143.3, 142.1, 124.6, 122.7, 102.7, 99.7, 18.6, 11.2.

MS (70 eV, EI): *m/z* (%) = 332 (29), 331 (100), 330 (17), 329 (81), 305 (16), 303 (35), 301 (29), 288 (19), 286 (16), 274 (29), 272 (22), 260 (22), 258 (15), 159 (17), 97 (15), 85 (20), 83 (15), 71 (28), 69 (23), 57 (45), 55 (15), 44 (20), 43 (28), 41 (17).

HRMS (EI): *m/z* calc. for [$C_{16}H_{23}BrClNSi$] 371.0472, found: 371.0458.

Synthesis of [(2-bromocyclopent-1-en-1-yl)ethynyl](triisopropyl)silane (73y)



Prepared according to **TP3** from 1,2-dibromocyclopentene (226 mg, 1.0 mmol) [reaction conditions: Br/Mg-exchange with *i*PrMgCl·LiCl at 25 °C for 48 h] and 1-triisopropylsilylethynyllithium (2.0 mmol; prepared by adding *n*BuLi (2 mmol) to a 0.5 M solution of triisopropylsilylacetylene in THF (365 mg, 2 mmol) at 0 °C and stirring for 30 min). Purification by flash chromatography (pentane) yielded **73y** (200 mg, 61 %) as a colourless oil.

IR (ATR) $\tilde{\nu}$ (cm^{-1}): 2943, 2892, 2866, 2147, 1763, 1717, 1608, 1581, 1463, 1384, 1367, 1311, 1291, 1244, 1230, 1092, 1072, 1016, 996, 935, 881, 730, 674.

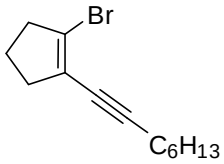
^{1}H NMR (600 MHz, $CDCl_3$): δ = 2.79-2.69 (m, 2H), 2.56-2.48 (m, 2H), 2.06-1.94 (m, 2H), 1.12 (s, 21H, Si(*i*Pr)$_3$).

^{13}C NMR (150 MHz, $CDCl_3$): δ = 128.8, 124.9, 102.2, 97.6, 40.5, 36.1, 22.7, 18.8, 11.4.

MS (70 eV, EI): *m/z* (%) = 328 (15), 326 (14), 286 (30), 285 (100), 284 (31), 283 (100), 257 (38), 255 (38), 243 (34), 241 (34), 229 (33), 227 (33), 215 (62), 213 (63), 199 (16), 175 (14), 173 (12), 161 (22), 159 (13), 147 (15), 139 (23), 137 (24), 133 (19), 117 (16), 109 (11), 107 (13), 91 (19).

HRMS (EI): *m/z* calc. for [$C_{16}H_{27}BrSi$] 326.1065, found: 326.1058.

Synthesis of 1-bromo-2-oct-1-yn-1-ylcyclopentene (73z)



Prepared according to **TP3** from 1,2-dibromocyclopentene (226 mg, 1.0 mmol) [reaction conditions: Br/Mg-exchange with *i*PrMgCl·LiCl at 25 °C for 48 h] and 1-octynyllithium (2.0 mmol; prepared by adding *n*BuLi (2 mmol) to a 0.5 M solution of 1-octyne in THF (220 mg, 2 mmol) at 0 °C and stirring for 30 min). Purification by flash chromatography (pentane) yielded **73z** (158 mg, 62 %) as a colourless viscous oil, which turns to brownish colour.

IR (ATR) $\tilde{\nu}$ (cm^{-1}): 2955, 2929, 2855, 2223, 1714, 1617, 1457, 1444, 1378, 1328, 1311, 1200, 1100, 941, 859, 724.

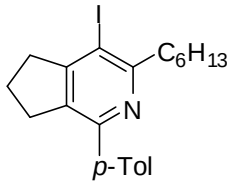
^{1}H NMR (300 MHz, $CDCl_3$): δ = 2.67 (m, 2H), 2.43 (m, 2H), 2.35 (t, *J* = 6.9 Hz, 2H), 1.95 (quint, *J* = 7.5 Hz, 2H), 1.55 (quint, *J* = 7.5 Hz, 2H), 1.48-1.22 (m, 6H), 0.88 (t, *J* = 6.9 Hz, 3H, CH_3).

^{13}C NMR (75 MHz, $CDCl_3$): δ = 125.4, 124.7, 97.0, 76.1, 40.0, 36.1, 31.3, 28.6, 28.5, 22.5, 22.4, 19.7, 14.0.

MS (70 eV, EI): *m/z* (%) = 256 (93), 254 (100), 211 (29), 186 (27), 172 (25), 145 (26), 131 (29), 119 (41), 105 (52), 91 (65), 57 (30), 41 (48).

HRMS (EI): *m/z* calc. for [$C_{13}H_{19}{}^{79}Br$] 254.0670, found: 254.0666.

Synthesis of 3-hexyl-4-iodo-1-(4-methylphenyl)-6,7-dihydro-5*H*-cyclopenta[*c*]pyridine (78)



A dry and argon-flushed Schlenk-flask, equipped with a magnetic stirring bar and a septum, was charged with **73z** (127 mg, 0.5 mmol) in 3 mL Et_2O. After cooling to –78 °C, *t*BuLi (1.0 mmol, 1.6 M in pentane) was added dropwise and stirred for 1 h. Then, *p*-tolunitrile (76 mg, 0.65 mmol), dissolved in 1 mL of Et_2O, was added dropwise and the mixture was stirred for 1 h at -78 °C. Next, I_2 (253 mg, 1 mmol) in 2 mL Et_2O was added at –78 °C and the mixture was allowed to reach 25 °C within 6 h. Et_2O (10 mL) was poured into the crude reaction mixture, the reaction mixture was washed with 2 x 5 mL portions of $Na_2S_2O_3$ solution and extracted with Et_2O. The combined organic layers were dried ($MgSO_4$), filtered, and concentrated under reduced pressure. Purification by flash chromatography (pentane/Et_2O 30:1 (0.5% Et_3N)) yielded **78** (126 mg, 60 %) as a brown viscous oil.

IR (ATR) $\tilde{\nu}$ (cm^{-1}): 2954, 2925, 2855, 1664, 1610, 1560, 1539, 1511, 1456, 1431, 1394, 1351, 1307, 1180, 1103, 1020, 824, 749.

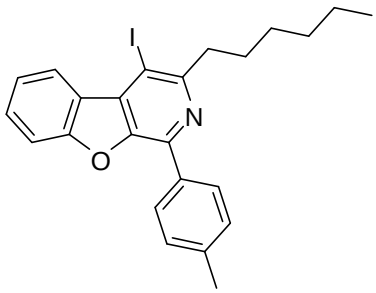
^{1}H NMR (600 MHz, $CDCl_3$): δ = 7.65 (d, *J* = 8.2 Hz, 2H, Ar*H*), 7.24 (d, *J* = 8.2 Hz, 2H, Ar*H*), 3.22 (t, *J* = 7.4 Hz, 2H), 3.02 (br.t, *J* = 7.9 Hz, 2H), 2.96 (t, *J* = 7.4 Hz, 2H), 2.39 (s, 3H, CH_3), 2.07 (quint, *J* = 7.4 Hz, 2H), 1.76 (quint, *J* = 7.9 Hz, 2H), 1.46-1.32 (m, 6H), 0.90 (t, *J* = 7.1 Hz, 3H, CH_3).

^{13}C NMR (150 MHz, $CDCl_3$): δ = 161.0, 160.2, 152.7, 138.3, 136.9, 134.8, 129.2, 128.6, 94.3, 40.9, 40.1, 34.4, 32.0, 29.5, 29.4, 24.0, 22.9, 21.5, 14.4.

MS (70 eV, EI): *m/z* (%) = 419 (6), 376 (10), 350 (19), 349 (100), 292 (11), 248 (7), 236 (10), 223 (48).

HRMS (EI): *m/z* calc. for [$C_{21}H_{26}N^{127}I$] 419.1110, found: 419.1115

Synthesis of 3-hexyl-4-iodo-1-(4-methylphenyl)[1]benzofuro[2,3-*c*]pyridine (80a)



A dry and argon-flushed Schlenk-flask, equipped with a magnetic stirring bar and a septum, was charged with 3-oct-1-yn-1-yl-1-benzofuran (93 mg, 0.41 mmol) in 1 mL Et_2O. After cooling to –55 °C, *n*BuLi (0.47 mmol, 2.26 M in hexane) was added dropwise and stirred for 4 h. Then, *p*-tolunitrile (62 mg, 0.53 mmol), dissolved in 1 mL of Et_2O, was added dropwise and the mixture was stirred for 1 h at –40 °C. Then, I_2 (208 mg, 0.82 mmol) in 3 mL Et_2O was added at –35 °C and the mixture was stirred at this temperature for 15 h. Et_2O (10 mL) was poured into the crude reaction mixture, the reaction mixture was washed with 2 x 5 mL portions of $Na_2S_2O_3$ solution and extracted with Et_2O. The combined organic layers were dried ($MgSO_4$), filtered, and concentrated under reduced pressure. Purification by flash chromatography (pentane) yielded **80a** (120 mg, 62 %) as a pale yellow solid.

mp: 108.1 – 108.9 °C.

IR (ATR) $\tilde{\nu}$ (cm^{-1}): 2952, 2916, 2851, 2359, 1624, 1556, 1513, 1460, 1397, 1354, 1197, 1187, 1063, 1023, 884, 826, 743.

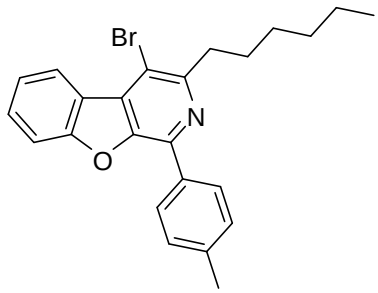
^{1}H NMR (300 MHz, $CDCl_3$): δ = 8.90 (d, *J* = 7.7 Hz, 1H, Ar*H*), 8.37 (d, *J* = 8.2 Hz, 2H, Ar*H*), 7.73-7.61 (m, 2H, Ar*H*), 7.54-7.45 (m, 1H, Ar*H*), 7.39 (d, *J* = 8.2 Hz, 2H, Ar*H*), 3.25 (t, *J* = 8.2 Hz, 2H, CH_2), 2.48 (s, 3H, CH_3), 1.97-1.84 (m, 2H, CH_2), 1.62-1.27 (m, 6H), 0.95 (t, *J* = 7.1 Hz, 3H, CH_3).

^{13}C NMR (75 MHz, $CDCl_3$): δ = 157.1, 156.6, 148.2, 140.8, 139.7, 135.2, 133.2, 130.2, 129.6, 128.8, 124.1, 123.0, 122.6, 112.5, 85.2, 40.2, 32.1, 29.6, 29.4, 23.0, 21.7, 14.4.

MS (70 eV, EI): *m/z* (%) = 426 (10), 400 (17), 399 (100), 342 (14), 273 (16).

HRMS (EI): *m/z* calc. for [$C_{24}H_{24}INO$] 469.0903, found: 469.0903.

Synthesis of 4-bromo-3-hexyl-1-(4-methylphenyl)[1]benzofuro[2,3-*c*]pyridine (80b)



A dry and argon-flushed Schlenk-flask, equipped with a magnetic stirring bar and a septum, was charged with 3-oct-1-yn-1-yl-1-benzofuran (92 mg, 0.41 mmol) in 1 mL Et_2O. After cooling to –55 °C, *n*BuLi (0.47 mmol, 2.26 M in hexane) was added dropwise and stirred for 4 h. Then, *p*-tolunitrile (62 mg, 0.53 mmol), dissolved in 1 mL of Et_2O, was added dropwise and the mixture was stirred for 2.5 h at –40 °C. Then, Br_2 (129 mg, 0.81 mmol) in 3 mL CH_2Cl was added at –35 °C and the mixture was stirred at this temperature for 15 h. Et_2O (10 mL) was poured into the crude reaction mixture, the reaction mixture was washed with 2 x 5 mL portions of $Na_2S_2O_3$ solution and extracted with Et_2O. The combined organic layers were dried ($MgSO_4$), filtered, and concentrated under reduced pressure. Purification by flash chromatography (pentane) yielded **80b** (94 mg, 55 %) as a yellow solid.

mp: 100.2 – 101.3 °C.

IR (ATR) $\tilde{\nu}$ (cm^{-1}): 2950, 2919, 2854, 1624, 1564, 1512, 1456, 1405, 1353, 1280, 1222, 1196, 1185, 1149, 1108, 1064, 1020, 936, 884, 857, 820, 747, 739, 623.

^{1}H-NMR (300 MHz, $CDCl_3$): δ = 8.65 (dq, *J* = 7.9 Hz, *J* = 0.7 Hz, 1H, Ar*H*), 8.37 (d, *J* = 8.0 Hz, 2H, Ar*H*), 7.73-7.62 (m, 2H, Ar*H*), 7.51-7.45 (m, 1H, Ar*H*), 7.39 (d, *J* = 8.0 Hz, 2H, Ar*H*), 3.20 (t, *J* = 7.7 Hz, 2H, CH_2), 2.47 (s, 3H, CH_3), 1.97-1.85 (m, 2H, CH_2), 1.60-1.27 (m, 6H, 3 x CH_2), 0.94 (t, *J* = 7.1 Hz, 3H, CH_3).

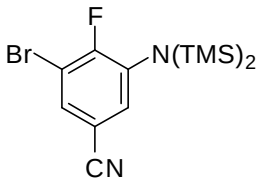
^{13}C-NMR (75 MHz, $CDCl_3$): δ = 157.0, 153.9, 148.7, 140.1, 139.6, 133.3, 132.09, 132.08, 129.6, 128.8, 123.9, 123.3, 123.1, 112.5, 111.7, 36.7, 32.0, 29.4, 29.2, 22.9, 21.7, 14.4.

MS (70 eV, EI): *m/z* (%) = 380 (12), 378 (12), 366 (11), 364 (11), 354 (24), 353 (100), 352 (31), 351 (100), 342 (19).

HRMS (EI): *m/z* calc. for [$C_{24}H_{24}NOBr$] 421.1041, found: 421.1038.

6. Oxidative Cross-Coupling Reactions Using Organo Manganese Reagents

Synthesis of 3-[bis(trimethylsilyl)amino]-5-bromo-4-fluorobenzonitrile (84a)



Prepared according to **TP5** from 3-bromo-4-fluorobenzonitrile (200 mg, 1.0 mmol) and $LiN(SiCH_3)_2$ (2.0 mL, 1.0 M in THF, 2.0 mmol). Purification by flash chromatography (pentane, Al_2O_3 III) yielded **84a** (309 mg, 86 %) as a colourless solid.

mp: 85.3 – 86.7 °C.

IR (ATR) $\tilde{\nu}$ (cm^{-1}): 2957, 2234, 1559, 1460, 1396, 1292, 1252, 1228, 1122, 1002, 954, 899, 866, 840, 821, 757, 732, 686, 627, 614.

^{1}H-NMR (300 MHz, C_6D_6): δ = 6.88 (dd, *J* = 7.1 Hz, *J* = 2.1 Hz, 1H, Ar*H*), 6.83 (dd, *J* = 5.6 Hz, *J* = 2.1 Hz, 1H, Ar*H*), -0.08 (s, 18H, 2 x C(C*H*$_3$)$_3$).

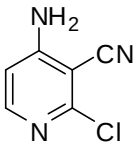
^{13}C-NMR (75 MHz, C_6D_6): δ = 160.8 (d, ^1J(C,F) = 250 Hz), 130.1 (d, ^2J(C,F) = 17 Hz), 135.0, 132.8, 117.2, 110.9 (d, ^2J(C,F) = 23 Hz), 109.8 (d, ^3J(C,F) = 5 Hz), 1.1.

^{19}F-NMR (282 MHz, C_6D_6): δ = –104.1.

MS (70 eV, EI) *m/z* (%): 360 (8), 358 (8), 346 (19), 345 (77), 344 (19), 343 (72), 77 (16), 73 (100).

HRMS (EI): *m/z* calc. for [$C_{13}H_{20}BrFN_2Si_2$] 358.0332, found: 358.0329.

Synthesis of 4-amino-2-chloronicotinonitrile (84b)



Prepared according to **TP5** from 2-chloronicotinonitrile (139 mg, 1.0 mmol) [reaction conditions: deprotonation with $TMP_2Mn{\cdot}2MgCl_2{\cdot}4LiCl$ (1.10 mL, 0.5 M in THF, 0.55 mmol)

at –40 °C for 1 h] and $LiN(SiCH_3)_2$. The crude product was redissolved in Et_2O (3 mL) before TBAF (2 mL, 1.0 M in THF, 2 mmol) was added in one portion and the mixture was stirred at room temperature for 10 min, poured in EtOAc (10 mL) and washed with water (3 x 10 mL). The combined organic extracts were dried ($MgSO_4$), filtered and concentrated in vacuo. Purification by flash chromatography (EtOAc) yielded **84b** (115 mg, 75 %) as a yellow solid.

mp: 255.8 – 257.6 °C.

IR (ATR) $\tilde{\nu}$ (cm^{-1}): 3388, 3345, 3130, 2224, 1673, 1602, 1539, 1505, 1409, 1373, 1354, 1294, 1218, 1202, 1187, 1043, 974, 937, 825, 799, 747, 678, 621, 610.

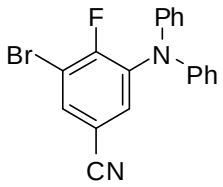
^{1}H-NMR (400 MHz, DMSO): δ = 7.91 (d, *J* = 6.0 Hz, 1H, Ar*H*), 7.45 (br. s, 2H, NH_2), 6.65 (d, *J* = 6.0 Hz, 1H, Ar*H*).

^{13}C-NMR (100 MHz, DMSO): δ = 158.8, 152.8, 150.8, 114.9, 109.5, 91.1.

MS (70 eV, EI) *m/z* (%):155 (32), 153 (100), 118 (57), 91 (17).

HRMS (EI): *m/z* calc. for [$C_6H_4ClN_3$] 153.0094, found: 153.0088.

Synthesis of 3-bromo-5-(diphenylamino)-4-fluorobenzonitrile (84c)



Prepared according to **TP5** from 3-bromo-4-fluorobenzonitrile (200 mg, 1.0 mmol) and lithium diphenylamide (2.0 mmol, prepared by adding *n*BuLi to a 1.0 M solution of diphenylamine (338 mg, 2 mmol) in THF at –40 °C and stirring for 5 min before the mixture was allowed to reach 0 °C and was then stirred for additional 30 min). Purification by flash chromatography (pentane/CH_2Cl_2; 5:1 to pentane/Et_2O; 20:1) yielded **84c** (243 mg, 66 %) as a colourless solid.

mp: 103.2 – 104.8 °C.

IR (ATR) $\tilde{\nu}$ (cm^{-1}): 2235, 1588, 1565, 1485, 1474, 1449, 1410, 1327, 1305, 1279, 1242, 1204, 1178, 1153, 1122, 1081, 1028, 1007, 925, 888, 871, 835, 756, 728, 706, 692, 632, 623, 615.

^{1}H-NMR (300 MHz, $CDCl_3$): δ = 7.55 (dd, *J* = 5.6 Hz, *J* = 2.1 Hz, 1H, Ar*H*), 7.36-7.26 (m, 5H, Ar*H*), 7.15-7.08 (m, 2H, Ar*H*), 7.04-6.96 (m, 4H, Ar*H*).

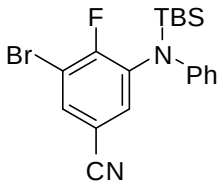
^{13}C-NMR (75 MHz, $CDCl_3$): δ = 156.3 (d, ^{1}J(C,F) = 261 Hz), 145.7, 136,9 (d, ^{2}J(C,F) = 11 Hz), 130.6, 129.7 (d, ^{3}J(C,F) = 3 Hz), 129.1, 123.8, 122.9 (d, ^{4}J(C,F) = 1 Hz), 116.2 (d, ^{5}J(C,F) = 2 Hz), 111.4 (d, ^{2}J(C,F) = 21 Hz), 109.4 (d, ^{3}J(C,F) = 5 Hz).

^{19}F-NMR (282 MHz, $CDCl_3$): δ = –101.4.

MS (70 eV, EI) *m/z* (%): 369 (18), 368 (96), 367 (31), 366 (100), 365 (11), 287 (17), 286 (15), 167 (11).

HRMS (EI): *m/z* calc. for [$C_{19}H_{12}BrFN_2$] 366.0168, found: 366.0154.

Synthesis of 3-bromo-5-[[*tert*-butyl(dimethyl)silyl](phenyl)amino]-4-fluorobenzonitrile (84e)



Prepared according to **TP5** from 3-bromo-4-fluorobenzonitrile (200 mg, 1.0 mmol) and lithium [*tert*-butyl(dimethyl)silyl]phenylamine (2.0 mmol, prepared by adding *n*BuLi to a 0.5 M solution of [*tert*-butyl(dimethyl)silyl]phenylamine (415 mg, 2 mmol) in THF at –40 °C and stirring for 5 min before the mixture was allowed to reach 0 °C and was then stirred for additional 30 min). Purification by flash chromatography (pentane/ether; 20:1) yielded **84e** (269 mg, 66 %) as a yellow solid.

mp: 99.2 – 101.0 °C.

IR (ATR) $\tilde{\nu}$ (cm^{-1}): 2926, 2856, 2235, 1557, 1488, 1461, 1398, 1296, 1260, 1254, 1235, 1223, 1023, 1003, 947, 916, 898, 885, 860, 836, 822, 810, 782, 770, 745, 737, 709, 700, 672.

^{1}H-NMR (300 MHz, $CDCl_3$): δ = 7.66 (dd, *J* = 5.4 Hz, *J* = 2.1 Hz, 1H, Ar*H*), 7.51 (dd, *J* = 7.0 Hz, *J* = 2.1 Hz, 1H, Ar*H*), 7.29-7.21 (m, 2H, Ar*H*), 7.10-7.00 (m, 3H, Ar*H*), 0.92 (s, 9H, C(CH_3)$_3$), 0.22 (s, 6H, 2 x CH_3).

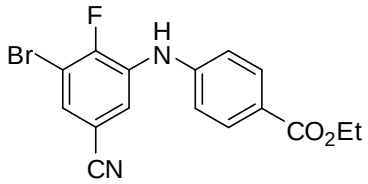
^{13}C-NMR (75 MHz, $CDCl_3$): δ = 160.3 (d, ^{1}J(C,F) = 256 Hz), 147.9, 139.3 (d, ^{2}J(C,F) = 14 Hz), 134.9 (d, ^{3}J(C,F) = 3 Hz), 133.4, 129.0, 125.3, 123.7, 116.7, 111.3 (d, ^{2}J(C,F) = 23 Hz), 109.2 (d, ^{3}J(C,F) = 5 Hz), 27.2, 19.9, –2.5.

^{19}F-NMR (282 MHz, $CDCl_3$): δ = –101.8.

MS (70 eV, EI) *m/z* (%): 406 (4), 404 (4), 349 (21), 347 (20), 269 (22), 268 (100), 77 (25).

HRMS (EI): *m/z* calc. for [$C_{19}H_{22}BrFN_2Si$] 404.0720, found: 404.0716.

Synthesis of ethyl 4-[(3-bromo-5-cyano-2-fluorophenyl)amino]benzoate (84f)



Prepared according to **TP5** from 3-bromo-4-fluorobenzonitrile (200 mg, 1.0 mmol) and ethyl 4-{[*tert*-butyl(dimethyl)silyl]amino}benzoate (deprotonated by adding LDA (2.0 mmol, 0.5 M) to ethyl 4-{[*tert*-butyl(dimethyl)silyl]amino}benzoate (559 mg, 2 mmol in 4 mL THF) at –20 °C and stirring for 90 min). The crude product was redissolved in Et_2O (3 mL) before TBAF (1 mL, 1.0 M in THF, 1 mmol) was added in one portion and the mixture was stirred at room temperature for 10 min, poured in EtOAc (10 mL) and washed with water (3 x 10 mL). The combined organic extracts were dried ($MgSO_4$), filtered and concentrated in vacuo. Purification by flash-chromatography (pentane/ether; 1:2; Al_2O_3 (III)) yielded **84f** (240 mg, 66 %) as a colourless solid.

mp: 176.0 – 177.7 °C.

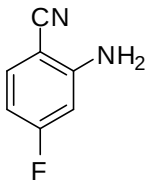
IR (ATR) $\tilde{\nu}$ (cm^{-1}): 3360, 2238, 1709, 1597, 1533, 1499, 1456, 1364, 1339, 1283, 1241, 1224, 1177, 1108, 1020, 999, 854, 837, 765, 746.

^{1}H-NMR (300 MHz, $CDCl_3$): δ = 8.04 (d, *J* = 9.0 Hz, 2H, Ar*H*), 7.54 (dd, *J* = 7.1 Hz, *J* = 2.1 Hz, 1H, Ar*H*), 7.38 (dd, *J* = 5.8 Hz, *J* = 1.9 Hz, 1H, Ar*H*), 7.13 (d, *J* = 9.0 Hz, 2H, Ar*H*), 6.22 (br. s, 1H, N*H*), 4.37 (q, *J* = 7.1 Hz, 2H, CH_2), 1.38 (t, *J* = 7.1 Hz, 3H, CH_3).

^{13}C-NMR (75 MHz, $CDCl_3$): δ = 165.9, 152.0 (d, ^1J(C,F) = 251 Hz), 143.7, 133.0 (d, ^2J(C,F) = 13 Hz), 131.6, 128.0, 125.4, 118.8, 118.3, 116.9, 110.4 (d, ^2J(C,F) = 21 Hz), 109.7 (d, ^3J(C,F) = 5 Hz), 60.9, 14.4.

HRMS (ESI): *m/z* calc. for [$C_{16}H_{12}BrFN_2O_2$+NH_4] 380.0410, found: 380.0400.

Synthesis of 2-amino-4-fluorobenzonitrile (84g)



Prepared according to **TP5** from 4-fluorobenzonitrile (121 mg, 1.0 mmol) [reaction conditions: deprotonation with $TMP_2Mn{\cdot}2MgCl_2{\cdot}4LiCl$ (1.10 mL, 0.5 M in THF, 0.55 mmol) 0 °C for 2 h] and $LiN(SiMe_3)_2$. The crude product was redissolved in Et_2O (3 mL) before TBAF (2 mL, 1.0 M in THF, 2 mmol) was added in one portion and the mixture was stirred at 25 °C for 10 min, poured in EtOAc (10 mL) and washed with water (3 x 10 mL). The combined organic extracts were dried ($MgSO_4$), filtered and concentrated in vacuo. Purification by flash chromatography pentane/ether; 2:1) yielded **84g** (102 mg, 75 %) as an off-white solid.

mp: 102.2 °C (decomp.).

IR (ATR) $\tilde{\nu}$ (cm^{-1}): 3433, 3352, 3225, 3075, 2228, 1646, 1590, 1513, 1483, 1432, 1328, 1309, 1274, 1218, 1155, 1135, 1086, 954, 933, 860, 814, 768, 695.

^{1}H-NMR (300 MHz, $CDCl_3$): δ = 7.08 (m, 3H, Ar*H*), 3.94 (br. s, 2H, NH_2).

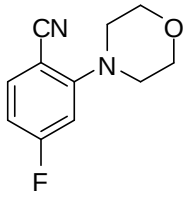
^{13}C-NMR (75 MHz, $CDCl_3$): δ = 153.7 (d, ^1J(C,F) = 248 Hz), 135.8 (d, ^3J(C,F) = 14 Hz), 122.9 (d, ^2J(C,F) = 8 Hz), 119.6 (d, ^3J(C,F) = 5 Hz), 118.6, 116.3 (d, ^2J(C,F) = 20 Hz), 108.5 (d, ^4J(C,F) = 4 Hz).

^{19}F-NMR (282 MHz, $CDCl_3$): δ = –126.3.

MS (70 eV, EI): *m/z* (%) = 136 (100), 109 (24), 97 (15), 91 (15), 83 (17), 81 (10), 71 (16), 69 (24), 59 (14), 57 (27), 55 (21), 45 (11), 44 (48), 43 (23), 41 (21).

HRMS (EI): *m/z* calc. for [$C_7H_5FN_2$] 136.0437, found: 136.0433.

Synthesis of 4-fluoro-2-morpholin-4-ylbenzonitrile (84h)



Prepared according to **TP5** from 4-fluorobenzonitrile (121 mg, 1.0 mmol) [reaction conditions: deprotonation with $TMP_2Mn{\cdot}2MgCl_2{\cdot}4LiCl$ (1.10 mL, 0.5 M in THF, 0.55 mmol) at 25 °C for 2 h] and *N*-lithium morpholide (2.0 mmol; prepared by adding *n*BuLi (2 mmol) to a 0.5 M solution of morpholine (174 mg, 2 mmol) in THF at 0 °C and stirring for 30 min). Purification by flash chromatography (pentane/ether; 2:1) yielded **84h** (167 mg, 81 %) as a colourless solid.

mp: 140.3 – 142.1 °C.

IR (ATR) $\tilde{\nu}$ (cm^{-1}): 2864, 2222, 1603, 1509, 1444, 1412, 1266, 1252, 1226, 1171, 1116, 1054, 975, 878, 815, 759, 654, 618.

^{1}H-NMR (600 MHz, $CDCl_3$): δ = 7.28-7.26 (m, 1H, Ar*H*), 7.20 (dd, *J* = 8.1 Hz, *J* = 1.9 Hz, 1H, Ar*H*), 7.10 (dd, *J* = 8.1 Hz, *J* = 4.3 Hz, 1H, Ar*H*), 3.87 (t, *J* = 4.3 Hz, 4H, 2 x CH_2), 3.14-3.07 (t, *J* = 4.3 Hz, 4H, 2 x CH_2).

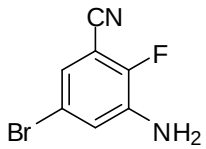
^{13}C-NMR (150 MHz, $CDCl_3$): δ = 158.2 (d, ^1J(C,F) = 256 Hz), 141.0 (d, ^3J(C,F) = 9 Hz), 127.2 (d, ^2J(C,F) = 9 Hz), 122.7 (d, ^3J(C,F) = 5 Hz), 118.5, 117.6 (d, ^2J(C,F) = 23 Hz), 109.1 (d, ^4J(C,F) = 4 Hz), 66.9, 50.6.

^{19}F-NMR (282 MHz, $CDCl_3$): δ = –112.6.

MS (70 eV, EI): *m/z* (%) = 206 (56), 149 (12), 148 (100), 147 (44), 120 (13), 111 (10), 97 (18), 91 (11), 86 (26), 85 (12), 84 (41), 83 (19), 71 (15), 69 (23), 59 (12), 57 (32), 55 (22), 51 (13).

HRMS (EI): *m/z* calc. for [$C_{11}H_{11}FN_2O$] 206.0855, found: 206.0843.

Synthesis of 3-amino-5-bromo-2-fluorobenzonitrile (84i)



Prepared according to **TP5** from 5-bromo-2-fluorobenzonitrile (200 mg, 1.0 mmol) [reaction conditions: deprotonation with $TMP_2Mn{\cdot}2MgCl_2{\cdot}4LiCl$ (1.10 mL, 0.5 M in THF, 0.55 mmol) at –5 °C for 2 h] and and $LiN(SiMe_3)_2$ (2.0 mL, 1.0 M in THF, 2.0 mmol). The crude product was redissolved in Et_2O (3 mL) before TBAF (2 mL, 1.0 M in THF, 2 mmol) was added in one portion and the mixture was stirred at room temperature for 10 min, poured in EtOAc (10

mL) and washed with water (3 x 10 mL). The combined organic extracts were dried ($MgSO_4$), filtered and concentrated in vacuo. Purification by flash chromatography (pentane/ether; 2:1) yielded **84i** (181 mg, 84 %) as a colourless solid.

mp: 76.4 – 78.1 °C.

IR (ATR) $\tilde{\nu}$ (cm^{-1}): 3482, 3372, 2238, 1626, 1565, 1492, 1428, 1326, 1314, 1214, 1116, 1015, 996, 858, 830, 726, 715.

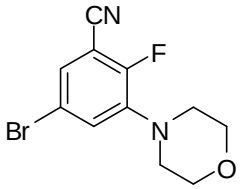
^{1}H-NMR (300 MHz, $CDCl_3$): δ = 7.11 (d, *J* = 7.5 Hz, 1H, Ar*H*), 7.06-6.98 (m, 1H, Ar*H*), 3.89 (br. s, 2H, NH_2).

^{13}C-NMR (75 MHz, $CDCl_3$): δ = 150.8 (d, ^1J(C,F) = 252 Hz), 136.6 (d, ^2J(C,F) = 12.3 Hz), 123.4 (d, ^3J(C,F) = 4.8 Hz), 123.1, 117.1 (d, ^3J(C,F) = 3.9 Hz), 112.9 (d, ^3J(C,F) = 1.1 Hz), 102.6 (d, ^2J(C,F) = 14.3 Hz).

MS (70 eV, EI): *m/z* (%) = 216 (100), 214 (96), 135 (59), 108 (43), 83 (11), 69 (12), 57 (18), 55 (12).

HRMS (EI): *m/z* calc. for [$C_7H_4BrFN_2$] 213.9542, found: 213.9534.

Synthesis of 5-bromo-2-fluoro-3-morpholin-4-ylbenzonitrile (84j)



Prepared according to **TP5** from 5-bromo-2-fluorobenzonitrile (200 mg, 1.0 mmol) [reaction conditions: deprotonation with $TMP_2Mn{\cdot}2MgCl_2{\cdot}4LiCl$ (1.10 mL, 0.5 M in THF, 0.55 mmol) at –5 °C for 2 h] and *N*-lithium morpholide (2.0 mmol; prepared by adding *n*BuLi (2 mmol) to a 0.5 M solution of morpholine (174 mg, 2 mmol) in THF at 0 °C and stirring for 30 min). Purification by flash-chromatography (pentane/ether; 4:1) yielded **84j** (211 mg, 74 %) as a colourless solid.

mp: 154.1 – 155.8 °C.

IR (ATR) $\tilde{\nu}$ (cm^{-1}): 3064, 2869, 2235, 1602, 1560, 1477, 1444, 1415, 1384, 1344, 1305, 1272, 1261, 1245, 1213, 1166, 1118, 1083, 1072, 1030, 994, 930, 878, 869, 860, 848, 806, 730, 721, 634.

^{1}H-NMR (400 MHz, C_6D_6): δ = 6.58-6.52 (m, 2H, Ar*H*), 3.34 (t, *J* = 4.7 Hz, 4H, 2 x CH_2), 2.26 (t, *J* = 4.7 Hz, 4H, 2 x CH_2).

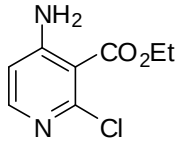
^{13}C-NMR (100 MHz, C_6D_6): δ = 155.2 (d, ^{1}J(C,F) = 259 Hz), 141.5 (d, ^{2}J(C,F) = 7.6 Hz), 126.4, 125.9 (d, ^{3}J(C,F) = 4.2 Hz), 117.3 (d, ^{3}J(C,F) = 3.9 Hz), 112.8 (d, ^{4}J(C,F) = 2.0 Hz), 104.1 (d, ^{2}J(C,F) = 16.3 Hz), 66.3, 49.9.

^{19}F-NMR (282 MHz, $CDCl_3$): δ = –118.5.

MS (70 eV, EI): *m/z* (%) = 286 (32), 284 (35), 228 (96), 227 (45), 226 (100), 225 (36), 198 (11), 120 (15), 119 (29), 100 (13).

HRMS (EI): *m/z* calc. for [$C_{11}H_{10}BrFN_2O$] 283.9961, found: 283.9941.

Synthesis of ethyl 4-amino-2-chloronicotinate (84k)



Prepared according to **TP5** from ethyl 2-chloronicotinate (186 mg, 1.0 mmol) [reaction conditions: deprotonation with $TMP_2Mn{\cdot}2MgCl_2{\cdot}4LiCl$ (1.10 mL, 0.5 M in THF, 0.55 mmol) at 0 °C for 0.5 h] and $LiN(SiMe_3)_2$. The crude product was redissolved in Et_2O (3 mL) before TBAF (2 mL, 1.0 M in THF, 2 mmol) was added in one portion and the mixture was stirred at room temperature for 10 min, poured in EtOAc (10 mL) and washed with water (3 x 10 mL). The combined organic extracts were dried ($MgSO_4$), filtered and concentrated in vacuum. Purification by flash chromatography (ether) yielded **84k** (131 mg, 65 %) as a colourless solid.

mp: 55.7 – 57.5 °C.

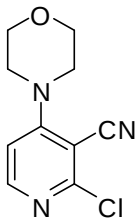
IR (ATR) $\tilde{\nu}$ (cm^{-1}): 3418, 3342, 3149, 2981, 2936, 1700, 1665, 1588, 1547, 1475, 1446, 1412, 1390, 1368, 1304, 1263, 1204, 1172, 1123, 1095, 1049, 1012, 956, 929, 855, 820, 732, 652.

^{1}H-NMR (300 MHz, $CDCl_3$): δ = 7.93 (d, *J* = 5.8 Hz, 1H, Ar*H*), 6.54 (d, *J* = 5.8 Hz, 1H, Ar*H*), 5.92 (br. s, 2H, NH_2), 4.43 (q, *J* = 7.1 Hz, 2H, CH_2CH$_3$), 1.43 (t, *J* = 7.1 Hz, 3H, CH$_2$CH_3).

^{13}C-NMR (75 MHz, $CDCl_3$): δ = 166.3, 156.0, 151.2, 148.9, 110.2, 109.3, 61.8, 14.1.

HRMS (EI): *m/z* calc. for [$C_8H_9ClN_2O_2$] 200.0353, found: 200.0349.

Synthesis of 2-chloro-4-morpholin-4-ylnicotinonitrile (84l)



Prepared according to **TP5** from 2-chloronicotinonitrile (139 mg, 1.0 mmol) [reaction conditions: deprotonation with (TMP)$_2$Mn·2MgCl$_2$·4LiCl at –40 °C for 60 min] and lithium morpholide (2.0 mmol; prepared by adding *n*BuLi (2 mmol) to a 0.5 M solution of morpholine (174 mg, 2 mmol) in THF at 0 °C and stirring for 30 min). Purification by flash chromatography (Et_2O, Al_2O_3 III) yielded **84l** (190 mg, 51 %) as a yellow solid.

mp: 145.3 – 147.2 °C.

IR (ATR) $\tilde{\nu}$ (cm^{-1}): 2956, 2827, 2212, 1578, 1526, 1482, 1446, 1388, 1362, 1300, 1264, 1250, 1148, 1117, 1080, 1018, 963, 925, 863, 818, 794, 781.

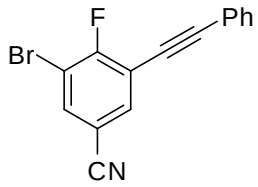
^{1}H-NMR (300 MHz, $CDCl_3$): δ = 8.16 (d, *J* = 6.1 Hz, 1H, Ar*H*), 6.68 (d, *J* = 6.1 Hz, 1H, Ar*H*), 3.84 (t, *J* = 4.7 Hz, 4H, 2 x CH_2), 3.51 (t, *J* = 4.7 Hz, 4H, 2 x CH_2).

^{13}C-NMR (75 MHz, $CDCl_3$): δ = 160.9, 155.7, 151.5, 115.5, 110.3, 98.4, 66.4, 49.8.

MS (70 eV, EI): *m/z* (%) = 225 (23), 224 (16), 223 (75), 222 (12), 194 (14), 193 (15), 167 (27), 166 (13), 165 (86), 140 (28), 138 (100), 128 (11), 103 (16), 102 (13), 76 (15).

HRMS (EI): *m/z* calc. for [$C_{10}H_{10}ClN_3O$] 223.0512, found: 223.0504.

Synthesis of 3-bromo-4-fluoro-5-(phenylethynyl)benzonitrile (87b)



Prepared according to **TP6** from 3-bromo-4-fluorobenzonitrile (200 mg, 1.0 mmol) and and phenylethynyllithium (2.0 mmol; prepared by adding *n*BuLi (2 mmol) to a 0.5 M solution of phenyl acetylene (204 mg, 2 mmol) in THF at 0 °C and stirring for 30 min). Purification by flash chromatography (pentane/Et_2O; 20:1) yielded **87b** (161 mg, 54 %) as a colourless solid.

mp: 93.1 – 94.3 °C.

IR (ATR) $\tilde{\nu}$ (cm^{-1}): 2923, 2853, 2234, 2218, 1603, 1591, 1561, 1490, 1459, 1442, 1319, 1245 1211, 1104, 958, 878, 861, 853, 758, 748, 720, 690, 610.

^{1}H-NMR (400 MHz, C_6D_6): δ = 7.44-7.40 (m, 2H), 7.01-6.97 (m, 3H), 6.81 (dd, *J* = 5.9 Hz, *J* = 2.0 Hz, 1H), 6.72 (dd, *J* = 5.9 Hz, *J* = 2.0 Hz, 1H).

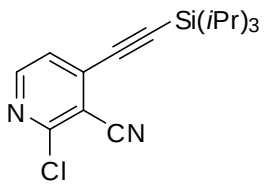
^{13}C-NMR (100 MHz, C_6D_6): δ = 161.3 (d, ^1J(C,F) = 259 Hz), 136.3 (d, ^4J(C,F) = 1.6 Hz), 136.0 (d, ^4J(C,F) = 2.0 Hz), 132.0, 129.6, 128.8, 122.1, 116.1 (d, ^5J(C,F) = 1.4 Hz), 114.7 (d, ^2J(C,F) = 18.3 Hz), 110.3 (d, ^2J(C,F) = 22.4 Hz), 110.1 (d, ^3J(C,F) = 5.1 Hz), 98.0 (d, ^3J(C,F) = 3.9 Hz), 80.3.

^{19}F-NMR (282 MHz, $CDCl_3$): δ = –95.2.

MS (70 eV, EI): *m/z* (%) = 302 (13), 301 (100), 300 (14), 299 (91), 219 (20).

HRMS (EI): *m/z* calc. for [$C_{15}H_7BrFN$] 298.9746, found: 298.9734.

Synthesis of 2-chloro-4-[(triisopropylsilyl)ethynyl]nicotinonitrile (87c)



Prepared according to **TP6** from 2-chloronicotinonitrile (139 mg, 1.0 mmol) [reaction conditions: deprotonation with $TMP_2Mn{\cdot}2MgCl_2{\cdot}4LiCl$ at –40 °C for 60 min] and

triisopropylsilylethynyllithium (2.0 mmol; prepared by adding *n*BuLi (2.0 mmol) to a 0.5 M solution of triisopropylsilylacetylene (365 mg, 2.0 mmol) in THF at 0 °C and stirring for 30 min). Purification by flash chromatography (pentane/Et_2O; 9:1) yielded **87c** (165 mg, 52 %) as a light yellow solid.

mp: 47.8 – 49.6 °C.

IR (ATR) $\tilde{\nu}$ (cm^{-1}): 2957, 2939, 2863, 1566, 1521, 1462, 1441, 1375, 1365, 1257, 1176, 1072, 1021, 995, 909, 890, 881, 853, 798, 757, 678, 641.

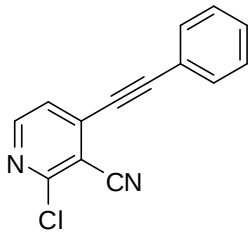
^{1}H-NMR (300 MHz, $CDCl_3$): δ = 7.57 (d, *J* = 5.1 Hz, 1H), 6.30 (d, *J* = 5.1 Hz, 1H), 1.20-1.06 (m, 21H).

^{13}C-NMR (75 MHz, $CDCl_3$): δ = 153.2, 151.3, 137.1, 123.9, 113.9, 113.3, 106.5, 100.3, 18.7, 11.4.

MS (70 eV, EI): *m/z* (%) = 277 (37), 276 (22), 275 (100), 249 (18), 248 (10), 247 (48), 235 (10), 233 (27), 221 (26), 220 (11), 219 (67), 207 (20), 205 (49), 189 (14).

HRMS (EI): *m/z* calc. for [$C_{17}H_{23}ClN_2Si$] 318.1319, found: 318.1311.

Synthesis of 2-chloro-4-(phenylethynyl)nicotinonitrile (87d)



Prepared according to **TP6** from 2-chloronicotinonitrile (139 mg, 1.0 mmol) [reaction conditions: deprotonation with $TMP_2Mn{\cdot}2MgCl_2{\cdot}4LiCl$ at –40 °C for 60 min] and phenylethynyllithium (2.0 mmol; prepared by adding *n*BuLi (2 mmol) to a 0.5 M solution of phenyl acetylene (204 mg, 2 mmol) in THF at 0 °C and stirring for 30 min). Purification by flash chromatography (pentane/Et_2O; 4:1) yielded **87d** (149 mg, 62 %) as a light yellow solid.

mp: 116.8 – 117.9 °C.

IR (ATR) $\tilde{\nu}$ (cm^{-1}): 2233, 2203, 1569, 1538, 1520, 1492, 1452, 1442, 1406, 1378, 1346, 1321, 1235, 1187, 1152, 1068, 1026, 995, 964, 903, 845, 801, 763, 735, 691, 610.

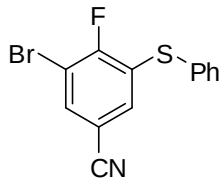
^{1}H-NMR (300 MHz, $CDCl_3$): δ = 8.51 (d, *J* = 5.1 Hz, 1H, Ar*H*), 7.69-7.60 (m, 2H, Ar*H*), 7.51-7.36 (m, 4H, Ar*H*).

^{13}C-NMR (75 MHz, $CDCl_3$): δ = 153.3, 151.7, 138.3, 132.6, 130.7, 128.7, 123.8, 120.5, 113.8, 112.4, 102.9, 83.4.

MS (70 eV, EI): *m/z* (%) = 240 (29), 239 (14), 238 (100), 203 (11), 176 (13),

HRMS (EI): *m/z* calc. for [$C_{14}H_7ClN_2$] 238.0298, found: 238.0285.

Synthesis of 3-bromo-4-fluoro-5-(phenylthio)benzonitrile (89)



A dry and argon-flushed Schlenk-flask, equipped with a magnetic stirring bar and a septum, was charged with 3-bromo-4-fluorobenzonitrile (200 mg, 1.0 mmol). After cooling to –4 °C, $TMP_2Mn{\cdot}2MgCl_2{\cdot}4LiCl$ (1.70 mL, 1.32 M in THF, 1.1 mmol) was added dropwise and stirred for 30 min. Then, CuCl·2LiCl (1.1 mL, 1.0 M in THF, 1.1 mmol) was added dropwise at –50 °C and the mixture was stirred for 30 min. *S*-lithium benzenethiolate (2.0 mmol; prepared by adding *n*BuLi (2.0 mmol) to a 0.5 M solution of benzenethiole in THF (174 mg, 2 mmol) at 0 °C and stirring for 30 min) was added dropwise to the resulting cuprate, and the mixture was stirred for 1 h at –50 °C. The reaction mixture was cooled to –78 °C, then, a solution of $PhI(OAc)_2$ (420 mg, 1.3 mmol) in dry THF (12 mL) was added slowly over a period of 1 h. The reaction mixture was then warmed to –50 °C and stirred for 3 h. Et_2O (100 mL) was poured into the crude reaction mixture. The organic phase was washed with 2 x 10 mL portions of aqueous NH_4OH (2.0 M) and extracted with Et_2O. The combined organic layers were dried (Na_2SO_4), filtered, and concentrated under reduced pressure. Purification by flash chromatography (pentane/ether; 9:1) yielded **89** (145 mg, 51 %) as a colourless solid.

mp: 110.8 – 112.5 °C.

IR (ATR) $\tilde{\nu}$ (cm^{-1}): 3080, 2928, 2230, 1740, 1559, 1472, 1448, 1440, 1386, 1200, 1158, 1070, 1022, 925, 871, 846, 774, 750, 736, 707, 692.

^{1}H-NMR (300 MHz, $CDCl_3$): δ = 7.65-7.60 (m, 1H, Ar*H*), 7.53-7.41 (m, 5H, Ar*H*), 7.05 (dd, *J* = 6.2 Hz, *J* = 1.9 Hz, 1H, Ar*H*).

^{13}C-NMR (75 MHz, $CDCl_3$): δ = 158.0 (d, ^1J(C,F) = 256 Hz), 134.5, 134.1, 131.9 (d, ^3J(C,F) = 4 Hz), 130.5 (d, ^2J(C,F) = 19 Hz), 130.3, 130.0, 129.0 (d, ^4J(C,F) = 2 Hz), 116.5 (d, ^4J(C,F) = 1 Hz), 110.4 (d, ^2J(C,F) = 23 Hz), 110.0 (d, ^3J(C,F) = 5 Hz).

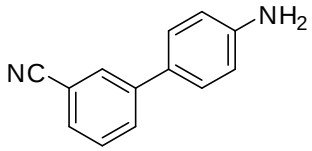
^{19}F-NMR (282 MHz, $CDCl_3$): δ = –94.6.

MS (70 eV, EI): *m/z* (%) = 310 (17), 309 (100), 308 (37), 307 (93), 306 (21), 229 (10), 228 (42), 227 (81), 209 (19), 208 (12), 201 (11), 195 (10), 114 (29), 109 (18), 101 (10), 100 (15), 77 (32), 69 (12), 65 (19), 51 (31).

HRMS (EI): *m/z* calc. for [$C_{13}H_7BrFNS$] 306.9467, found: 306.9466.

7. *i*PrI-Acceleration of Negishi Cross-Coupling Reactions

Preparation of 4'-aminobiphenyl-3-carbonitrile (93a)



To a solution of bis(3-cyanophenyl)zinc (prepared from 3-iodobenzonitrile (458 mg, 2.0 mmol) and *i*PrMgCl·LiCl (1.7 mL, 2.2 mmol, 0.84 M in THF; I/Mg exchange: 1 h at –20 °C) and subsequent transmetalation with $ZnCl_2$·2LiCl (1.1 mL, 1.1 mmol, 1.0 M in THF)) was added $Pd(dba)_2$ (11.6 mg, 0.02 mmol), RuPhos (18.7 mg, 0.04 mmol) and 4-bromoaniline (310 mg, 1.8 mmol) according to **TP7**. The resulting mixture was stirred for 12 min at 25 °C. Then, the reaction mixture was quenched with sat. aq. NH_4Cl solution and extracted with ether (3 x 50 mL). The combined organic phases were washed with sat. thiourea solution (2 x 5 mL) and dried over Na_2SO_4. After evaporation of the solvents the crude residue was purified by flash chromatography (pentane/ether; 1:1) yielding 4'-aminobiphenyl-3-carbonitrile as a colourless solid (311 mg, 89 %). The spectroscopic data match with the literature.[93]

mp: 128.9 – 129.8 °C.

IR (ATR) $\tilde{\nu}$ (cm^{-1}): 3475, 3375, 2224, 1619, 1524, 1480, 1403, 1301, 1283, 1271, 1203, 1184, 889, 831, 796, 681, 610.

^{1}H-NMR (300 MHz, $CDCl_3$): δ = 7.78 (s, 1H, Ar*H*), 7.73 (dt, *J* = 7.8 Hz, *J* = 1.5 Hz, 1H, Ar*H*), 7.54-7.43 (m, 2H, Ar*H*), 7.37 (d, *J* = 8.8 Hz, 2H, Ar*H*), 6.76 (d, *J* = 8.8 Hz, 2H, Ar*H*), 3.82 (br, 2H, NH_2).

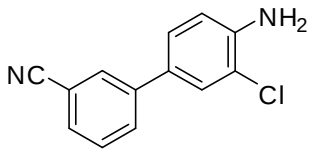
^{13}C-NMR (75 MHz, $CDCl_3$): δ = 146.8, 142.3, 130.5, 129.8, 129.5, 129.4, 128.8, 128.0, 119.1, 115.4, 112.7.

MS (70 eV, EI): *m/z* (%) = 195 (14), 194 (100), 193 (12), 192 (6), 166 (8).

HRMS (EI): *m/z* calc. for [$C_{13}H_{10}N_2$] 194.0844, found: 194.0832.

[93] A. Palani, S. Shapiro, M. D. McBriar, J. W. Clader, W. J. Greenlee, B. Spar, T. J. Kowalski, C. Farley, J. Cook, M. van Heek, B. Weig, K. O'Neill, M. Graziano, B. Hawes, *J. Med. Chem.* **2005**, *48*, 4746.

Preparation of 4'-amino-3'-chlorobiphenyl-3-carbonitrile (93b)



To a solution of bis(3-cyanophenyl)zinc (prepared from 3-iodobenzonitrile (458 mg, 2.0 mmol) and *i*PrMgCl·LiCl (1.7 mL, 2.2 mmol, 0.84 M in THF; I/Mg exchange: 1 h at –20 °C)) and subsequent transmetalation with $ZnCl_2$·2LiCl (1.1 mL, 1.1 mmol, 1.0 M in THF) was added $Pd(dba)_2$ (11.6 mg, 0.02 mmol), RuPhos (18.7 mg, 0.04 mmol) and 4-bromo-2-chloroaniline (372 mg, 1.8 mmol) according to **TP7**. The resulting mixture was stirred for 5min at 25 °C. Then, the reaction mixture was quenched with sat. aq. NH_4Cl solution and extracted with ether (3 x 50 mL). The combined organic phases were washed with sat. thiourea solution (2 x 5 mL) and dried over Na_2SO_4. After evaporation of the solvents the crude residue was purified by flash chromatography (pentane/ether; 2:1) yielding 4'-amino-3'-chlorobiphenyl-3-carbonitrile as a light brown solid (400 mg, 97 %).

mp: 90.5 – 91.2 °C.

IR (ATR) $\tilde{\nu}$ (cm^{-1}): 3420, 3341, 2230, 1626, 1596, 1512, 1476, 1430, 1396, 1328, 1313, 1289, 1254, 1176, 1165, 1048, 905, 887, 872, 824, 790, 717, 691, 682, 624.

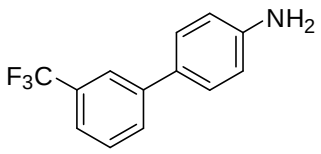
^{1}H-NMR (300 MHz, $CDCl_3$): δ = 7.76 (m, 1H, Ar*H*), 7.69 (dt, *J* = 7.8 Hz, *J* = 1.5 Hz, 1H, Ar*H*), 7.54 (dt, *J* = 7.8 Hz, *J* = 1.5 Hz, 1H, Ar*H*), 7.50-7.43 (m, 2H, Ar*H*), 7.26 (dd, *J* = 8.3 Hz, *J* = 2.2 Hz, 1H, Ar*H*), 6.83 (d, *J* = 8.5 Hz, 1H, Ar*H*), 4.20 (br. s, 2H, NH_2).

^{13}C-NMR (75 MHz, $CDCl_3$): δ = 143.2, 141.1, 130.5, 130.0, 129.7, 129.5, 129.5, 127.8, 126.2, 119.6, 118.8, 116.1, 112.8.

MS (70 eV, EI): *m/z* (%) = 230 (31), 229 (15), 228 (100), 192 (14), 164 (10).

HRMS (EI): *m/z* calc. for [$C_{13}H_9ClN_2$] 228.0454, found: 228.0440.

Preparation of 3'-(trifluoromethyl)biphenyl-4-amine (93c)



To a solution of bis[3-(trifluoromethyl)phenyl]zinc (prepared from 3-trifluoromethyl-iodobenzene (544 mg, 2.0 mmol) and *i*PrMgCl·LiCl (1.7 mL, 2.2 mmol, 0.84 M in THF; I/Mg exchange: 1 h at –20 °C) and subsequent transmetalation with $ZnCl_2$·2LiCl (1.1 mL, 1.1 mmol, 1.0 M in THF) was added $Pd(dba)_2$ (11.6 mg, 0.02 mmol), RuPhos (18.7 mg, 0.04 mmol) and 4-bromoaniline (310 mg, 1.8 mmol) according to **TP7**. The resulting mixture was stirred for 5 min at 25 °C. Then, the reaction mixture was quenched with sat. aq. NH_4Cl solution and extracted with ether (3 x 50 mL). The combined organic phases were washed with sat. thiourea solution (2 x 5 mL) and dried over Na_2SO_4. After evaporation of the solvents the crude residue was purified by flash chromatography (pentane/ether; 1:1) yielding 3'-(trifluoromethyl)biphenyl-4-amine as a colourless solid (394 mg, 92 %).

mp: 68.9 – 70.3 °C.

IR (ATR) $\tilde{\nu}$ (cm^{-1}): 3505, 3408, 1619, 1607, 1520, 1486, 1451, 1416, 1327, 1296, 1260, 1195, 1180, 1157, 1137, 1107, 1098, 1071, 1033, 1006, 984, 898, 828, 798, 716, 697, 656, 638.

^{1}H-NMR (300 MHz, $CDCl_3$): δ = 7.79 (s, 1H), 7.74-7.66 (m, 1H), 7.55-7.40 (m, 4H), 6.77 (d, *J* = 8.8 Hz, 2H), 3.69 (br. s, 2H, NH_2).

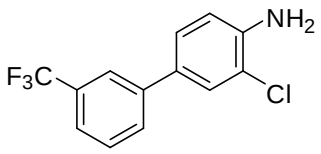
^{13}C-NMR (75 MHz, $CDCl_3$): δ = 146.5, 141.9, 131.0 (q, ^2J(C,F) = 32 Hz), 129.8, 129.5 (q, ^4J(C,F) = 1.4 Hz), 129.0, 128.0, 124.3 (q, ^1J(C,F) = 272 Hz), 123.0 (q, ^3J(C,F) = 3.7 Hz), 122.8 (q, ^3J(C,F) = 4.0 Hz), 115.4.

^{19}F-NMR (282 MHz, $CDCl_3$): δ = –62.5.

MS (70 eV, EI): *m/z* (%) = 238 (11), 237 (100), 216 (7), 167 (8).

HRMS (EI): *m/z* calc. for [$C_{13}H_{10}F_3N$] 237.0765, found: 237.0760.

Preparation of 3-chloro-3'-(trifluoromethyl)biphenyl-4-amine (93d)



To a solution of bis[3-(trifluoromethyl)phenyl]zinc (prepared from 3-trifluoromethyl-iodobenzene (544 mg, 2.0 mmol) and *i*PrMgCl·LiCl (1.7 mL, 2.2 mmol, 0.84 M in THF; I/Mg exchange: 1 h at –20 °C) and subsequent transmetalation with $ZnCl_2$·2LiCl (1.1 mL, 1.1 mmol, 1.0 M in THF) was added $Pd(dba)_2$ (11.6 mg, 0.02 mmol), RuPhos (18.7 mg, 0.04 mmol) and 4-bromo-2-chloroaniline (372 mg, 1.8 mmol) according to **TP7**. The resulting mixture was stirred for 5 min at 25 °C. Then, the reaction mixture was quenched with sat. aq. NH_4Cl solution and extracted with ether (3 x 50 mL). The combined organic phases were washed with sat. thiourea solution (2 x 5 mL) and dried over Na_2SO_4. After evaporation of the solvents the crude residue was purified by flash chromatography (pentane/ether; 2:1) yielding 3-chloro-3'-(trifluoromethyl)biphenyl-4-amine as a colourless oil (434 mg, 89 %).

IR (ATR) $\tilde{\nu}$ (cm^{-1}): 3391, 1621, 1515, 1485, 1443, 1398, 1333, 1310, 1274, 1260, 1161, 1116, 1096, 1073, 1045, 1000, 945, 904, 877, 820, 796, 735, 719, 692, 654.

^{1}H-NMR (300 MHz, $CDCl_3$): δ = 7.74 (s, 1H), 7.70-7.64 (m, 1H), 7.56-7.46 (m, 3H), 7.32 (dd, *J* = 8.9 Hz, *J* = 2.2 Hz, 1H), 6.84 (dd, *J* = 8.2 Hz, 1H), 4.12 (br. s, 2H, N*H*$_2$).

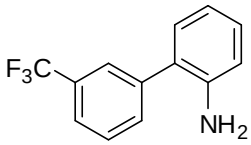
^{13}C-NMR (75 MHz, $CDCl_3$): δ = 142.8, 140.7, 131.2 (q, ^2J(C,F) = 32 Hz), 130.7, 129.5 (q, ^4J(C,F) = 1.1 Hz), 129.2, 127.9, 126.4, 124.2 (q, ^1J(C,F) = 272 Hz), 123.3 (q, ^3J(C,F) = 4.0 Hz), 123.0 (q, ^3J(C,F) = 4.0 Hz), 119.7, 116.1.

^{19}F-NMR (282 MHz, $CDCl_3$): δ = –62.6.

MS (70 eV, EI): *m/z* (%) = 273 (30), 272 (13), 271 (100), 235 (6), 167 (8).

HRMS (EI): *m/z* calc. for [$C_{13}H_9ClF_3N$] 271.0376, found: 271.0375.

Preparation of 3'-(trifluoromethyl)biphenyl-2-amine (93e)



To a solution of bis[3-(trifluoromethyl)phenyl]zinc (prepared from 3-trifluoromethyl-iodobenzene (544 mg, 2.0 mmol) and *i*PrMgCl·LiCl (1.7 mL, 2.2 mmol, 0.84 M in THF; I/Mg exchange: 1 h at –20 °C) and subsequent transmetalation with $ZnCl_2$·2LiCl (1.1 mL, 1.1 mmol, 1.0 M in THF) was added $Pd(dba)_2$ (11.6 mg, 0.02 mmol), RuPhos (18.7 mg, 0.04 mmol) and 2-bromoaniline (310 mg, 1.8 mmol) according to **TP7**. The resulting mixture was stirred for 10 min at 25 °C. Then, the reaction mixture was quenched with sat. aq. NH_4Cl solution and extracted with ether (3 x 50 mL). The combined organic phases were washed with sat. thiourea solution (2 x 5 mL) and dried over Na_2SO_4. After evaporation of the solvents the crude residue was purified by flash chromatography (pentane/ether; 9:1) yielding 3'-(trifluoromethyl)biphenyl-2-amine as a colourless oil (340 mg, 80 %). The spectroscopic data match with the literature.[94]

IR (ATR) $\tilde{\nu}$ (cm^{-1}): 3378, 1738, 1616, 1582, 1500, 1484, 1452, 1427, 1332, 1303, 1285, 1259, 1249, 1163, 1117, 1094, 1072, 1047, 1020, 906, 846, 807, 747, 720, 704, 657, 621.

^{1}H-NMR (300 MHz, $CDCl_3$): δ = 7.76 (s, 1H), 7.71-7.52 (m, 3H), 7.24-7.10 (m, 2H), 6.90-6.76 (m, 2H), 3.77 (br. s, 2H, NH_2).

^{13}C-NMR (75 MHz, $CDCl_3$): δ = 143.3, 140.4, 132.5, 132.4, 131.9, 131.4, 131.0, 130.6, 130.4, 129.24, 129.16, 128.3, 126.0, 125.95, 125.90, 128.85, 124.0, 123.96, 123.91, 123.85, 122.3, 119.4, 118.9, 115.9, 115.7.

Observed complexicity due to C-F splitting, definitive assignments have not been made.

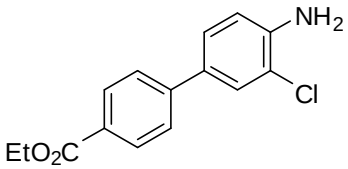
^{19}F-NMR (282 MHz, $CDCl_3$): δ = –62.6

MS (70 eV, EI): *m/z* (%) = 238 (12), 237 (100), 216 (52), 168 (10), 167 (35).

HRMS (EI): *m/z* calc. for [$C_{13}H_{10}F_3N$] 237.0765, found: 237.0750.

[94] B. J. Stokes, B. Jovanovic, H. Dong, K. J. Richert, R. D. Riell, T. G. Driver, *J. Org. Chem.* **2009**, *74*, 3225.

Preparation of ethyl 4'-amino-3'-chlorobiphenyl-4-carboxylate (93f)



To a solution of bis[4-(ethoxycarbonyl)phenyl]zinc (prepared from ethyl 4-iodobenzoate (552 mg, 2.0 mmol) and *i*PrMgCl·LiCl (1.7 mL, 2.2 mmol, 0.84 M in THF; I/Mg exchange: 20 min at –20 °C) and subsequent transmetalation with $ZnCl_2$·2LiCl (1.1 mL, 1.1 mmol, 1.0 M in THF)) was added $Pd(dba)_2$ (11.6 mg, 0.02 mmol), RuPhos (18.7 mg, 0.04 mmol) and 4-bromo-2-chloroaniline (372 mg, 1.8 mmol) according to **TP7**. The resulting mixture was stirred for 15 min at 25 °C. Then, the reaction mixture was quenched with sat. aq. NH_4Cl solution and extracted with ether (3 x 50 mL). The combined organic phases were washed with sat. thiourea solution (2 x 5 mL) and dried over Na_2SO_4. After evaporation of the solvents the crude residue was purified by flash chromatography (pentane/ether; 3:2) yielding ethyl 4'-amino-3'-chlorobiphenyl-4-carboxylate as a light yellow solid (452 mg, 91 %). The spectroscopic data match with the literature.[47b]

mp: 69.0 – 70.4 °C.

IR (ATR) $\tilde{\nu}$ (cm^{-1}): 3475, 3371, 1682, 1617, 1598, 1525, 1495, 1424, 1393, 1367, 1316, 1282, 1269, 1255, 1185, 1166, 1108, 1044, 1014, 854, 814, 772, 744, 700.

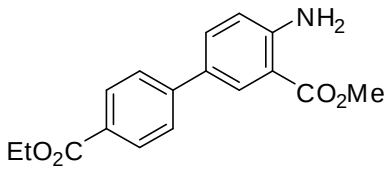
^{1}H-NMR (300 MHz, $CDCl_3$): δ = 8.05 (d, *J* = 8.8 Hz, 2H, Ar*H*), 7.55 (d, *J* = 7.3 Hz, 2H, Ar*H*), 7.53 (s, 1H, Ar*H*), 7.34 (dd, *J* = 8.3 Hz, *J* = 2.2 Hz, 1H, Ar*H*), 6.82 (d, *J* = 8.3 Hz, 1H, Ar*H*), 4.38 (q, *J* = 7.3 Hz, 2H, C*H*$_2$CH$_3$), 4.14 (br. s, 2H, N*H*$_2$), 1.40 (t, *J* = 7.3 Hz, 3H, CH$_2$C*H*$_3$).

^{13}C-NMR (75 MHz, $CDCl_3$): δ = 166.5, 144.1, 142.9, 130.8, 130.1, 128.6, 128.0, 126.4, 125.9, 119.6, 116.0, 60.9, 14.3.

MS (70 eV, EI): *m/z* (%) = 277 (34), 276 (17), 275 (100), 249 (15), 247 (42), 232 (19), 230 (56), 202 (10), 167 (39), 139 (12), 84 (21).

HRMS (EI): *m/z* calc. for [$C_{15}H_{14}ClNO_2$] 275.0713, found: 275.0706.

Preparation of 4'-ethyl 3-methyl 4-aminobiphenyl-3,4'-dicarboxylate (93g)



To a solution of bis[4-(ethoxycarbonyl)phenyl]zinc (prepared from ethyl 4-iodobenzoate (552 mg, 2.0 mmol) and *i*PrMgCl·LiCl (1.7 mL, 2.2 mmol, 0.84 M in THF; I/Mg exchange: 20 min at -20 °C) and subsequent transmetalation with $ZnCl_2$·2LiCl (1.1 mL, 1.1 mmol, 1.0 M in THF)) was added $Pd(dba)_2$ (11.6 mg, 0.02 mmol), RuPhos (18.7 mg, 0.04 mmol) and methyl 2-amino-5-bromobenzoate (368 mg, 1.6 mmol) according to **TP7**. The resulting mixture was stirred for 10 min at 25 °C. Then, the reaction mixture was quenched with sat. aq. NH_4Cl solution and extracted with ether (3 x 50 mL). The combined organic phases were washed with sat. thiourea solution (2 x 5 mL) and dried over Na_2SO_4. After evaporation of the solvents the crude residue was purified by flash chromatography (pentane/ether; 2:1) yielding 4'-ethyl 3-methyl 4-aminobiphenyl-3,4'-dicarboxylate as a yellow solid (449 mg, 94 %).

mp: 87.9 – 89.5 °C.

IR (ATR) $\tilde{\nu}$ (cm^{-1}): 3470, 3359, 1706, 1690, 1625, 1601, 1573, 1556, 1522, 1490, 1462, 1436, 1403, 1367, 1311, 1277, 1233, 1183, 1170, 1104, 1084, 1042, 1018, 971, 957, 853, 827, 792, 772, 741, 717, 702, 687.

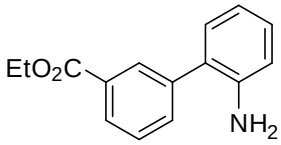
^{1}H-NMR (300 MHz, $CDCl_3$): δ = 8.16 (d, *J* = 1.9 Hz, 1H, Ar*H*), 8.06 (d, *J* = 8.8 Hz, 2H, Ar*H*), 7.62-7.54 (m, 3H, Ar*H*), 6.74 (d, *J* = 8.5 Hz, 1H, Ar*H*), 5.86 (br. s, 2H, NH_2), 4.38 (q, *J* = 7.3 Hz, 2H, CH_2CH$_3$), 3.90 (s, 3H, CH_3), 1.40 (t, *J* = 7.3 Hz, 3H, CH$_2$CH_3).

^{13}C-NMR (75 MHz, $CDCl_3$): δ = 168.3, 166.5, 150.3, 144.6, 132.7, 130.0, 129.8, 128.3, 127.9, 125.8, 117.3, 110.9, 60.8, 51.7, 14.3.

MS (70 eV, EI): *m/z* (%) = 300 (19), 299 (100), 268 (16), 267 (59), 254 (15), 239 (15), 211 (12), 194 (11), 167 (10), 139 (13), 111 (12).

HRMS (EI): *m/z* calc. for [$C_{17}H_{17}NO_4$] 299.1158, found: 299.1144.

Preparation of ethyl 2'-aminobiphenyl-3-carboxylate (93h)



To a solution of bis[3-(ethoxycarbonyl)phenyl]zinc (prepared from ethyl 3-iodobenzoate (552 mg, 2.0 mmol) and *i*PrMgCl·LiCl (1.7 mL, 2.2 mmol, 0.84 M in THF; I/Mg exchange: 30 min at –20 °C) and subsequent transmetalation with $ZnCl_2$·2LiCl (1.1 mL, 1.1 mmol, 1.0 M in THF)) was added $Pd(dba)_2$ (11.6 mg, 0.02 mmol), RuPhos (18.7 mg, 0.04 mmol) and 2-bromoaniline (310 mg, 1.8 mmol) according to **TP7**. The resulting mixture was stirred for 10 min at 25 °C. Then, the reaction mixture was quenched with sat. aq. NH_4Cl solution and extracted with ether (3 x 50 mL). The combined organic phases were washed with sat. thiourea solution (2 x 5 mL) and dried over Na_2SO_4. After evaporation of the solvents the crude residue was purified by flash chromatography (pentane/ether; 2:1) yielding ethyl 2'-aminobiphenyl-3-carboxylate as colourless oil (341 mg, 79 %).

IR (ATR) $\tilde{\nu}$ (cm^{-1}): 3462, 3371, 2980, 1710, 1616, 1582, 1499, 1477, 1454, 1424, 1297, 1233, 1170, 1158, 1107, 1083, 1050, 1027, 1017, 935, 917, 889, 858, 746, 735, 698.

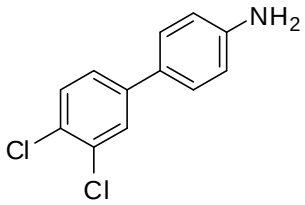
^{1}H-NMR (300 MHz, $CDCl_3$): δ = 8.14 (t, *J* = 1.9 Hz, 1H, Ar*H*), 8.03 (dt, *J* = 7.8 Hz, *J* = 1.5 Hz, 1H, Ar*H*), 7.65 (dt, *J* = 7.8 Hz, *J* = 1.5 Hz, 1H, Ar*H*), 7.51 (t, *J* = 7.8 Hz, 1H, Ar*H*), 7.22-7.10 (m, 2H, Ar*H*), 6.88-6.75 (m, 2H, Ar*H*), 4.38 (q, *J* = 7.1 Hz, 2H, C*H*$_2$CH$_3$), 3.72 (br. s, 2H, N*H*$_2$), 1.39 (t, *J* = 7.1Hz, 3H, CH$_2$C*H*$_3$).

^{13}C-NMR (75 MHz, $CDCl_3$): δ = 166.4, 143.3, 139.7, 133.5, 131.1, 130.4, 130.1, 128.9, 128.8, 128.3, 126.6, 118.8, 115.8, 61.0, 14.3.

MS (70 eV, EI): *m/z* (%) = 242 (18), 241 (100), 194 (28), 168 (13), 167 (23), 166 (21), 139 (12), 84 (26).

HRMS (EI): *m/z* calc. for [$C_{15}H_{15}NO_2$] 241.1103, found: 241.1097.

Preparation of 3',4'-dichlorobiphenyl-4-amine (93j)



To a solution of bis(3,4-dichlorophenyl)zinc (prepared from 1,2-dichloro-4-bromobenzene (452 mg, 2.0 mmol) and *i*PrMgCl·LiCl (1.7 mL, 2.2 mmol, 0.84 M in THF; I/Mg exchange: 1 h at 25 °C) and subsequent transmetalation with $ZnCl_2$·2LiCl (1.1 mL, 1.1 mmol, 1.0 M in THF)) was added *i*PrI (340 mg, 2.0 mmol), $Pd(dba)_2$ (11.6 mg, 0.02 mmol), RuPhos (18.7 mg, 0.04 mmol) and 4-bromoaniline (310 mg, 1.8 mmol) according to **TP8**. The resulting mixture was stirred for 5 min at 25 °C. Then, the reaction mixture was quenched with sat. aq. NH_4Cl solution and extracted with ether (3 x 50 mL). The combined organic phases were washed with sat. thiourea solution (2 x 5 mL) and dried over Na_2SO_4. After evaporation of the solvents the crude residue was purified by flash chromatography (pentane/ether; 2:1) yielding 3',4'-dichlorobiphenyl-4-amine as a light yellow solid (325 mg, 76 %).

mp: 85.6 – 86.8 °C.

IR (ATR) $\tilde{\nu}$ (cm^{-1}): 3443, 3350, 1608, 1588, 1552, 1520, 1474, 1461, 1376, 1286, 1254, 1192, 1136, 1021, 878, 835, 812, 799, 677, 628.

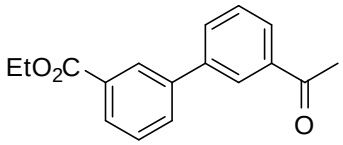
^{1}H-NMR (300 MHz, $CDCl_3$): δ = 7.60 (d, *J* = 2.2 Hz, 1H, Ar*H*), 7.43 (d, *J* = 8.4 Hz, 1H, Ar*H*), 7.39-7.28 (m, 3H, Ar*H*), 6.73 (d, *J* = 8.6 Hz, 2H, Ar*H*), 3.75 (br. s, 2H, NH_2).

^{13}C-NMR (75 MHz, $CDCl_3$): δ = 146.6, 141.2, 132.6, 130.5, 130.0, 128.8, 128.0, 127.8, 125.5, 115.3.

MS (70 eV, EI): *m/z* (%) = 241 (10), 239 (63), 238 (14), 237 (100), 167 (18), 83 (12).

HRMS (EI): *m/z* calc. for [$C_{12}H_9Cl_2N$] 237.0112, found: 237.0108.

Preparation of ethyl 3'-acetylbiphenyl-3-carboxylate (95a)



To a solution of bis[4-(ethoxycarbonyl)phenyl]zinc (prepared from ethyl 4-iodobenzoate (552 mg, 2.0 mmol) and *i*PrMgCl·LiCl (1.7 mL, 2.2 mmol, 0.84 M in THF; I/Mg exchange: 20 min at –20 °C) and subsequent transmetalation with $ZnCl_2$·2LiCl (1.1 mL, 1.1 mmol, 1.0 M in THF)) was added $Pd(dba)_2$ (11.6 mg, 0.02 mmol), RuPhos (18.7 mg, 0.04 mmol) and 3-bromoacetophenone (358 mg, 1.8 mmol) according to **TP7**. The resulting mixture was stirred for 5 min at 25 °C. Then, the reaction mixture was quenched with sat. aq. NH_4Cl solution and extracted with ether (3 x 50 mL). The combined organic phases were washed with sat. thiourea solution (2 x 5 mL) and dried over Na_2SO_4. After evaporation of the solvents the crude residue was purified by flash chromatography (pentane/ether; 4:1) yielding ethyl 3'-acetylbiphenyl-3-carboxylate as a colourless oil (417 mg, 86 %).

IR (ATR) $\tilde{\nu}$ (cm^{-1}): 2981, 1715, 1683, 1599, 1584, 1437, 1357, 1306, 1274, 1253, 1227, 1169, 1108, 1084, 1051, 1020, 967, 904, 799, 752, 716, 691, 667, 634, 620.

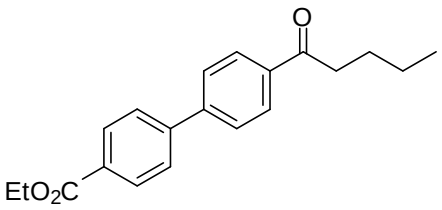
^{1}H-NMR (300 MHz, $CDCl_3$): δ = 8.29-8.26 (m, 1H, Ar*H*), 8.18 (dd, *J* = 1.9 Hz, *J* = 0.6 Hz, 1H, Ar*H*), 8.05 (ddd, *J* = 7.7 Hz, *J* = 1.5 Hz, *J* = 1.1 Hz, 1H, Ar*H*), 7.94 (ddd, *J* = 7.7 Hz, *J* = 1.7 Hz, *J* = 1.1 Hz, 1H, Ar*H*), 7.84-7.75 (m, 2H, Ar*H*), 7.59-7.47 (m, 2H, Ar*H*), 4.41 (q, *J* = 7.1 Hz, 2H, C*H*$_2$CH$_3$), 2.65 (s, 3H, C*H*$_3$), 1.41 (t, *J* = 7.1 Hz, 3H, CH$_2$C*H*$_3$)

^{13}C-NMR (75 MHz, $CDCl_3$): δ = 197.9, 166.3, 140.7, 140.4, 137.7, 131.7, 131.4, 131.2, 129.1, 128.9, 128.8, 128.2, 127.6, 126.9, 61.1, 26.7, 14.3.

MS (70 eV, EI): *m/z* (%) = 268 (49), 254 (15), 253 (100), 223 (18), 152 (23), 43 (12).

HRMS (EI): *m/z* calc. for [$C_{17}H_{16}O_3$] 268.1099, found: 268.1091.

Preparation of ethyl 4'-pentanoylbiphenyl-4-carboxylate (95b)



To a solution of bis[4-(ethoxycarbonyl)phenyl]zinc (prepared from ethyl 4-iodobenzoate (552 mg, 2.0 mmol) and *i*PrMgCl·LiCl (1.7 mL, 2.2 mmol, 0.84 M in THF; I/Mg exchange: 20 min at –20 °C) and subsequent transmetalation with $ZnCl_2$·2LiCl (1.1 mL, 1.1 mmol, 1.0 M in THF)) was added $Pd(dba)_2$ (11.6 mg, 0.02 mmol), RuPhos (18.7 mg, 0.04 mmol) and 4-bromovalerophenone (434 mg, 1.8 mmol) according to **TP7**. The resulting mixture was stirred for 5 min at 25 °C. Then, the reaction mixture was quenched with sat. aq. NH_4Cl solution and extracted with ether (3 x 50 mL). The combined organic phases were washed with sat. thiourea solution (2 x 5 mL) and dried over Na_2SO_4. After evaporation of the solvents the crude residue was purified by flash chromatography (pentane/ether; 4:1) yielding ethyl 4'-pentanoylbiphenyl-4-carboxylate as a colourless solid (516 mg, 92 %).

mp: 87.6 – 89.2 °C.

IR (ATR) $\tilde{\nu}$ (cm^{-1}): 2988, 2954, 2928, 2869, 1716, 1673, 1603, 1556, 1468, 1396, 1381, 1364, 1346, 1323, 1275, 1266, 1210, 1177, 1119, 1102, 1025, 1005, 970, 871, 847, 804, 770, 759, 746, 732, 698, 662, 642.

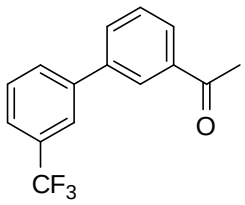
^{1}H-NMR (300 MHz, $CDCl_3$): δ = 8.12 (d, *J* = 8.2 Hz, 2H, Ar*H*), 8.04 (d, *J* = 8.2 Hz, 2H, Ar*H*), 7.69 (d, *J* = 8.0 Hz, 2H, Ar*H*), 7.66 (d, *J* = 8.0 Hz, 2H, Ar*H*), 4.39 (q, *J* = 7.1 Hz, 2H, CH_2), 2.98 (t, *J* = 7.3 Hz, 2H, CH_2), 1.73 (quint. *J* = 7.3 Hz, 2H, CH_2), 1.49-1.35 (m, 5H, CH_2, CH_3), 0.95 (t, *J* = 7.3 Hz, 3H, CH_3).

^{13}C-NMR (75 MHz, $CDCl_3$): δ = 200.0, 166.3, 144.2, 144.1, 136.4, 130.1, 130.0, 128.7, 127.4, 127.1, 61.1, 38.4, 26.5, 22.5, 14.3, 13.9.

MS (70 eV, EI): *m/z* (%) = 310 (11), 298 (10), 269 (15), 268 (83), 265 (11), 254 (18), 253 (100), 225 (14), 152 (27).

HRMS (EI): *m/z* calc. for [$C_{20}H_{22}O_3$] 310.1569, found: 310.1565.

Preparation of 1-[3'-(trifluoromethyl)biphenyl-3-yl]ethanone (95c)



To a solution of bis[3-(trifluoromethyl)phenyl]zinc (prepared from 3-trifluoromethyl-iodobenzene (544 mg, 2.0 mmol) and *i*PrMgCl·LiCl (1.7 mL, 2.2 mmol, 0.84 M in THF; I/Mg exchange: 1 h at –20 °C) and subsequent transmetalation with $ZnCl_2$·2LiCl (1.1 mL, 1.1 mmol, 1.0 M in THF)) was added $Pd(dba)_2$ (11.6 mg, 0.02 mmol), RuPhos (18.7 mg, 0.04 mmol) and 3-bromoacetophenone (358 mg, 1.8 mmol) according to **TP7**. The resulting mixture was stirred for 5 min at 25 °C. Then, the reaction mixture was quenched with sat. aq. NH_4Cl solution and extracted with ether (3 x 50 mL). The combined organic phases were washed with sat. thiourea solution (2 x 5 mL) and dried over Na_2SO_4. After evaporation of the solvents the crude residue was purified by flash chromatography (pentane/ether; 4:1) yielding 1-[3'-(trifluoromethyl)biphenyl-3-yl]ethanone as a colourless solid (407 mg, 86 %). The spectroscopic data match with the literature.[95]

mp: 46.1 – 47.6 °C.

IR (ATR) $\tilde{\nu}$ (cm^{-1}): 1685, 1599, 1473, 1408, 1356, 1334, 1297, 1280, 1264, 1235, 1178, 1158, 1115, 1096, 1074, 1045, 970, 924, 894, 852, 818, 789, 701, 694, 656, 622.

^{1}H-NMR (300 MHz, $CDCl_3$): δ = 8.17 (t, *J* = 1.7 Hz, 1H, Ar*H*), 7.97 (dt, *J* = 7.6 Hz, *J* = 1.2 Hz, 1H, Ar*H*), 7.84 (s, 1H, Ar*H*), 7.82-7.73 (m, 2H, Ar*H*), 7.67-7.53 (m, 3H, Ar*H*), 2.66 (s, 3H, CH_3).

^{13}C-NMR (75 MHz, $CDCl_3$): δ = 197.8, 141.0, 140.3, 137.8, 131.7, 131.4 (q, ^2J(C,F) = 32 Hz), 130.5 (q, ^4J(C,F) = 1.3 Hz), 129.4, 129.3, 128.0, 126.8, 124.5 (q, ^3J(C,F) = 3.9 Hz), 124.1 (q, ^1J(C,F) = 272 Hz), 124.0 (q, ^3J(C,F) = 3.9 Hz), 26.7.

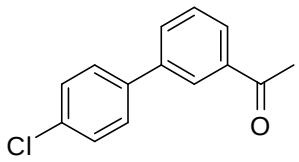
^{19}F-NMR (282 MHz, $CDCl_3$): δ = –62.6.

MS (70 eV, EI): *m/z* (%) = 265 (10), 264 (47), 250 (15), 249 (100), 221 (28), 201 (34), 162 (19), 44 (17), 43 (13).

HRMS (EI): *m/z* calc. for [$C_{15}H_{11}F_3O$] 264.0762, found: 264.0756.

[95] A. Gavryushin, C. Kofink, G. Manolikakes, P. Knochel, *Org. Lett*. **2005**, *7*, 4871.

Preparation of 1-(4'-chlorobiphenyl-3-yl)ethanone (95d)



To a solution of bis(4-chlorophenyl)zinc (prepared from 4-iodochlorobenzene (477 mg, 2.0 mmol) and *i*PrMgCl·LiCl (1.7 mL, 2.2 mmol, 0.84 M in THF; I/Mg exchange: 1 h at –20 °C) and subsequent transmetalation with $ZnCl_2$·2LiCl (1.1 mL, 1.1 mmol, 1.0 M in THF) was added $Pd(dba)_2$ (11.6 mg, 0.02 mmol), RuPhos (18.7 mg, 0.04 mmol) and 3-bromoacetophenone (358 mg, 1.8 mmol) according to **TP7**. The resulting mixture was stirred for 5 min at 25 °C. Then, the reaction mixture was quenched with sat. aq. NH_4Cl solution and extracted with ether (3 x 50 mL). The combined organic phases were washed with sat. thiourea solution (2 x 5 mL) and dried over Na_2SO_4. After evaporation of the solvents the crude residue was purified by flash chromatography (pentane/ether; 4:1) yielding 1-(4'-chlorobiphenyl-3-yl)ethanone as a colourless oil (354 mg, 85 %).

IR (ATR) $\tilde{\nu}$ (cm^{-1}): 1681, 1599, 1583, 1566, 1499, 1475, 1432, 1393, 1355, 1294, 1233, 1092, 1012, 961, 914, 833, 790, 726, 691.

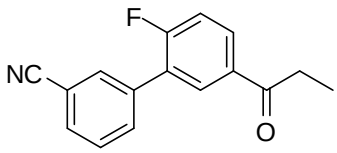
^{1}H-NMR (300 MHz, $CDCl_3$): δ = 8.11 (dt, *J* = 1.9 Hz, *J* = 1.7 Hz, 1H, Ar*H*), 7.91 (ddd, *J* = 7.6 Hz, *J* = 1.2 Hz, *J* = 1.2 Hz, 1H, Ar*H*), 7.70 (ddd, *J* = 7.9 Hz, *J* = 1.2 Hz, *J* = 1.2 Hz, 1H, Ar*H*), 7.55-7.46 (m, 3H, Ar*H*), 7.42-7.35 (m, 2H, Ar*H*), 2.62 (s, 3H, CH_3).

^{13}C-NMR (75 MHz, $CDCl_3$): δ = 197.7, 140.3, 138.4, 137.6, 133.9, 131.3, 129.1, 129.0, 128.3, 127.4, 126.5, 26.6.

MS (70 eV, EI): *m/z* (%) = 232 (17), 230 (54), 217 (29), 216 (12), 215 (100), 187 (15), 152 (67), 151 (10), 76 (14).

HRMS (EI): *m/z* calc. for [$C_{14}H_{11}ClO$] 230.0498, found: 230.0493.

Preparation of 2'-methyl-5'-propionylbiphenyl-3-carbonitrile (95e)



To a solution of bis(3-cyanophenyl)zinc (prepared from 3-iodobenzonitrile (458 mg, 2.0 mmol) and *i*PrMgCl·LiCl (1.7 mL, 2.2 mmol, 0.84 M in THF; I/Mg exchange: 1 h at –20 °C) and subsequent transmetalation with $ZnCl_2$·2LiCl (1.1 mL, 1.1 mmol, 1.0 M in THF) was added $Pd(dba)_2$ (11.6 mg, 0.02 mmol), RuPhos (18.7 mg, 0.04 mmol) and 3-bromo-4-fluoropropiophenone (370 mg, 1.6 mmol) according to **TP7**. The resulting mixture was stirred for 12 min at 25 °C. Then, the reaction mixture was quenched with sat. aq. NH_4Cl solution and extracted with ether (3 x 50 mL). The combined organic phases were washed with sat. thiourea solution (2 x 5 mL) and dried over Na_2SO_4. After evaporation of the solvents the crude residue was purified by flash chromatography (pentane/ether; 4:1) yielding 2'-methyl-5'-propionylbiphenyl-3-carbonitrile as a colourless solid (295 mg, 73 %).

mp: 117.8 – 119.7 °C.

IR (ATR) $\tilde{\nu}$ (cm^{-1}): 2980, 2232, 1688, 1603, 1584, 1482, 1418, 1400, 1358, 1260, 1212, 1168, 1119, 1094, 1012, 968, 962, 890, 836, 800, 688.

^{1}H-NMR (300 MHz, $CDCl_3$): δ = 8.07-7.95 (m, 2H, Ar*H*), 7.86-7.81 (m, 1H, Ar*H*), 7.80-7.74 (m, 1H, Ar*H*), 7.67 (dt, *J* = 7.9 Hz, *J* = 1.5 Hz, 1H, Ar*H*), 7.56 (dt, *J* = 7.9 Hz, *J* = 0.6 Hz, 1H, Ar*H*), 7.30-7.21 (m, 1H, Ar*H*), 3.00 (q, *J*(H,H) = 7.3 Hz, 2H, CH_2CH$_3$), 1.22 (t, *J* = 7.3 Hz, 3H, CH$_2$CH_3).

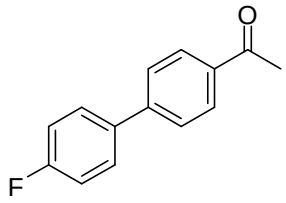
^{13}C-NMR (75 MHz, $CDCl_3$): δ = 198.8, 162.2 (d, ^1J(C,F) = 257 Hz), 136.0 (d, ^5J(C,F) = 1.3 Hz), 133.8 (d, ^3J(C,F) = 3.6 Hz), 133.2 (d, ^4J(C,F) = 3.1 Hz), 132.4 (d, ^4J(C,F) = 3.4 Hz), 131.6, 130.7 (d, ^3J(C,F) = 4.4 Hz), 130.2 (d, ^3J(C,F) = 10 Hz), 129.5, 127.1 (d, ^2J(C,F) = 14 Hz), 118.4, 116.6 (d, ^2J(C,F) = 23 Hz), 112.9, 31.8, 8.1.

^{19}F-NMR (282 MHz, $CDCl_3$): δ = –110.8.

MS (70 eV, EI): *m/z* (%) = 253 (8), 225 (11), 224 (100), 196 (13), 195 (12), 169 (9).

HRMS (EI): *m/z* calc. for [$C_{16}H_{12}FNO$] 253.0903, found: 253.0886.

Preparation of 1-(3'-fluorobiphenyl-4-yl)ethanone (95f)



To a solution of bis[3-(trifluoromethyl)phenyl]zinc (prepared from 4-fluorophenylmagnesium bromide (2.35 mL, 2.0 mmol, 0.85 M in THF) and $ZnCl_2 \cdot 2LiCl$ (1.1 mL, 1.1 mmol, 1.0 M in THF) was added *i*PrI (340 mg, 2.0 mmol), $Pd(dba)_2$ (11.6 mg, 0.02 mmol), RuPhos (18.7 mg, 0.04 mmol) and 4-bromoacetophenone (358 mg, 1.8 mmol) according to **TP9**. The resulting mixture was stirred for 5 min at 25 °C. Then, the reaction mixture was quenched with sat. aq. NH_4Cl solution and extracted with ether (3 x 50 mL). The combined organic phases were washed with sat. thiourea solution (2 x 5 mL) and dried over Na_2SO_4. After evaporation of the solvents the crude residue was purified by flash chromatography (pentane/ether; 4:1) yielding 1-(3'-fluorobiphenyl-4-yl)ethanone as a colourless solid (351 mg, 91 %). The spectroscopic data match with the literature.[96]

mp: 108.7 – 110.4 °C.

IR (ATR) $\tilde{\nu}$ (cm^{-1}): 1680, 1598, 1562, 1527, 1494, 1422, 1395, 1360, 1324, 1278, 1264, 1252, 1194, 1162, 1100, 1014, 1003, 960, 840, 817, 732, 707, 638.

^{1}H-NMR (300 MHz, $CDCl_3$): δ = 8.01 (d, *J* = 8.6 Hz, 2H, Ar*H*), 7.65-7.54 (m, 4H, Ar*H*), 7.14 (t, *J* = 8.6 Hz, 2H, Ar*H*), 2.62 (s, 3H, CH_3).

^{13}C-NMR (75 MHz, $CDCl_3$): δ = 197.6, 162.8 (d, ^1J(C,F) = 248 Hz), 144.7, 135.9 (d, ^4J(C,F) = 3 Hz), 135.8, 128.9, 128.9 (d, ^3J(C,F) = 8 Hz), 127.0 (d, ^5J(C,F) = 1 Hz), 115.9 (d, ^2J(C,F) = 22 Hz), 26.6.

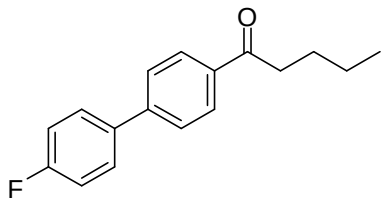
^{19}F-NMR (282 MHz, $CDCl_3$): δ = –105.9.

MS (70 eV, EI): *m/z* (%) = 214 (45), 200 (13), 199 (100), 171 (45), 170 (48), 85 (12), 44 (15).

HRMS (EI): *m/z* calc. for [$C_{14}H_{11}FO$] 214.0794, found: 214.0789.

[96] J.-H. Li, W.-J. Liu, *Org. Lett.* **2004**, *6*, 2809.

Preparation of 1-(4'-fluorobiphenyl-4-yl)pentan-1-one (95g)



To a solution of bis[3-(trifluoromethyl)phenyl]zinc (prepared from 4-fluorophenylmagnesium bromide (2.35 mL, 2.0 mmol, 0.85 M in THF)) and $ZnCl_2 \cdot 2LiCl$ (1.1 mL, 1.1 mmol, 1.0 M in THF) was added *i*PrI (340 mg, 2.0 mmol), $Pd(dba)_2$ (11.6 mg, 0.02 mmol), RuPhos (18.7 mg, 0.04 mmol) and 4-bromovalerophenone (434 mg, 1.8 mmol) according to **TP9**. The resulting mixture was stirred for 5 min at 25 °C. Then, the reaction mixture was quenched with sat. aq. NH_4Cl solution and extracted with ether (3 x 50 mL). The combined organic phases were washed with sat. thiourea solution (2 x 5 mL) and dried over Na_2SO_4. After evaporation of the solvents the crude residue was purified by flash chromatography (pentane/ether; 9:1) yielding 1-(4'-fluorobiphenyl-4-yl)pentan-1-one as a colourless solid (420 mg, 91 %).

mp: 100.0 – 101.4 °C.

IR (ATR) $\tilde{\nu}$ (cm^{-1}): 2957, 2930, 2871, 1674, 1595, 1564, 1521, 1494, 1468, 1456, 1395, 1380, 1342, 1266, 1240, 1210, 1190, 1162, 1100, 1004, 977, 858, 832, 822, 802, 744, 732, 702.

^{1}H-NMR (300 MHz, $CDCl_3$): δ = 8.02 (d, *J* = 8.6 Hz, 2H, Ar*H*), 7.65-7.52 (m, 4H, Ar*H*), 7.14 (dd, *J* = 8.6 Hz, *J* = 8.8 Hz , 2H, Ar*H*), 2.98 (t, *J* = 7.7 Hz, 2H, CH_2), 1.74 (quint, *J* = 7.7 Hz, 2H, CH_2), 1.42 (sext, *J* = 7.7 Hz, 2H, CH_2), 0.96 (t, *J* = 7.4 Hz, 3H, CH_3).

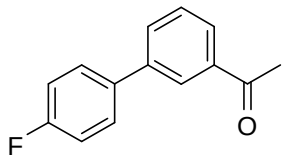
^{13}C-NMR (75 MHz, $CDCl_3$): δ = 200.0, 162.9 (d, ^1J(C,F) = 248 Hz), 144.4, 136.0 (d, ^4J(C,F) = 3 Hz), 135.8 (d, ^5J(C,F) = 0.5 Hz), 128.9 (d, ^3J(C,F) = 8 Hz), 128.7, 127.0, 115.9 (d, ^2J(C,F) = 22 Hz), 38.4, 26.5, 22.5, 13.9.

^{19}F-NMR (282 MHz, $CDCl_3$): δ = –114.1.

MS (70 eV, EI): *m/z* (%) = 256 (9), 215 (10), 214 (72), 200 (15), 199 (100), 171 (31), 170 (37).

HRMS (EI): *m/z* calc. for [$C_{17}H_{17}FO$] 256.1263, found: 256.1260.

Preparation of 1-(4'-fluorobiphenyl-3-yl)ethanone (95h)



To a solution of bis[3-(trifluoromethyl)phenyl]zinc (prepared from 4-fluorophenylmagnesium bromide (2.35 mL, 2.0 mmol, 0.85 M in THF)) and $ZnCl_2 \cdot 2LiCl$ (1.1 mL, 1.1 mmol, 1.0 M in THF) was added *i*PrI (340 mg, 2.0 mmol), $Pd(dba)_2$ (11.6 mg, 0.02 mmol), RuPhos (18.7 mg, 0.04 mmol) and 3-bromoacetophenone (358 mg, 1.8 mmol) according to **TP9**. The resulting mixture was stirred for 5 min at 25 °C. Then, the reaction mixture was quenched with sat. aq. NH_4Cl solution and extracted with ether (3 x 50 mL). The combined organic phases were washed with sat. thiourea solution (2 x 5 mL) and dried over Na_2SO_4. After evaporation of the solvents the crude residue was purified by flash chromatography (pentane/ether; 4:1) yielding 1-(4'-fluorobiphenyl-3-yl)ethanone as a colourless oil (351 mg, 91 %).

IR (ATR) $\tilde{\nu}$ (cm^{-1}): 3065, 1682, 1604, 1596, 1580, 1513, 1479, 1435, 1398, 1356, 1295, 1232, 1223, 1178, 1159, 1098, 1014, 961, 914, 837, 792, 692, 641, 624.

^{1}H-NMR (300 MHz, $CDCl_3$): δ = 8.12 (t, *J* = 1.8 Hz, 1H), 7.91 (d, *J* = 7.9 Hz, 1H), 7.72 (dd, *J* = 7.9 Hz, *J* = 1.1 Hz, 1H), 7.61-7.47 (m, 3H), 7.14 (t, *J* = 8.4 Hz, 2H), 2.64 (s, 3H, CH_3).

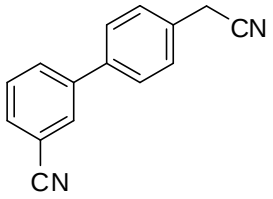
^{13}C-NMR (75 MHz, $CDCl_3$): δ = 197.9, 162.7 (d, ^1J(C,F) = 247 Hz), 140.7, 137.7, 136.3 (d, ^4J(C,F) = 3.4 Hz), 131.5, 129.1, 128.8 (d, ^3J(C,F) = 8.3 Hz), 127.2, 126.7, 115.8 (d, ^2J(C,F) = 22 Hz), 26.7.

^{19}F-NMR (282 MHz, $CDCl_3$): δ = –114.8.

MS (70 eV, EI): *m/z* (%) = 215 (12), 214 (54), 200 (12), 199 (100), 172 (11), 171 (58), 170 (44), 131 (51), 103 (14), 85 (14), 83 (18), 71 (10), 69 (21), 57 (26), 56 (10), 55 (20), 44 (29).

HRMS (EI): *m/z* calc. for [$C_{14}H_{11}FO$] 214.0794, found: 214.0779.

Preparation of 4'-(cyanomethyl)biphenyl-3-carbonitrile (97a)



To a solution of bis(3-cyanophenyl)zinc (prepared from 3-iodobenzonitrile (458 mg, 2.0 mmol) and *i*PrMgCl·LiCl (1.7 mL, 2.2 mmol, 0.84 M in THF; I/Mg exchange: 1 h at –20 °C) and subsequent transmetalation with $ZnCl_2$·2LiCl (1.1 mL, 1.1 mmol, 1.0 M in THF)) was added $Pd(dba)_2$ (11.6 mg, 0.02 mmol), RuPhos (18.7 mg, 0.04 mmol) and (4-bromophenyl)acetonitrile (353 mg, 1.8 mmol) according to **TP7**. The resulting mixture was stirred for 5 min at 25 °C. Then, the reaction mixture was quenched with sat. aq. NH_4Cl solution and extracted with ether (3 x 50 mL). The combined organic phases were washed with sat. thiourea solution (2 x 5 mL) and dried over Na_2SO_4. After evaporation of the solvents the crude residue was purified by flash chromatography (pentane/ether; 1:1) yielding 4'-(cyanomethyl)biphenyl-3-carbonitrile as a colourless solid (336 mg, 86 %).

mp: 118.8– 120.6 °C.

IR (ATR) $\tilde{\nu}$ (cm^{-1}): 3068, 3036, 2253, 2228, 1737, 1598, 1514, 1478, 1408, 1396, 1199, 1176, 1118, 1018, 930, 905, 837, 808, 787, 689.

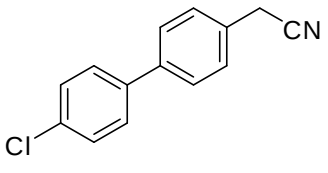
^{1}H-NMR (300 MHz, $CDCl_3$): δ = 7.84-7.76 (m, 2H), 7.64 (dt, *J* = 7.7 Hz, *J* = 1.1 Hz, 1H), 7.59-7.51 (m, 3H), 7.44 (d, *J* = 8.6 Hz, 2H), 3.81 (s, 2H, CH_2).

^{13}C-NMR (75 MHz, $CDCl_3$): δ = 141.4, 138.7, 131.3, 131.0, 130.5, 130.2, 129.7, 128.7, 127.7, 118.6, 117.5, 113.0, 23.3.

MS (70 eV, EI): *m/z* (%) = 219 (15), 218 (100), 217 (11), 191 (13), 190 (29).

HRMS (EI): *m/z* calc. for [$C_{15}H_{10}N_2$] 218.0844, found: 218.0823.

Preparation of (4'-chlorobiphenyl-4-yl)acetonitrile (97b)



To a solution of bis(4-chlorophenyl)zinc (prepared from 4-iodochlorobenzene (477 mg, 2.0 mmol) and *i*PrMgCl·LiCl (1.7 mL, 2.2 mmol, 0.84 M in THF; I/Mg exchange: 1 h at -20 °C) and subsequent transmetalation with $ZnCl_2$·2LiCl (1.1 mL, 1.1 mmol, 1.0 M in THF)) was added $Pd(dba)_2$ (11.6 mg, 0.02 mmol), RuPhos (18.7 mg, 0.04 mmol) and (4-bromophenyl)acetonitrile (353 mg, 1.8 mmol) according to **TP7**. The resulting mixture was stirred for 5 min at 25 °C. Then, the reaction mixture was quenched with sat. aq. NH_4Cl solution and extracted with ether (3 x 50 mL). The combined organic phases were washed with sat. thiourea solution (2 x 5 mL) and dried over Na_2SO_4. After evaporation of the solvents the crude residue was purified by flash chromatography (pentane/ether; 4:1) yielding (4'-chlorobiphenyl-4-yl)acetonitrile as a colourless solid (397 mg, 97 %).

mp: 86.0 – 87.8 °C.

IR (ATR) $\tilde{\nu}$ (cm^{-1}): 2252, 1611, 1592, 1483, 1426, 1412, 1395, 1135, 1101, 1014, 1002, 955, 936, 916, 840, 820, 799, 749, 648.

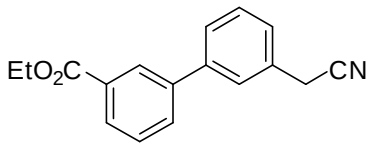
^{1}H-NMR (300 MHz, $CDCl_3$): δ = 7.60-7.46 (m, 4H, Ar*H*), 7.45-7.36 (m, 4H, Ar*H*), 3.78 (s, 2H, CH_2).

^{13}C-NMR (75 MHz, $CDCl_3$): δ = 139.8, 138.6, 133.8, 129.2, 129.0, 128.4, 128.3, 127.6, 117.7, 23.3

MS (70 eV, EI): *m/z* (%) = 229 (33), 228 (17), 227 (100), 193 (11), 192 (69), 190 (19), 165 (35), 96 (12), 83 (11), 82 (13).

HRMS (EI): *m/z* calc. for [$C_{14}H_{10}ClN$] 227.0502, found: 227.0493.

Preparation of ethyl [3'-(trifluoromethyl)biphenyl-4-yl]acetate (97c)



To a solution of bis[3-(ethoxycarbonyl)phenyl]zinc (prepared from ethyl 3-iodobenzoate (552 mg, 2.0 mmol) and *i*PrMgCl·LiCl (1.7 mL, 2.2 mmol, 0.84 M in THF; I/Mg exchange: 30 min at –20 °C) and subsequent transmetalation with $ZnCl_2$·2LiCl (1.1 mL, 1.1 mmol, 1.0 M in THF) was added $Pd(dba)_2$ (11.6 mg, 0.02 mmol), RuPhos (18.7 mg, 0.04 mmol) and (3-bromophenyl)acetonitrile (353 mg, 1.8 mmol) according to **TP7**. The resulting mixture was

stirred for 10 min at 25 °C. Then, the reaction mixture was quenched with sat. aq. NH_4Cl solution and extracted with ether (3 x 50 mL). The combined organic phases were washed with sat. thiourea solution (2 x 5 mL) and dried over Na_2SO_4. After evaporation of the solvents the crude residue was purified by flash chromatography (pentane/ether; 2:1) yielding ethyl [3'-(trifluoromethyl)biphenyl-4-yl]acetate as a colourless oil (423 mg, 89 %).

IR (ATR) $\tilde{\nu}$ (cm^{-1}): 2982, 2250, 1712, 1606, 1580, 1474, 1443, 1413, 1367, 1301, 1283, 1244, 1171, 1109, 1084, 1057, 1020, 938, 901, 865, 790, 752, 740, 692, 672, 621.

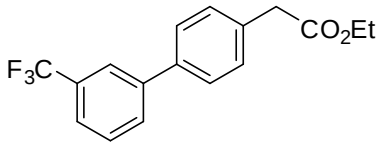
^{1}H-NMR (300 MHz, $CDCl_3$): δ = 8.27-8.18 (m, 1H, Ar*H*), 8.02 (dt, *J* = 7.6 Hz, *J* = 1.2 Hz, 1H, Ar*H*), 7.72 (ddd, *J* = 7.9 Hz, *J* = 1.2 Hz, *J* = 1.2 Hz, 1H, Ar*H*), 7.57-7.38 (m, 4H, Ar*H*), 7.34-7.28 (m, 1H, Ar*H*), 4.39 (q, *J* = 7.2 Hz, 2H, C*H*$_2$CH$_3$), 3.79 (s, 2H, C*H*$_2$), 1.39 (t, *J* = 7.2 Hz, 3H, CH$_2$C*H*$_3$).

^{13}C-NMR (75 MHz, $CDCl_3$): δ = 166.2, 141.0, 140.3, 131.2, 131.9, 130.6, 129.5, 128.8, 128.5, 127.9, 127.0, 126.7, 126.5, 117.6, 61.0, 23.4, 14.2.

MS (70 eV, EI): *m/z* (%) = 266 (11), 265 (63), 237 (32), 221 (19), 220 (100), 165 (21), 152 (37).

HRMS (EI): *m/z* calc. for [$C_{17}H_{15}NO_2$] 265.1103, found: 265.1097.

Preparation of ethyl [3'-(trifluoromethyl)biphenyl-4-yl]acetate (97e)



To a solution of bis[3-(trifluoromethyl)phenyl]zinc (prepared from 3-trifluoromethyl-iodobenzene (544 mg, 2.0 mmol) and *i*PrMgCl·LiCl (1.7 mL, 2.2 mmol, 0.84 M in THF; I/Mg exchange: 1 h at –20 °C) and subsequent transmetalation with $ZnCl_2$·2LiCl (1.1 mL, 1.1 mmol, 1.0 M in THF)) was added $Pd(dba)_2$ (11.6 mg, 0.02 mmol), RuPhos (18.7 mg, 0.04 mmol) and ethyl (4-bromophenyl)acetate (438 mg, 1.8 mmol) according to **TP7**. The resulting mixture was stirred for 5 min at 25 °C. Then, the reaction mixture was quenched with sat. aq. NH_4Cl solution and extracted with ether (3 x 50 mL). The combined organic phases were washed with sat. thiourea solution (2 x 5 mL) and dried over Na_2SO_4. After evaporation of the

solvents the crude residue was purified by flash chromatography (pentane/ether; 4:1) yielding ethyl [3'-(trifluoromethyl)biphenyl-4-yl]acetate as a colourless oil (522 mg, 94 %).

IR (ATR) $\tilde{\nu}$ (cm^{-1}): 1732, 1444, 1410, 1333, 1260, 1222, 1160, 1120, 1096, 1074, 1031, 903, 828, 794, 717, 700, 658.

^{1}H-NMR (300 MHz, $CDCl_3$): δ = 7.83 (s, 1H, Ar*H*), 7.75 (d, *J* = 7.5 Hz, 1H, Ar*H*), 7.63-7.50 (m, 4H, Ar*H*), 7.40 (d, *J* = 8.2 Hz, 2H, Ar*H*), 4.19 (q, *J* = 7.1 Hz, 2H, C*H*$_2$CH$_3$), 3.67 (s, 2H, C*H*$_2$), 1.28 (t, *J* = 7.1 Hz, 3H, CH$_2$C*H*$_3$).

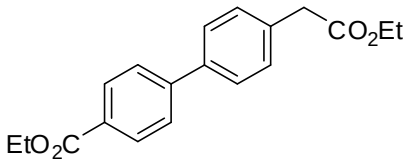
^{13}C-NMR (75 MHz, $CDCl_3$): δ = 171.3, 141.6, 138.5, 134.1, 131.1 (q, ^{2}J(C,F) = 32 Hz), 130.3 (q, ^{4}J(C,F) = 1.3 Hz), 129.9, 129.2, 127.3, 124.1 (q, ^{1}J(C,F) = 272 Hz), 123.9 (q, ^{3}J(C,F) = 4 Hz), 123.8 (q, ^{3}J(C,F) = 4 Hz), 60.9, 41.0, 14.1.

^{19}F-NMR (282 MHz, $CDCl_3$): δ = –62.6.

MS (70 eV, EI): *m/z* (%) = 308 (28), 236 (15), 235 (100), 165 (13).

HRMS (EI): *m/z* calc. for [$C_{17}H_{15}F_3O_2$] 308.1024, found: 308.1017.

Preparation of ethyl 4'-(2-ethoxy-2-oxoethyl)biphenyl-4-carboxylate (97f)



To a solution of bis[4-(ethoxycarbonyl)phenyl]zinc (prepared from ethyl 4-iodobenzoate (552 mg, 2.0 mmol) and *i*PrMgCl·LiCl (1.7 mL, 2.2 mmol, 0.84 M in THF; I/Mg exchange: 20 min at –20 °C) and subsequent transmetalation with $ZnCl_2$·2LiCl (1.1 mL, 1.1 mmol, 1.0 M in THF)) was added $Pd(dba)_2$ (11.6 mg, 0.02 mmol), RuPhos (18.7 mg, 0.04 mmol) and 4 ethyl (4-bromophenyl)acetate (438 mg, 1.8 mmol) according to **TP7**. The resulting mixture was stirred for 15 min at 25 °C. Then, the reaction mixture was quenched with sat. aq. NH_4Cl solution and extracted with ether (3 x 50 mL). The combined organic phases were washed with sat. thiourea solution (2 x 5 mL) and dried over Na_2SO_4. After evaporation of the solvents the crude residue was purified by flash chromatography (pentane/ether; 4:1) yielding ethyl 4'-(2-ethoxy-2-oxoethyl)biphenyl-4-carboxylate as a colourless solid (479 mg, 85 %).

mp: 41.8 – 43.4 °C.

IR (ATR) $\tilde{\nu}$ (cm^{-1}): 2980, 2932, 1730, 1709, 1607, 1580, 1464, 1400, 1368, 1340, 1274, 1222, 1160, 1111, 1025, 1004, 885, 819, 769, 745, 724, 698.

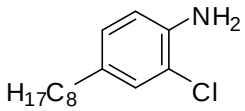
^{1}H-NMR (300 MHz, $CDCl_3$): δ = 8.09 (d, *J* = 8.8 Hz, 2H, Ar*H*), 7.64 (d, *J* = 8.6 Hz, 2H, Ar*H*), 7.58 (d, *J* = 8.2 Hz, 2H, Ar*H*), 7.38 (d, *J* = 8.4 Hz, 2H, Ar*H*), 4.39 (q, *J* = 7.1 Hz, 2H, C*H*$_2$CH$_3$), 4.17 (q, *J* = 7.1 Hz, 2H, C*H*$_2$CH$_3$), 3.66 (s, 2H, C*H*$_2$), 1.40 (t, *J* = 7.1 Hz, 3H, CH$_2$C*H*$_3$), 1.26 (t, *J* = 7.1 Hz, 3H, CH$_2$C*H*$_3$).

^{13}C-NMR (75 MHz, $CDCl_3$): δ = 171.4, 166.4, 145.1, 138.8, 134.1, 130.0, 129.8, 129.2, 127.4, 126.8, 60.93, 60.91, 41.0, 14.3, 14.2.

MS (70 eV, EI): *m/z* (%) = 313 (13), 312 (49), 267 (14), 240 (18), 239 (100), 211 (24), 166 (12), 165 (24).

HRMS (EI): *m/z* calc. for [$C_{19}H_{20}O_4$] 312.1362, found: 312.1350.

Preparation of 2-chloro-4-octylaniline (93k)



To 1-ocytlmagnesium bromide (2.50 mL, 2.0 mmol, 0.80 M in THF) was added $ZnCl_2$·2LiCl (1.1 mL, 1.1 mmol, 1.0 M in THF), and *i*PrI (340 mg, 2.0 mmol) according to **TP9**. To this mixture was added Pd(dba)$_2$ (11.6mg, 0.02 mmol), Ru-Phos (18.7 mg, 0.04 mmol) and 4-bromo-2-chloroaniline (330 mg, 1.6 mmol) in one portion followed by 2 mL THF. The resulting mixture was stirred for 10 min at 25 °C. Then, the reaction mixture was quenched with sat. aq. NH_4Cl solution and extracted with ether (3 x 50 mL). The combined organic phases were washed with sat. thiourea solution (2 x 5 mL) and dried over Na_2SO_4. After evaporation of the solvents the crude residue was purified by flash chromatography (pentane/ether; 9:1) yielding 2-chloro-4-octylaniline as a colourless oil (302 mg, 79 %).

IR (ATR) $\tilde{\nu}$ (cm^{-1}): 3474, 3385, 2955, 2924, 2853, 1624, 1505, 1465, 1415, 1378, 1306, 1260, 1206, 1154, 1046, 876, 814, 785, 721, 689.

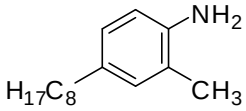
^{1}H-NMR (300 MHz, $CDCl_3$): δ = 7.07 (d, *J* = 1.9 Hz, 1H, Ar*H*), 6.89 (d, *J* = 7.9 Hz, *J* = 1.9 Hz, 1H, Ar*H*), 6.74 (d, *J* = 7.9 Hz, 1H, Ar*H*), 4.24 (br. s, 2H, N*H*$_2$), 2.47 (t, *J* = 7.5 Hz, 2H, C*H*$_2$), 1.55 (quint, *J* = 7.5 Hz, 2H, C*H*$_2$), 1.36-1.20 (m, 10H, 5 x C*H*$_2$), 0.88 (t, *J* = 6.0 Hz, 3H, C*H*$_3$).

^{13}C-NMR (75 MHz, $CDCl_3$): δ = 139.6, 134.7, 129.1, 127.6, 119.7, 116.4, 34.8, 31.9, 31.5, 29.4, 29.2, 29.2, 22.7, 14.1.

MS (70 eV, EI): *m/z* (%) = 239 (19), 142 (34), 140 (100), 57 (15), 44 (12).

HRMS (EI): *m/z* calc. for [$C_{14}H_{22}ClN$] 239.1441, found: 239.1441.

Preparation of 2-methyl-4-octylaniline (93l)



To 1-ocytlmagnesium bromide (2.50 mL, 2.0 mmol, 0.80 M in THF) was added $ZnCl_2$·2LiCl (1.1 mL, 1.1 mmol, 1.0 M in THF), and *i*PrI (340 mg, 2.0 mmol) according to **TP9**. To this mixture was added $Pd(dba)_2$ (11.6mg, 0.02 mmol), Ru-Phos (18.7 mg, 0.04 mmol) and 4-bromo-2-methylaniline (398 mg, 1.6 mmol) in one portion followed by 2 mL THF. The resulting mixture was stirred for 10 min at 25 °C. Then, the reaction mixture was quenched with sat. aq. NH_4Cl solution and extracted with ether (3 x 50 mL). The combined organic phases were washed with sat. thiourea solution (2 x 5 mL) and dried over Na_2SO_4. After evaporation of the solvents the crude residue was purified by flash chromatography (pentane/ether; 4:1) yielding 2-methyl-4-octylaniline as a colourless oil (235 mg, 67 %).

IR (ATR) $\tilde{\nu}$ (cm^{-1}): 3372, 3009, 2955, 2923, 2853, 1625, 1508, 1459, 1378, 1274, 1151, 994, 882, 815, 740, 723.

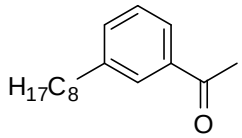
^{1}H-NMR (300 MHz, $CDCl_3$): δ = 6.91-6.83 (m, 2H, Ar*H*), 6.65 (d, *J* = 7.7 Hz, 1H, Ar*H*), 3.76 (br. s, 2H, NH_2), 2.49 (t, *J* = 7.5 Hz, 2H, CH_2), 2.18 (s, 3H, CH_3), 1.56 (quint, *J* = 7.7 Hz, 2H, CH_2), 1.37-1.23 (m, 10H, 5 x CH_2), 0.89 (t, *J* = 6.7 Hz, 3H, CH_3).

^{13}C-NMR (75 MHz, $CDCl_3$): δ = 141.6, 133.6, 130.5, 126.7, 122.6, 115.3, 35.1, 31.89, 31.88, 29.5, 29.34, 29.26, 22.6, 17.3, 14.1.

MS (70 eV, EI): *m/z* (%) = 219 (17), 121 (10), 120 (100), 44 (11).

HRMS (EI): *m/z* calc. for [$C_{15}H_{25}N$] 219.1987, found: 219.1975.

Preparation of 1-(3-octylphenyl)ethanone (95i)



To 1-ocytlmagnesium bromide (2.50 mL, 2.0 mmol, 0.80 M in THF) was added $ZnCl_2 \cdot 2LiCl$ (1.1 mL, 1.1 mmol, 1.0 M in THF), and *i*PrI (340 mg, 2.0 mmol) according to **TP9**. To this mixture was added $Pd(dba)_2$ (11.6mg, 0.02 mmol), Ru-Phos (18.7 mg, 0.04 mmol) and 3-bromoacetophenone (318 mg, 1.6 mmol) in one portion followed by 2 mL THF. The resulting mixture was stirred for 10 min at 25 °C. Then, the reaction mixture was quenched with sat. aq. NH_4Cl solution and extracted with ether (3 x 50 mL). The combined organic phases were washed with sat. thiourea solution (2 x 5 mL) and dried over Na_2SO_4. After evaporation of the solvents the crude residue was purified by flash chromatography (pentane/ether; 9:1) yielding 1-(3-octylphenyl)ethanone as a colourless oil (267 mg, 72 %).

IR (ATR) $\tilde{\nu}$ (cm^{-1}): 2955, 2924, 2854, 1684, 1602, 1585, 1465, 1438, 1356, 1269, 1188, 1117, 1082, 1020, 971, 955, 916, 791, 693.

^{1}H-NMR (300 MHz, $CDCl_3$): δ = 7.79 (m, 2H, Ar*H*), 7.38-7.33 (m, 2H, Ar*H*), 2.65 (t, *J* = 7.7 Hz, 2H, CH_2), 2.57 (s, 3H, CH_3), 1.62 (quint, *J* = 7.7 Hz, 2H, CH_2), 1.35-1.21 (m, 10H, 5 x CH_2), 0.87 (t, *J* = 6.9 Hz, 3H, CH_3).

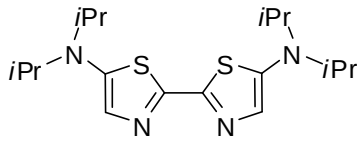
^{13}C-NMR (75 MHz, $CDCl_3$): δ = 198.3, 143.4, 137.2, 133.2, 128.4, 128.1, 125.8, 35.8, 31.8, 31.4, 29.4, 29.23, 29.19, 26.6, 22.6, 14.0.

MS (70 eV, EI): *m/z* (%) = 235 (16), 232 (30), 218 (15), 217 (100), 134 (15), 133 (16), 131 (10), 91 (27), 57 (13), 55 (11), 44 (28), 43 (24), 41 (11).

HRMS (EI): *m/z* calc. for [$C_{16}H_{24}O$] 232.1827, found: 232.1821.

8. Preparation of Small Oligomers for the Use as Donors in Blended Organic Solar Cells

Synthesis of *N*,*N*,*N*',*N*'-tetraisopropyl-2,2'-bi-1,3-thiazole-5,5'-diamine (100)



A dry and argon-flushed Schlenk-flask, equipped with a magnetic stirring bar and a septum, was charged with 2-bromo-*N*,*N*-diisopropyl-1,3-thiazol-5-amine (132 mg, 0.50 mmol) and 0.5 mL THF. After cooling to –30 °C, *i*PrMgCl·LiCl (0.42 mL, 1.32 M in THF, 0.55 mmol) was added dropwise and stirred for 0.5 h. Then, the mixture was cooled to –50 °C and a solution of CuCl·2LiCl (0.3 mL, 1.0 M in THF, 0.3 mmol) was added and the resulting mixture was stirred for 1 h. After cooling to –78 °C a solution of chloranil (74 mg, 0.3 mmol) in THF (5 mL) was added and the mixture was warmed up to 25 °C during 12 h. The mixture was diluted with Et_2O (100 mL) and washed with NH_4OH solution (2 M; 3 x 20 mL). The organic layer was dried (Na_2SO_4), filtered, and concentrated under reduced pressure. Purification by flash chromatography (pentane/Et_2O; 4:1) yielded **100** (78 mg, 85 %) as a yellow solid.

mp: 195.3 – 197.1 °C.

IR (ATR) $\tilde{\nu}$ (cm^{-1}): 2969, 2930, 2172, 1979, 1716, 1488, 1453, 1431, 1379, 1334, 1274, 1248, 1222, 1178, 1144, 1124, 1100, 1017, 920, 905, 858, 814, 772, 735, 654, 609.

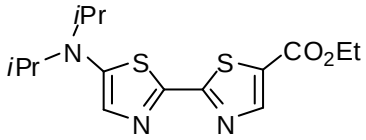
^{1}H-NMR (400 MHz, d8-THF): δ = 6.99 (s, 2H, Ar*H*), 3.63 (sept, *J* = 6.7 Hz, 4H, 4 x C*H*), 1.20 (d, *J* = 6.7 Hz, 24H, 8 x CH_3).

^{13}C-NMR (100 MHz, d8-THF): δ = 152.6, 150.2, 130.6, 52.2, 21.0.

MS (70 eV, EI): *m/z* (%) = 367 (17), 366 (69), 325 (12), 324 (22), 323 (100), 308 (12), 281 (12), 227 (32), 185 (27), 168 (11), 143 (18).

HRMS (EI): *m/z* calc. for [$C_{18}H_{30}N_4S_2$] 366.1912, found: 366.1903.

Synthesis of ethyl 5'-(diisopropylamino)-2,2'-bi-1,3-thiazole-5-carboxylate (102)



A dry and argon-flushed Schlenk-flask, equipped with a magnetic stirring bar and a septum, was charged with 2-bromo-*N*,*N*-diisopropyl-1,3-thiazol-5-amine (263 mg, 1.0 mmol) and 1 mL THF. After cooling to –30 °C, *i*PrMgCl·LiCl (0.84 mL, 1.31 M in THF, 1.1 mmol) was added dropwise and stirred for 0.5 h. Then a solution of $ZnCl_2$·2LiCl (0.55 mL, 1.0 M in THF, 0.55 mmol) was added and the mixture was warmed up to 0 °C and stirred for 30 min. A dry and argon flushed two-necked round-bottomed flask, equipped with a magnetic stirrer, a reflux condenser was charged with ethyl 2-bromo-1,3-thiazole-5-carboxylate (354 mg, 1.5 mmol) and $Pd(PPh_3)_4$ (79 mg, 0.06 mmol) in 4.5 mL THF. The solution of the zinc reagent was cannulated under argon to the two-necked flask and the mixture was heated under reflux for 24 h. The mixture was cooled to 25 °C, diluted with EtOAc (50 mL) and washed with sat. NaCl solution (2 x 15 mL). The combined organic layers were dried ($MgSO_4$), filtered, and concentrated under reduced pressure. Purification by flash chromatography (pentane/Et_2O; 4:1) yielded **102** (297 mg, 87 %) as an orange solid.

mp: 77.2 – 79.5 °C.

IR (ATR) $\tilde{\nu}$ (cm^{-1}): 2976, 2929, 1701, 1524, 1501, 1471, 1441, 1408, 1386, 1364, 1345, 1288, 1278, 1256, 1178, 1146, 1130, 1086, 1015, 916, 860, 822, 804, 753, 690, 620.

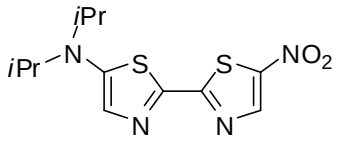
^{1}H-NMR (300 MHz, $CDCl_3$): δ = 8.44 (s, 1H, Ar*H*), 7.02 (s, 1H, Ar*H*), 3.98 (q, *J* = 7.1 Hz, 2H, C*H*$_2$CH$_3$), 3.20 (sept, *J* = 6.9 Hz, 2H, 2 x C*H*(CH$_3$)$_2$), 0.92 (t, *J* = 7.1 Hz, 3H, CH$_2$C*H*$_3$), 0.84 (d, *J* = 6.9 Hz, 12H, 2 x CH(C*H*$_3$)$_2$).

^{13}C-NMR (75 MHz, $CDCl_3$): δ = 167.7, 160.9, 154.1, 148.9, 143.9, 128.1, 124.6, 60.9, 51.3, 19.4, 13.8.

MS (70 eV, EI): *m/z* (%) = 340 (17), 339 (83), 324 (63), 282 (100), 254 (25), 200 (18), 184 (17), 172 (37), 157 (22), 155 (41), 128 (55), 112 (22), 86 (62).

HRMS (EI): *m/z* calc. for [$C_{15}H_{21}N_3O_2S_2$] 339.1075, found: 339.1067.

Synthesis of *N*,*N*-diisopropyl-5'-nitro-2,2'-bi-1,3-thiazol-5-amine (103)



A dry and argon-flushed Schlenk-flask, equipped with a magnetic stirring bar and a septum, was charged with 2-bromo-*N*,*N*-diisopropyl-1,3-thiazol-5-amine (263 mg, 1.0 mmol) and 1 mL THF. After cooling to –30 °C, *i*PrMgCl·LiCl (0.83 mL, 1.33 M in THF, 1.1 mmol) was added dropwise and stirred for 30 min. Then, a solution of $ZnCl_2$ (0.55 mL, 1.0 M in THF, 0.55 mmol) was added and the mixture was warmed up to 0 °C and stirred for 30 min. A dry and argon flushed two-necked round-bottomed flask, equipped with a magnetic stirring bar and a reflux condenser was charged with 2-bromo-5-nitrothiazole (272 mg, 1.3 mmol) and $Pd(PPh_3)_4$ (69 mg, 0.06 mmol) in 1.5 mL THF. The zinc reagent was added and the resulting mixture was heated under reflux for 24 h. The mixture was cooled to 25 °C, diluted with EtOAc (200 mL) and washed with sat. NaCl solution (30 mL). The organic layer was dried (Na_2SO_4), filtered, and concentrated under reduced pressure. Purification by flash chromatography (pentane/Et_2O; 4:1 to 1:1) yielded **103** (280 mg, 90 %) as a violet solid.

mp: 176.4 – 178.8 °C.

IR (ATR) $\tilde{\nu}$ (cm^{-1}): 3114, 3076, 2936, 1526, 1499, 1468, 1443, 1391, 1371, 1345, 1309, 1280, 1246, 1222, 1188, 1167, 1137, 1118, 1024, 915, 806, 762, 744, 734, 686, 636, 624, 617, 612.

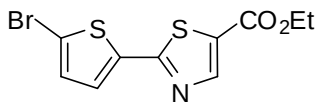
^{1}H-NMR (300 MHz, C_6D_6): δ = 7.98 (s, 1H, Ar*H*), 6.92 (s, 1H, Ar*H*), 3.13 (sept, *J* = 6.8 Hz, 2H, 2 x C*H*CH_3), 0.75 (d, *J* = 6.8 Hz, 12H, 2 x CHC*H*$_3$).

^{13}C-NMR (75 MHz, C_6D_6): δ = 167.2, 156.3, 144.6, 141.2, 132.7, 124.3, 51.9, 19.4.

MS (70 eV, EI): *m/z* (%) = 312 (23), 297 (28), 255 (45), 173 (36), 152 (10), 130 (42), 128 (45), 86 (49), 84 (37), 60 (11), 57 (27), 44 (19), 43 (100), 41 (28).

HRMS (EI): *m/z* calc. for [$C_{12}H_{16}N_4O_2S_2$] 312.0715, found: 312.0714.

Synthesis of ethyl 2-(5-bromo-2-thienyl)-1,3-thiazole-5-carboxylate (106)



A dry and argon-flushed Schlenk-flask, equipped with a magnetic stirring bar and a septum, was charged with 2,5-dibromothiophene (1.21 g, 5.0 mmol) and 5 mL THF. *i*PrMgCl·LiCl (2.70 mL, 2.04 M in THF, 5.5 mmol) was added dropwise at ambient temperature and the resulting mixture was stirred for 30 min. Then a solution of $ZnCl_2$ (1.1 mL, 1.0 M in THF, 1.1 mmol) was added and the mixture was stirred for additional 30 min. A dry and argon flushed two-necked round-bottomed flask, equipped with a magnetic stirring bar and a reflux condenser was charged with ethyl 2-bromo-1,3-thiazole-5-carboxylate (1.77 g, 7.5 mmol) and $Pd(PPh_3)_4$ (347 mg, 0.30 mmol) in 7.5 mL THF. The zinc reagent was added and the resulting mixture was heated under reflux for 24 h. The mixture was cooled to 25 °C, diluted with Et_2O (100 mL) and washed with water (100 mL) and sat. NaCl solution (100 mL). The aqueous layers were extracted with Et_2O (3 x 100 mL) and combined organic layers were dried ($MgSO_4$), filtered, and concentrated under reduced pressure. Purification by flash chromatography (pentane/Et_2O; 9:1) yielded **106** (1.46 g, 92 %) as a yellow solid.

mp: 111.4 – 113.0 °C.

IR (ATR) $\tilde{\nu}$ (cm^{-1}): 2980, 1702, 1544, 1507, 1440, 1400, 1366, 1317, 1302, 1275, 1246, 1230, 1172, 1148, 1079, 1005, 974, 896, 864, 796, 787, 748, 686, 633.

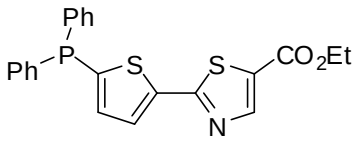
^{1}H-NMR (300 MHz, $CDCl_3$): δ = 8.27 (s, 1H, Ar*H*), 7.32 (d, *J* = 3.8 Hz, 1H, Ar*H*), 7.06 (d, *J* = 3.8 Hz, 1H, Ar*H*), 4.36 (q, *J* = 7.1 Hz, 2H, C*H*$_2$CH$_3$), 1.38 (t, *J* = 7.1 Hz, 3H, CH$_2$C*H*$_3$).

^{13}C-NMR (75 MHz, $CDCl_3$): δ = 165.5, 161.1, 148.8, 138.0, 131.1, 128.5, 128.0, 117.5, 61.8, 14.3.

MS (70 eV, EI): *m/z* (%) = 320 (12), 319 (100), 318 (11), 317 (89), 291 (30), 289 (28), 274 (26). 272 (24), 246 (17), 244 (14), 210 (16), 191 (13), 189 (25), 187 (14).

HRMS (EI): *m/z* calc. for [$C_{10}H_8BrNO_2S_2$] 316.9180, found: 316.9178.

Synthesis of ethyl 2-[5-(diphenylphosphino)-2-thienyl]-1,3-thiazole-5-carboxylate (107)



A dry and argon-flushed Schlenk-flask, equipped with a magnetic stirring bar and a septum, was charged with ethyl 2-(5-bromo-2-thienyl)-1,3-thiazole-5-carboxylate (**106**; 318 mg, 1.0 mmol) and 2 mL THF. After cooling to –30 °C, *i*PrMgCl·LiCl (0.90 mL, 1.22 M in THF, 1.1 mmol) was added dropwise and stirred for 0.5 h. Then, $ClPPh_2$ (232 mg, 1.05 mmol) was added in one portion and the resulting mixture was warmed up to 25 °C within 2 h. The crude mixture was diluted with Et_2O (100 mL) and washed with sat. NaCl solution (20 mL). The organic layer was dried (Na_2SO_4), filtered, and concentrated under reduced pressure. Purification by flash chromatography (pentane/Et_2O; 4:1) yielded **107** (347 mg, 82 %) as a yellow solid.

mp: 68.7 – 69.6 °C.

IR (ATR) $\tilde{\nu}$ (cm^{-1}): 2977, 1704, 1496, 1476, 1432, 1400, 1368, 1284, 1248, 1148, 1085, 1025, 993, 900, 804, 739, 693.

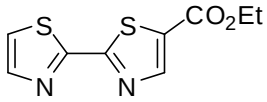
^{1}H-NMR (600 MHz, d8-THF): δ = 8.23 (s, 1H, Ar*H*), 7.73-7.70 (m, 1H, Ar*H*), 7.44-7.34 (m, 10H, Ar*H*), 7.30-7.27 (m, 1H, Ar*H*), 4.32 (q, *J* = 7.1 Hz, 2H, C*H*$_2$CH$_3$), 1.34 (t, *J* = 7.1 Hz, 3H, CH$_2$C*H*$_3$).

^{13}C-NMR (150 MHz, d8-THF): δ = 166.4, 161.3, 149.5, 145.1 (d, *J*(C,P) = 33 Hz), 143.1, 138.0 (d, *J*(C,P) = 10 Hz), 137.5 (d, *J*(C,P) = 27 Hz), 134.0 (d, *J*(C,P) = 20 Hz), 130.1, 129.7 (d, *J*(C,P) = 7 Hz), 129.65, 129.5 (d, *J*(C,P) = 7 Hz), 62.2, 14.5.

MS (70 eV, EI): *m/z* (%) = 425 (12), 424 (29), 423 (100), 346 (14), 183 (11), 108 (12), 44 (36).

HRMS (EI): *m/z* calc. for [$C_{22}H_{18}NO_2PS_2$] 423.0517, found: 423.0511.

Synthesis of ethyl 2,2'-bi-1,3-thiazole-5-carboxylate (111)



A dry and argon-flushed Schlenk-flask, equipped with a magnetic stirring bar and a septum, was charged with 2-bromothiazole (1.64 g, 10.0 mmol) and 10 mL THF. After cooling to –30 °C, *i*PrMgCl·LiCl (9.0 mL, 1.22 M in THF, 11.0 mmol) was added dropwise and the resulting mixture was stirred for 30 min. Then, a solution of $ZnCl_2$ (5.5 mL, 1.0 M in THF, 5.5 mmol) was added and the mixture was warmed up to 25 °C. A dry and argon flushed two-necked round-bottomed flask, equipped with a magnetic stirring bar and a reflux condenser was charged with ethyl 2-bromo-1,3-thiazole-5-carboxylate (3.07 g, 13.0 mmol) and $Pd(PPh_3)_4$ (693 mg, 0.60 mmol) in 10 mL THF. The zinc reagent was added and the resulting mixture was heated under reflux for 24 h. The mixture was cooled to 25 °C, diluted with Et_2O (100 mL) and washed with water (100 mL) and sat. NaCl solution (100 mL). The aqueous layers were extracted with Et_2O (3 x 100 mL) and combined organic layers were dried ($MgSO_4$), filtered, and concentrated under reduced pressure. Purification by flash chromatography (pentane/Et_2O; 4:1) yielded **111** (870 mg, 36 %) as an orange solid.

mp: 103.6 – 105.2 °C.

IR (ATR) $\tilde{\nu}$ (cm^{-1}): 3077, 2976, 2929, 1694, 1492, 1437, 1374, 1284, 1246, 1171, 1146, 1088, 1057, 1019, 926, 899, 878, 864, 749, 632, 611.

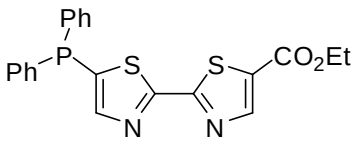
^{1}H-NMR (400 MHz, d8-THF): δ = 8.39 (s, 1H, Ar*H*), 7.95 (d, *J* = 3.1 Hz, 1H, Ar*H*), 7.77 (d, *J* = 3.1 Hz, 1H, Ar*H*), 4.36 (q, *J* = 7.1 Hz, 2H, C*H*$_2$CH$_3$), 1.37 (t, *J* = 7.1 Hz, 3H, CH$_2$C*H*$_3$).

^{13}C-NMR (100 MHz, d8-THF): δ = 166.7, 161.4, 161.3, 149.6, 145.4, 131.6, 123.8, 62.3, 14.5.

MS (70 eV, EI): *m/z* (%) = 241 (10), 240 (100), 213 (16), 212 (62), 197 (10), 196 (16), 195 (91), 168 (16), 167 (30), 111 (13), 96 (13), 81 (11), 69 (10), 58 (35), 57 (14), 55 (12).

HRMS (EI): *m/z* calc. for [$C_9H_8N_2O_2S_2$] 240.0027, found: 240.0021.

Synthesis of ethyl 5'-(diphenylphosphino)-2,2'-bi-1,3-thiazole-5-carboxylate (112)



A dry and argon-flushed Schlenk-flask, equipped with a magnetic stirring bar and a septum, was charged with ethyl 2,2'-bi-1,3-thiazole-5-carboxylate (**111**; 120 mg, 0.50 mmol) and 0.5

mL THF. After cooling to 0 °C, $TMP_2Mn{\cdot}2MgCl_2{\cdot}4LiCl$ (0.80, 0.35 M in THF, 0.55 mmol) was added dropwise and the resulting mixture was stirred for 1 h. Then, $ClPPh_2$ was added to the reaction mixture and the resulting mixture was warmed up to 25 °C within 2 h. The mixture was diluted with Et_2O (100 mL) and washed with water (20 mL). The aqueous layer was extracted with Et_2O (3 x 40 mL) and combined organic layers were dried (Na_2SO_4), filtered, and concentrated under reduced pressure. Purification by flash chromatography (pentane/Et_2O; 4:1) yielded **112** (61 mg, 29 %) as a yellow solid.

mp: 75.9 – 77.6 °C.

IR (ATR) $\tilde{\nu}$ (cm^{-1}): 1710, 1520, 1494, 1467, 1433, 1389, 1369, 1313, 1303, 1271, 1254, 1240, 1149, 1122, 1089, 1025, 924, 901, 871, 819, 752, 740, 695, 613.

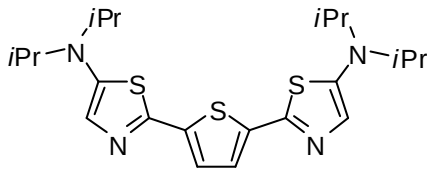
^{1}H-NMR (600 MHz, d8-THF): δ = 8.37 (s, 1H, Ar*H*), 7.98 (d, *J* = 2.7 Hz, 1H, Ar*H*), 7.46-7.36 (m, 10H, Ar*H*), 4.35 (q, *J* = 7.0 Hz, 2H, C*H*$_2$CH$_3$), 1.36 (t, *J* = 7.0 Hz, 3H, CH$_2$C*H*$_3$).

^{13}C-NMR (150 MHz, d8-THF): δ = 166.5 (d, *J*(C,P) = 1.4 Hz), 166.1, 161.3, 152.3 (d, *J*(C,P) = 31 Hz), 149.8, 139.1 (d, *J*(C,P) = 39 Hz), 137.5 (d, *J*(C,P) = 9 Hz), 133.9 (d, *J*(C,P) = 20 Hz), 132.0, 130.3, 129.7 (d, *J*(C,P) = 7 Hz), 62.4, 14.5.

MS (70 eV, EI): *m/z* (%) = 426 (12), 425 (23), 424 (100), 347 (37), 165 (10).

HRMS (EI): *m/z* calc. for [$C_{21}H_{17}N_2O_2PS_2$] 424.0469, found: 424.0471.

Synthesis of 2,2'-thiene-2,5-diylbis(*N*,*N*-diisopropyl-1,3-thiazol-5-amine) (114)



A dry and argon-flushed Schlenk-flask, equipped with a magnetic stirring bar and a septum, was charged with 2-bromo-*N*,*N*-diisopropyl-1,3-thiazol-5-amine (526 mg, 2.0 mmol) and 2 mL THF. After cooling to –30 °C, *i*PrMgCl·LiCl (1.70 mL, 1.31 M in THF, 2.2 mmol) was added dropwise and stirred for 30 min. Then, a solution of $ZnCl_2$ (1.1 mL, 1.0 M in THF, 1.1 mmol) was added and the mixture was warmed up to 0 °C and stirred for 30 min. A dry and argon flushed two-necked round-bottomed flask, equipped with a magnetic stirring bar and a reflux condenser was charged with 2,5-diiodothiophene (302 mg, 0.9 mmol) and $Pd(PPh_3)_4$

(139 mg, 0.12 mmol) in 2.0 mL THF. The zinc reagent was added and the resulting mixture was heated under reflux for 24 h. The mixture was cooled to 25 °C, diluted with EtOAc (50 mL) and washed with sat. NaCl solution (2 x 15 mL). The combined organic layers were dried (Na_2SO_4), filtered, and concentrated under reduced pressure. Purification by flash chromatography (pentane/Et_2O; 4:1) yielded **114** (150 mg, 37 %) as a red solid.

mp: 149.6 – 151.8 °C.

IR (ATR) $\tilde{\nu}$ (cm^{-1}): 2966, 2929, 1637, 1524, 1498, 1447, 1363, 1331, 1294, 1251, 1208, 1179, 1144, 1101, 1040, 921, 906, 882, 861, 824, 739, 711, 694, 637, 623, 615, 605.

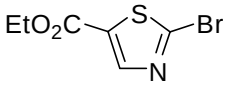
^{1}H-NMR (400 MHz, C_6D_6): δ = 7.16-7.12 (m, 4H, Ar*H*), 3.13 (sept, *J* = 6.8 Hz, 4H, 4 x C*H*(CH_3)$_2$), 0.89 (d, *J* = 6.8 Hz, 24H, 4 x CH(C*H*$_3$)$_2$).

^{13}C-NMR (100 MHz, C_6D_6): δ = 151.8, 148.3, 139.2, 131.8, 124.7, 51.1, 20.3.

MS (70 eV, EI): *m/z* (%) = 448 (2), 252 (18), 237 (12), 236 (33), 218 (20), 170 (19), 155 (17), 154 (62), 136 (27), 128 (47), 111 (27), 101 (13), 100 (78), 86 (84), 44 (100).

HRMS (EI): *m/z* calc. for [$C_{22}H_{32}N_4S_3$] 448.1789, found: 448.1792.

Synthesis of ethyl 2-bromo-1,3-thiazole-5-carboxylate (110)



A dry and argon-flushed Schlenk-flask, equipped with a magnetic stirring bar and a septum, was charged with 2-bromothiazole (8.20 g, 50.0 mmol) and 50 mL THF. After cooling to –40 °C, TMPMgCl·LiCl (44.0 mL, 1.25 M in THF, 55.0 mmol) was added dropwise and stirred for 30 min. Then, ethyl cyanoformate was added to the reaction mixture and the solution was allowed to warm up to 25 °C within 2 h. The crude reaction mixture was diluted with EtOAc (100 mL) and washed with sat. NaCl solution (2 x 30 mL). The organic layer was dried ($MgSO_4$), filtered, and concentrated under reduced pressure. Purification by flash chromatography (pentane/Et_2O; 9:1) yielded **110** (7.92 mg, 67 %) as a light yellow oil.

IR (ATR) $\tilde{\nu}$ (cm^{-1}): 2981, 2901, 1712, 1519, 1464, 1445, 1373, 1286, 1241, 1186, 1172, 1148, 1081, 1010, 882, 860, 822, 749.

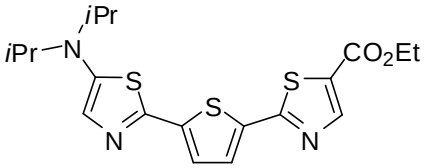
^{1}H-NMR (300 MHz, $CDCl_3$): δ = 8.12 (s, 1H, Ar*H*), 4.35 (q, *J* = 7.1 Hz, 2H, C*H*$_2$CH$_3$), 1.35 (t, *J* = 7.2 Hz, 3H, CH$_2$C*H*$_3$).

^{13}C-NMR (75 MHz, $CDCl_3$): δ = 160.0, 147.8, 142.0, 133.3, 62.1, 14.2.

MS (70 eV, EI): *m/z* (%) = 237 (32), 235 (31), 209 (97), 207 (95), 193 (11), 192 (44), 192 (44), 191 (11), 190 (100), 164 (14), 162 (14), 83 (13), 57 (16).

HRMS (EI): *m/z* calc. for [$C_6H_6BrNO_2S$] 234.9303, found: 234.9296

Synthesis of ethyl 2-{5-[5-(diisopropylamino)-1,3-thiazol-2-yl]-2-thienyl}-1,3-thiazole-5-carboxylate (115)



A dry and argon-flushed Schlenk-flask, equipped with a magnetic stirring bar and a septum, was charged with 2-bromo-*N*,*N*-diisopropyl-1,3-thiazol-5-amine (263 mg, 1.0 mmol) and 1 mL THF. After cooling to –30 °C, *i*PrMgCl·LiCl (0.54 mL, 2.04 M in THF, 1.1 mmol) was added dropwise and stirred for 30 min. Then, a solution of $ZnCl_2$ (0.55 mL, 1.0 M in THF, 0.55 mmol) was added and the mixture was warmed up to 0 °C and stirred for 30 min. A dry and argon flushed two-necked round-bottomed flask, equipped with a magnetic stirring bar and a reflux condenser was charged with ethyl 2-(5-bromo-2-thienyl)-1,3-thiazole-5-carboxylate (**106**; 477 mg, 1.5 mmol) and $Pd(PPh_3)_4$ (69 mg, 0.06 mmol) in 2.0 mL THF. The zinc reagent was added and the resulting mixture was heated under reflux for 24 h. The mixture was cooled to 25 °C, diluted with CH_2Cl_2 (150 mL) and washed with sat. NaCl solution (40 mL). The combined organic layers were dried (Na_2SO_4), filtered, and concentrated under reduced pressure. Purification by flash chromatography (pentane/CH_2Cl_2; 1:1) yielded **115** (252 mg, 60 %) as an orange solid.

mp: 124.1 – 125.7 °C.

IR (ATR) $\tilde{\nu}$ (cm^{-1}): 2965, 1709, 1638, 1529, 1512, 1474, 1409, 1306, 1291, 1247, 1210, 1173, 1143, 1119, 1085, 889, 862, 815, 751, 712, 640.

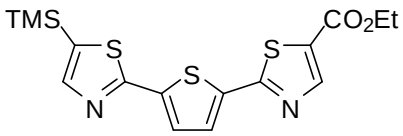
^{1}H-NMR (400 MHz, d8-THF): δ = 8.27 (s, 1H, Ar*H*), 7.62 (d, *J* = 3.7 Hz, 1H, Ar*H*), 7.31 (d, *J* = 3.7 Hz, 1H, Ar*H*), 7.05 (s, 1H, Ar*H*), 4.34 (q, *J* = 7.0 Hz, 2H, C*H*$_2$CH$_3$), 3.67 (sept, *J* = 6.7 Hz, 2H, 2 x C*H*(CH$_3$)$_2$), 1.35 (t, *J* = 7.0 Hz, 3H, CH$_2$C*H*$_3$), 1.23 (d, *J* = 6.7 Hz, 12H, 2 x CH(C*H*$_3$)$_2$).

^{13}C-NMR (100 MHz, d8-THF): δ = 166.8, 161.3, 151.0, 149.6, 149.2, 143.8, 136.7, 130.2, 129.5, 129.2, 125.0, 62.1, 52.5, 20.9, 14.5.

MS (70 eV, EI): *m/z* (%) = 423 (16), 422 (27), 421 (100), 406 (30), 379 (11), 378 (42), 364 (27), 336 (23), 321 (12), 282 (46), 254 (17).

HRMS (EI): *m/z* calc. for [C$_{19}$H$_{23}$N$_3$O$_2$S$_3$] 421.0952, found: 421.1010.

Synthesis of ethyl 2-{5-[5-(trimethylsilyl)-1,3-thiazol-2-yl]-2-thienyl}-1,3-thiazole-5-carboxylate (118)



A dry and argon-flushed Schlenk-flask, equipped with a magnetic stirring bar and a septum, was charged with 2-bromo-5-(trimethylsilyl)-1,3-thiazole (709 mg, 3.0 mmol) and 3 mL THF. After cooling to –30 °C, *i*PrMgCl·LiCl (2.50 mL, 1.33 M in THF, 3.3 mmol) was added dropwise and stirred for 30 min. Then, a solution of $ZnCl_2$ (1.65 mL, 1.0 M in THF, 1.65 mmol) was added and the mixture was warmed up to 0 °C and stirred for 30 min. A dry and argon flushed two-necked round-bottomed flask, equipped with a magnetic stirring bar and a reflux condenser was charged with ethyl 2-(5-bromo-2-thienyl)-1,3-thiazole-5-carboxylate (1.43 g, 4.5 mmol) and Pd(PPh$_3$)$_4$ (208 mg, 0.18 mmol) in 5.0 mL THF. The zinc reagent was added and the resulting mixture was heated under reflux for 24 h. The mixture was cooled to 25 °C, diluted with EtOAc (250 mL) and washed with sat. NaCl solution (50 mL). The organic layer was dried ($MgSO_4$), filtered, and concentrated under reduced pressure. Purification by flash chromatography (pentane/Et_2O; 9:1 to 4:1) yielded **118** (910 mg, 77 %) as a yellow solid.

mp: 134.1 – 135.2 °C.

IR (ATR) $\tilde{\nu}$ (cm^{-1}): 1705, 1510, 1490, 1455, 1402, 1316, 1303, 1242, 1220, 1150, 1084, 1020, 918, 882, 834, 799, 763, 749, 693, 639, 634.

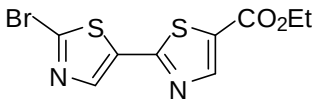
^{1}H-NMR (600 MHz, $CDCl_3$): δ = 8.33 (s, 1H, Ar*H*), 7.78 (s, 1H, Ar*H*), 7.55 (d, *J* = 4.0 Hz, 1H, Ar*H*), 7.52 (d, *J* = 4.0 Hz, 1H, Ar*H*), 4.38 (q, *J* = 7.2 Hz, 2H, C*H*$_2$CH$_3$), 1.38 (t, *J* = 7.2 Hz, 3H, CH$_2$C*H*$_3$), 0.36 (s, 9H, C(C*H*$_3$)$_3$).

^{13}C-NMR (150 MHz, $CDCl_3$): δ = 165.9, 164.9, 161.1, 149.2, 149.1, 140.4, 137.8, 134.1, 128.8, 128.5, 127.3, 61.8, 14.3, -0.1.

MS (70 eV, EI): *m/z* (%) = 396 (20), 395 (28), 394 (100), 379 (21), 116 (11), 115 (97).

HRMS (EI): *m/z* calc. for [$C_{16}H_{18}N_2O_2S_3Si$] 394.0300, found: 394.0296

Synthesis of ethyl 2'-bromo-2,5'-bi-1,3-thiazole-5-carboxylate (120)



A dry and argon-flushed Schlenk-flask, equipped with a magnetic stirring bar and a septum, was charged with 2-bromothiazole (1.64 g, 10.0 mmol) and 10 mL THF. $TMP_2Zn{\cdot}2MgCl_2{\cdot}2LiCl$ (13.5 mL, 0.44 M in THF, 5.5 mmol) was added dropwise at 25 °C and stirred for 1 h. A dry and argon flushed two-necked round-bottomed flask, equipped with a magnetic stirring bar and a reflux condenser was charged with ethyl 2-bromo-1,3-thiazole-5-carboxylate (2.83 g, 12.0 mmol) and $Pd(PPh_3)_4$ (690 mg, 0.60 mmol) in 12.0 mL THF. The zinc reagent was added and the resulting mixture was heated under reflux for 24 h. The mixture was cooled to 25 °C, diluted with EtOAc (150 mL) and washed with sat. NaCl solution (30 mL). The organic layer was dried (Na_2SO_4), filtered, and concentrated under reduced pressure. Purification by flash chromatography (pentane/Et_2O; 9:1) yielded **120** (762 g, 24 %) as an off-white solid.

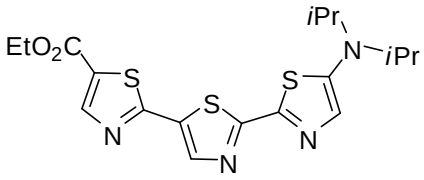
mp: 114.0 – 115.1 °C.

IR (ATR) $\tilde{\nu}$ (cm^{-1}): 3088, 2984, 1713, 1694, 1535, 1501, 1419, 1390, 1369, 1361, 1308, 1299, 1293, 1272, 1252, 1237, 1186, 1176, 1162, 1146, 1116, 1089, 1012, 920, 912, 901, 895, 869, 862, 851, 819, 772, 764, 755, 748, 633.

^{1}H-NMR (300 MHz, $CDCl_3$): δ = 8.32 (s, 1H, Ar*H*), 7.99 (s, 1H, Ar*H*), 4.38 (q, *J* = 7.1 Hz, 2H, C*H*$_2$CH$_3$), 1.38 (t, *J* = 7.1 Hz, 3H, CH$_2$C*H*$_3$).

^{13}C-NMR (75 MHz, $CDCl_3$): δ = 161.8, 160.7, 148.9, 141.8, 139.4, 136.1, 129.5, 62.0, 14.3.
MS (70 eV, EI): *m/z* (%) = 320 (100), 319 (12), 318 (87), 312 (35), 292 (43), 290 (41), 277 (15), 275 (44), 274 (11), 273 (37), 267 (26), 248 (13), 247 (23), 246 (12), 245 (22), 239 (12), 211 (18), 102 (13), 83 (18), 58 (14), 57 (35).
HRMS (EI): *m/z* calc. for [$C_9H_7BrN_2O_2S_2$] 317.9132, found: 317.9123.

Synthesis of ethyl 5-(diisopropylamino)-2,2':5',2''-ter-1,3-thiazole-5''-carboxylate (121)



A dry and argon-flushed Schlenk-flask, equipped with a magnetic stirring bar and a septum, was charged with 2-bromo-*N*,*N*-diisopropyl-1,3-thiazol-5-amine (263 mg, 1.0 mmol) and 1 mL THF. After cooling to –30 °C, *i*PrMgCl·LiCl (0.90 mL, 1.22 M in THF, 1.1 mmol) was added dropwise and stirred for 30 min. Then, a solution of $ZnCl_2$ (0.55 mL, 1.0 M in THF, 0.55 mmol) was added and the mixture was warmed up to 0 °C and stirred for 30 min. A dry and argon flushed two-necked round-bottomed flask, equipped with a magnetic stirring bar and a reflux condenser was charged with ethyl 2'-bromo-2,5'-bi-1,3-thiazole-5-carboxylate (**120**; 383 mg, 1.2 mmol) and $Pd(PPh_3)_4$ (69 mg, 0.06 mmol) in 4.0 mL THF. The zinc reagent was added and the resulting mixture was heated under reflux for 24 h. The mixture was cooled to 25 °C, diluted with EtOAc (200 mL) and washed with sat. NaCl solution (30 mL). The organic layer was dried (Na_2SO_4), filtered, and concentrated under reduced pressure. Purification by flash chromatography (pentane/CH_2Cl_2; 1:1; Al_2O_3 III) yielded **121** (351 mg, 83 %) as a red solid.

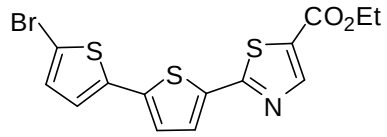
mp: 132.3 – 135.2 °C.
IR (ATR) $\tilde{\nu}$ (cm^{-1}): 2969, 2931, 1710, 1538, 1517, 1467, 1441, 1386, 1364, 1312, 1272, 1249, 1232, 1176, 1144, 1127, 1089, 1019, 926, 918, 903, 889, 850, 833, 821, 795, 767, 748, 692, 666, 631, 618, 604.
^{1}H-NMR (300 MHz, $CDCl_3$): δ = 8.31 (s, 1H, Ar*H*), 8.15 (s, 1H, Ar*H*), 7.02 (s, 1H, Ar*H*), 4.35 (q, *J* = 7.2 Hz, 2H, C*H*$_2$CH$_3$), 3.75 (sept. *J* = 6.7 Hz, 2H, 2 x C*H*(CH$_3$)$_2$), 1.36 (t, *J* = 7.2 Hz, 3H, CH$_2$C*H*$_3$), 1.28 (d, *J* = 6.7 Hz, 12H, 2 x CH(C*H*$_3$)$_2$).

^{13}C-NMR (75 MHz, $CDCl_3$): δ = 165.1, 163.5, 161.0, 154.3, 149.0, 143.2, 143.1, 130.9, 128.6, 124.0, 61.8, 51.9, 20.1, 14.3.

MS (70 eV, EI): *m/z* (%) = 424 (16), 423 (21), 422 (100), 408 (10), 407 (51), 379 (14), 367 (13), 366 (14), 365 (71), 337 (16), 284 (13), 283 (47), 265 (13), 255 (19), 240 (13), 238 (13), 212 (10), 128 (13), 86 (14), 69 (10), 57 (11), 44 (24), 43 (29).

HRMS (EI): *m/z* calc. for [$C_{18}H_{22}N_4O_2S_3$] 422.0905, found: 422.0896

Synthesis of ethyl 2-(5'-bromo-2,2'-bithien-5-yl)-1,3-thiazole-5-carboxylate (123)



A dry and argon-flushed Schlenk-flask, equipped with a magnetic stirring bar and a septum, was charged with 5,5'-dibromo-2,2'-bithiophene (1.62 g, 5.0 mmol) and 15 mL THF. *i*PrMgCl·LiCl (2.70 mL, 2.04 M in THF, 5.5 mmol) was added dropwise at 25 °C and stirred for 30 min. Then, a solution of $ZnCl_2$ (2.8 mL, 1.0 M in THF, 2.8 mmol) was added and the mixture was stirred for additional 30 min. A dry and argon flushed two-necked round-bottomed flask, equipped with a magnetic stirring bar and a reflux condenser was charged with ethyl 2-bromo-1,3-thiazole-5-carboxylate (1.77 g, 7.5 mmol) and $Pd(PPh_3)_4$ (347 mg, 0.30 mmol) in 8.0 mL THF. The zinc reagent was added and the resulting mixture was heated under reflux for 24 h. The mixture was cooled to 25 °C, diluted with CH_2Cl_2 (250 mL) and washed with water (70 mL) and sat. NaCl solution (70 mL). The aqueous layers were extracted with CH_2Cl_2 (2 x 100 mL) and combined organic layers were dried ($MgSO_4$), filtered, and concentrated under reduced pressure. Purification by flash chromatography (pentane/CH_2Cl_2; 1:1 to 1:2) yielded **123** (1.46 g, 73 %) as a yellow solid.

mp: 157.4 – 159.4 °C.

IR (ATR) $\tilde{\nu}$ (cm^{-1}): 1698, 1455, 1410, 1364, 1294, 1219, 1146, 1102, 1072, 1015, 969, 912, 889, 864, 783, 750, 634.

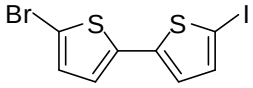
^{1}H-NMR (300 MHz, $CDCl_3$): δ = 8.29 (s, 1H, Ar*H*), 7.46 (d, *J* = 3.9 Hz, 1H, Ar*H*), 7.08 (d, *J* = 4.0 Hz, 1H, Ar*H*), 7.00 (s, 2H, Ar*H*), 4.37 (q, *J* = 7.1 Hz, 2H, CH_2CH_3), 1.38 (t, *J* = 7.1 Hz, 3H, CH_2CH_3).

^{13}C-NMR (75 MHz, $CDCl_3$): δ = 166.0, 161.2, 148.9, 140.3, 137.7, 135.2, 131.0, 128.7, 128.3, 125.0, 124.6, 112.7, 61.9, 14.3.

MS (70 eV, EI): *m/z* (%) = 403 (17), 402 (19), 401 (100), 400 (16), 399 (94), 374 (10), 373 (53), 371 (48), 273 (28), 271 (47), 269 (24), 146 (22), 44 (11).

HRMS (EI): *m/z* calc. for [$C_{14}H_{10}BrNO_2S_3$] 398.9057, found: 398.9045.

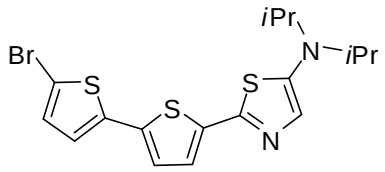
Synthesis of 5-bromo-5'-iodo-2,2'-bithiophene (124)



A dry and argon-flushed Schlenk-flask, equipped with a magnetic stirring bar and a septum, was charged with 5,5'-dibromo-2,2'-bithiophene (2.62 g, 8.00 mmol) and 25 mL THF. Then, *i*PrMgCl·LiCl (6.6 mL, 1.22 M in THF, 8.00 mmol) was added dropwise and stirred for 45 min. A solution of I_2 (2.23 g, 8.8 mmol) in THF (9 mL) was added to the magnesium reagent and the resulting solution was stirred for 30 min. The reaction was stopped by the addition of sat. $Na_2S_2O_3$ solution (10 mL) and the product was extracted with Et_2O (3 x 50 mL). The combined organic layers were dried ($MgSO_4$), filtered, and concentrated under reduced pressure. Purification by flash chromatography (pentane) yielded **124** (1.00 g, 34 %) as a colourless solid.

The product was obtained as a inseparable mixture of 5,5'-dibromo-2,2'-bithiophene (5%), 5,5'-diiodo-2,2'-bithiophene (5%) and 5-bromo-5'-iodo-2,2'-bithiophene (90%). Therefore, no analytical data were recorded. The formation of 5-bromo-5'-iodo-2,2'-bithiophene was approved by GC-MS and the so obtained mixture was used without further purifications.

Synthesis of 2-(5'-bromo-2,2'-bithien-5-yl)-*N*,*N*-diisopropyl-1,3-thiazol-5-amine (125)



A dry and argon-flushed Schlenk-flask, equipped with a magnetic stirring bar and a septum, was charged with 2-bromo-*N*,*N*-diisopropyl-1,3-thiazol-5-amine (790 mg, 3.0 mmol) and 3 mL THF. After cooling to –30 °C, *i*PrMgCl·LiCl (0.54 mL, 2.04 M in THF, 1.1 mmol) was added dropwise and stirred for 30 min. Then, a solution of $ZnCl_2$ (1.8 mL, 1.0 M in THF, 1.8 mmol) was added and the mixture was warmed up to 0 °C and stirred for 30 min. A dry and argon flushed two-necked round-bottomed flask, equipped with a magnetic stirring bar and a reflux condenser was charged with 5-bromo-5'-iodo-2,2'-bithiophene (**124**; 1.00 g, 2.7 mmol) and $Pd(PPh_3)_4$ (208 mg, 0.18 mmol) in 3.0 mL THF. The zinc reagent was added and the resulting mixture was heated under reflux for 24 h. The mixture was cooled to 25 °C, diluted with CH_2Cl_2 (150 mL) and washed with sat. NaCl solution (40 mL). The combined organic layers were dried (Na_2SO_4), filtered, and concentrated under reduced pressure. Purification by flash chromatography (pentane/CH_2Cl_2; 2:1; Al_2O_3 III) yielded **125** (961 mg, 75 %) as a yellow solid.

mp: 86.1 – 87.9 °C.

IR (ATR) $\tilde{\nu}$ (cm^{-1}): 2966, 2925, 1653, 1528, 1498, 1472, 1435, 1370, 1304, 1290, 1257, 1189, 1161, 1126, 1061, 1025, 967, 899, 858, 785, 762.

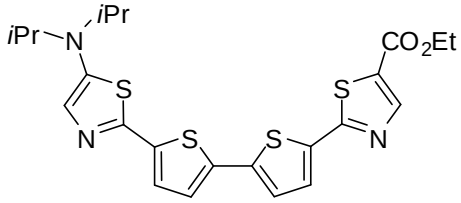
^{1}H-NMR (300 MHz, C_6D_6): δ = 7.17 (s, 1H, Ar*H*), 7.03 (d, *J* = 7.0 Hz, 1H, Ar*H*), 6.63 (d, *J* = 3.9 Hz, 1H, Ar*H*), 6.49 (d, *J* = 3.9 Hz, 1H, Ar*H*), 6.45 (d, *J* = 7.0 Hz, 1H, Ar*H*), 3.15 (sept. *J* = 6.6 Hz, 2H, 2 x C*H*(CH_3)$_2$), 0.91 (d, *J* = 6.6 Hz, 12H, 2 x CH(C*H*$_3$)$_2$).

^{13}C-NMR (75 MHz, C_6D_6): δ = 152.0, 148.7, 139.0, 138.7, 136.8, 132.4, 131.1, 125.1, 124.6, 124.4, 111.3, 51.5, 20.7.

MS (70 eV, EI): *m/z* (%) = 428 (19), 426 (16), 413 (14), 290 (11), 289 (57), 288 (10), 287 (55), 274 (11), 273 (96), 272 (17), 271 (100), 269 (19), 201 (20), 199 (20), 193 (30), 100 (27), 86 (28), 44 (34), 43 (33).

HRMS (EI): *m/z* calc. for [$C_{17}H_{19}BrN_2S_3$] 425.9894, found: 425.9902.

Synthesis of ethyl 2-{5'-[5-(diisopropylamino)-1,3-thiazol-2-yl]-2,2'-bithien-5-yl}-1,3-thiazole-5-carboxylate (126)



A dry and argon-flushed Schlenk-flask, equipped with a magnetic stirring bar and a septum, was charged with 2-(5'-bromo-2,2'-bithien-5-yl)-*N*,*N*-diisopropyl-1,3-thiazol-5-amine (**125**; 161 mg, 0.38 mmol) and 1.5 mL THF. After cooling to –30 °C, *i*PrMgCl·LiCl (0.31 mL, 1.33 M in THF, 0.42 mmol) was added dropwise and stirred for 0.5 h. Then, a solution of $ZnCl_2$ (0.21 mL, 1.0 M in THF, 0.21 mmol) was added and the mixture was warmed up to 0 °C and stirred for 30 min. A dry and argon flushed two-necked round-bottomed flask, equipped with a magnetic stirring bar and a reflux condenser was charged with 2-bromo-1,3-thiazole-5-carboxylate (0.135 g, 0.57 mmol) and $Pd(PPh_3)_4$ (26 mg, 0.023 mmol) in 1.5 mL THF. The zinc reagent was added and the resulting mixture was heated under reflux for 24 h. The mixture was cooled to 25 °C, diluted with EtOAc (200 mL) and washed with sat. NaCl solution (50 mL). The organic layer was dried (Na_2SO_4), filtered, and concentrated under reduced pressure. Purification by flash chromatography (pentane/CH_2Cl_2; 4:1 to pentane/EtOAc; 1:1) yielded **126** (146 mg, 76 %) as a red solid.

mp: 132.8 – 134.6 °C.

IR (ATR) $\tilde{\nu}$ (cm^{-1}): 2968, 1711, 1642, 1525, 1508, 1446, 1411, 1367, 1285, 1246, 1173, 1145, 1089, 1042, 1011, 932, 894, 862, 790, 751, 708.

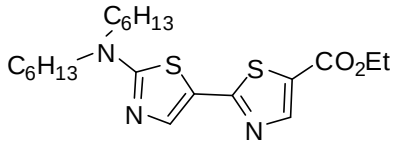
^{1}H-NMR (400 MHz, d8-THF): δ = 8.27 (s, 1H, Ar*H*), 7.62 (d, *J* = 3.9 Hz, 1H, Ar*H*), 7.33-7.27 (m, 3H, Ar*H*), 7.04 (s, 1H, Ar*H*), 4.34 (q, *J* = 7.0 Hz, 2H, C*H*$_2$CH$_3$), 3.62 (sept, *J* = 6.7 Hz, 2H, 2 x C*H*(CH$_3$)$_2$), 1.35 (t, *J* = 7.0 Hz, 3H, CH$_2$C*H*$_3$), 1.21 (d, *J* = 6.7 Hz, 12H, 2 x CH(C*H*$_3$)$_2$).

^{13}C-NMR (100 MHz, d8-THF): δ = 166.5, 161.3, 151.0, 149.9, 149.6, 142.1, 140.2, 137.0, 136.1, 131.7, 130.1, 129.3, 126.2, 125.58, 125.57, 62.1, 52.4, 21.0, 14.5.

MS (70 eV, EI): *m/z* (%) = 505 (21), 504 (33), 503 (100), 488 (12), 462 (14), 461 (16), 460 (60), 446 (13), 418 (12), 366 (11), 364 (48), 346 (10), 336 (20).

HRMS (EI): *m/z* calc. for [$C_{23}H_{25}N_3O_2S_4$] 503.0830, found: 503.0825.

Synthesis of ethyl 2'-(dihexylamino)-2,5'-bi-1,3-thiazole-5-carboxylate (130)



A dry and argon-flushed Schlenk-flask, equipped with a magnetic stirring bar and a septum, was charged with *N*,*N*-dihexyl-1,3-thiazol-2-amine (268 mg, 1.0 mmol) and 1.0 mL THF. After cooling to –78 °C, *n*BuLi (0.45 mL, 2.47 M in THF, 1.1 mmol) was added dropwise and stirred for 1 h. Then, a solution of $ZnCl_2$ (0.55 mL, 1.0 M in THF, 0.55 mmol) was added and the mixture was warmed up to 0 °C and stirred for 30 min. A dry and argon flushed two-necked round-bottomed flask, equipped with a magnetic stirring bar and a reflux condenser was charged with ethyl 2-bromo-1,3-thiazole-5-carboxylate (283 mg, 1.20 mmol), *i*PrI (187 mg, 1.1 mmol) and $Pd(PPh_3)_4$ (69 mg, 0.06 mmol) in 1.5 mL THF. The zinc reagent was added and the resulting mixture was heated under reflux for 12 h. The mixture was cooled to 25 °C, diluted with EtOAc (200 mL) and washed with sat. NaCl solution (30 mL). The organic layer was dried (Na_2SO_4), filtered, and concentrated under reduced pressure. Purification by flash chromatography (pentane/EtOAc; 9:1) yielded **130** (363 mg, 86 %) as a yellow solid.

mp: 29.8 – 30.7 °C.

IR (ATR) $\tilde{\nu}$ (cm^{-1}): 2927, 2857, 2362, 1705, 1525, 1500, 1465, 1420, 1364, 1275, 1250, 1231, 1169, 1143, 1079, 1008, 944, 906, 881, 793, 751, 724, 670.

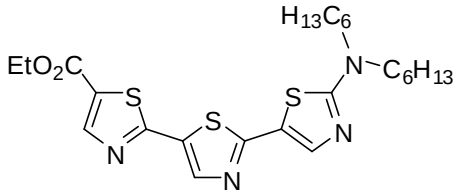
^{1}H-NMR (300 MHz, $CDCl_3$): δ = 8.19 (s, 1H, Ar*H*), 7.70 (s, 1H, Ar*H*), 4.33 (q, *J* = 7.3 Hz, 2H, C*H*$_2$CH$_3$), 3.43 (t, *J* = 7.7 Hz, 4H, 2 x C*H*$_2$), 1.66 (quint, *J* = 7.7 Hz, 4H, 2 x C*H*$_2$), 1.39-1.25 (m, 15H), 0.87 (t, *J* = 7.1 Hz, 6H, 2 x C*H*$_3$).

^{13}C-NMR (75 MHz, $CDCl_3$): δ = 171.9, 165.3, 161.3, 148.6, 142.4, 125.6, 118.9, 61.4, 51.9, 31.5, 27.1, 26.5, 22.5, 14.2, 13.9.

MS (70 eV, EI): *m/z* (%) = 425 (11), 424 (26), 423 (100), 353 (11), 352 (14), 339 (18), 324 (12), 323 (20), 306 (10), 283 (13), 282 (53), 269 (11), 268 (33), 240 (17), 199 (10), 71 (10), 69 (15), 57 (17), 55 (11).

HRMS (EI): *m/z* calc. for [$C_{21}H_{33}N_3O_2S_2$] 423.2014, found: 423.2006.

Synthesis of ethyl 2''-(dihexylamino)-2,5':2',5''-ter-1,3-thiazole-5-carboxylate (131)



A dry and argon-flushed Schlenk-flask, equipped with a magnetic stirring bar and a septum, was charged with *N*,*N*-dihexyl-1,3-thiazol-2-amine (210 mg, 0.78 mmol) and 0.8 mL THF. After cooling to –78 °C, *n*BuLi (0.35 mL, 2.47 M in THF, 0.86 mmol) was added dropwise and stirred for 1 h. Then, a solution of $ZnCl_2$ (0.43 mL, 1.0 M in THF, 0.43 mmol) was added and the mixture was warmed up to 0 °C and stirred for 30 min. A dry and argon flushed two-necked round-bottomed flask, equipped with a magnetic stirring bar and a reflux condenser was charged with ethyl 2'-bromo-2,5'-bi-1,3-thiazole-5-carboxylate (300 mg, 0.94 mmol), *i*PrI (146 mg, 0.86 mmol) and $Pd(PPh_3)_4$ (54 mg, 0.047 mmol) in 1.5 mL THF. The zinc reagent was added and the resulting mixture was heated under reflux for 12 h. The mixture was cooled to 25 °C, diluted with EtOAc (200 mL) and washed with sat. NaCl solution (30 mL). The organic layer was dried (Na_2SO_4), filtered, and concentrated under reduced pressure. Purification by flash chromatography (pentane/EtOAc; 9:1) yielded **131** (316 mg, 80 %) as a yellow solid.

mp: 123.2 – 125.2 °C.

IR (ATR) $\tilde{\nu}$ (cm^{-1}): 2927, 2858, 1716, 1524, 1505, 1462, 1427, 1355, 1311, 1291, 1277, 1255, 1232, 1171, 1152, 1085, 1008, 944, 921, 888, 863, 758, 749, 724.

^{1}H-NMR (400 MHz, C_6D_6): δ = 8.31 (s, 1H, Ar*H*), 7.93 (s, 1H, Ar*H*), 7.79 (s, 1H, Ar*H*), 4.00 (q, *J* = 7.0 Hz, 2H, C*H*$_2$CH$_3$), 3.19 (t, *J* = 7.6 Hz, 4H, 2 x C*H*$_2$), 1.46 (quint, *J* = 7.4 Hz, 4H, 2 x C*H*$_2$), 1.28-1.09 (m, 12H, 6 x C*H*$_2$), 0.95 (q, *J* = 7.02 Hz, 3H, CH$_2$C*H*$_3$), 0.88 (t, *J* = 6.9 Hz, 6H, 2 x C*H*$_3$).

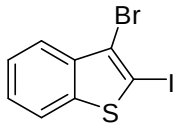
^{13}C-NMR (100 MHz, C_6D_6): δ = 172.1, 164.0, 163.3, 161.1, 149.3, 143.8, 143.0, 129.9, 129.1, 120.4, 61.6, 52.2, 32.1, 27.7, 27.0, 23.2, 14.4, 14.3.

HRMS (ESI): *m/z* calc. for [$C_{24}H_{34}N_4O_2S_3$+H] 507.1922, found: 507.1906.

9. Synthesis of Dibenzothiophenes and Related Classes of S-Heterocycles via an Anionic Electrocyclization

9.1 Starting Material Synthesis

Synthesis of 3-bromo-2-iodo-1-benzothiophene (146)



A dry and argon-flushed Schlenk-flask, equipped with a magnetic stirring bar and a septum, was charged with 3-bromobenzothiophene (5.33 g, 25.0 mmol) and 50 mL THF. After cooling to –78 °C, TMPMgCl·LiCl (24 mL, 1.14 M in THF, 27.5 mmol) was added dropwise and stirred for 1 h. Then, a solution of I_2 (7.61 g, 1.0 M in THF, 30.0 mmol) was added and the mixture was gradually warmed up to 25 °C within 1 h. The reaction was stopped by the addition of sat. $Na_2S_2O_3$ solution (70 mL) and the product was extracted with Et_2O (3 x 150 mL). The combined organic layers were dried (Na_2SO_4), filtered, and concentrated under reduced pressure. Purification by flash chromatography (pentane) yielded **146** (7.76 g, 92 %) as a light yellow solid.

mp: 75.5 – 77.1 °C.

IR (ATR) $\tilde{\nu}$ (cm^{-1}): 1480, 1451, 1415, 1295, 1238, 1157, 1128, 1016, 968, 940, 879, 852, 820, 749, 724, 705.

^{1}H-NMR (300 MHz, $CDCl_3$): δ = 7.54 (ddd, *J* = 8.8 Hz, *J* = 1.2 Hz, *J* = 0.7 Hz, 1H, Ar*H*), 7.07 (ddd, *J* = 8.0 Hz, *J* = 1.2 Hz, *J* = 0.7 Hz, 1H, Ar*H*), 6.98-6.91 (m, 1H, Ar*H*), 6.87-6.80 (m, 1H, Ar*H*).

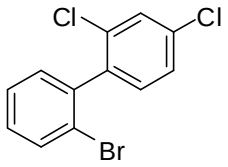
^{13}C-NMR (75 MHz, $CDCl_3$): δ = 143.1, 138.0, 125.5, 125.4, 123.8, 121.7, 118.5, 82.8.

MS (70 eV, EI): *m/z* (%) = 340 (100), 338 (95), 213 (14), 211 (13), 132 (28).

HRMS (EI): *m/z* calc. for [C_8H_4BrIS] 337.8262, found: 337.8260.

9.2 Preparation of Diaryls via Pd-Catalyzed Cross-Coupling Reactions

Synthesis of 2'-bromo-2,4-dichlorobiphenyl (140a)



Prepared according to **TP10** from 1,2-dibromobenzene (2.36 g, 10.00 mmol) [Br/Mg-exchange conditions: *i*PrMgCl·LiCl at –15 °C for 2 h], 2,4-dichloroiodobenzene (2.46 g, 9.0 mmol), $Pd(dba)_2$ (115 mg, 0.20 mmol) and tfp (93 mg, 0.40 mmol) in 10 mL THF. Purification by flash chromatography (pentane) yielded **140a** (2.04 g, 75 %) as a colourless oil.

IR (ATR) $\tilde{\nu}$ (cm^{-1}): 1581, 1564, 1490, 1457, 1426, 1378, 1250, 1119, 1100, 1081, 1052, 1028, 1002, 866, 812, 753, 727, 712, 669, 644.

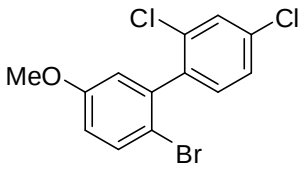
^{1}H-NMR (300 MHz, $CDCl_3$): δ = 7.71 (d, *J* = 7.8 Hz, 1H, Ar*H*), 7.53 (s, 1H, Ar*H*), 7.46-7.19 (m, 5H, Ar*H*).

^{13}C-NMR (75 MHz, $CDCl_3$): δ = 139.3, 138.5, 134.4, 134.2, 132.7, 131.9, 131.0, 129.7, 129.3, 127.2, 126.9, 123.5.

MS (70 eV, EI): *m/z* (%) = 304 (29), 302 (73), 300 (50), 267 (10), 223 (38), 221 (57), 188 (36), 187 (15), 186 (100), 151 (35), 150 (32), 97 (12), 93 (28), 83 (17), 75 (20), 71 (17), 69 (24), 67 (11), 57 (27), 56 (10), 55 (27).

HRMS (EI): *m/z* calc. for [$C_{12}H_7BrCl_2$] 299.9108, found: 299.9108.

Synthesis of 2'-bromo-2,4-dichloro-5'-methoxybiphenyl (140b)



Prepared according to **TP10** from 1-bromo-2-iodo-4-methoxybenzene (3.13 g, 10.0 mmol) [I/Mg-exchange conditions: *i*PrMgCl·LiCl at –20 °C for 1 h], 2,4-dichloroiodobenzene (2.46 g, 9.00 mmol), $Pd(dba)_2$ (115 mg, 0.20 mmol) and tfp (93 mg, 0.40 mmol) in 9 mL THF. Purification by flash chromatography (pentane) yielded **140b** (2.27 g, 76 %) as a colourless oil.

IR (ATR) $\tilde{\nu}$ (cm^{-1}): 1596, 1571, 1553, 1462, 1440, 1399, 1374, 1320, 1300, 1252, 1239, 1220, 1178, 1101, 1085, 1058, 1026, 1010, 876, 867, 820, 807, 791, 616.

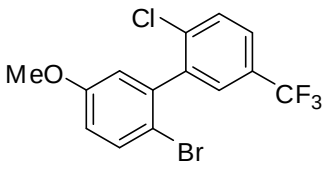
^{1}H-NMR (300 MHz, $CDCl_3$): δ =7.53 (d, *J* = 8.6 Hz, 1H), 7.49 (d, *J* = 2.1 Hz, 1H), 7.31 (dd, *J* = 8.2 Hz, *J* = 2.1 Hz, 1H), 7.18 (d, *J* = 8.2 Hz, 1H), 6.82 (dd, *J* = 8.8 Hz, *J* = 3.1 Hz, 1H), 6.77 (d, *J* = 3.1 Hz, 1H), 3.80 (s, 3H, O*C*H_3).

^{13}C-NMR (75 MHz, $CDCl_3$): δ = 158.7, 140.0, 138.5, 134.4, 134.1, 133.3, 131.8, 129.3, 126.9, 116.5, 115.6, 113.9, 55.5.

MS (70 eV, EI): *m/z* (%) = 334 (45), 333 (15), 332 (100), 330 (62), 289 (19), 287 (12), 253 (19), 251 (28), 218 (12), 216 (33), 175 (13), 173 (41).

HRMS (EI): *m/z* calc. for [$C_{13}H_9BrCl_2O$] 329.9214, found: 329.9206.

Synthesis of 2-bromo-2'-chloro-5-methoxy-5'-(trifluoromethyl)biphenyl (140c)



Prepared according to **TP10** from 1-bromo-2-iodo-4-methoxybenzene (3.13 g, 10.0 mmol) [I/Mg-exchange conditions: *i*PrMgCl·LiCl at –20 °C for 1 h], 4-chloro-3-iodobenzotrifluoride (2.76 g, 9.00 mmol), $Pd(dba)_2$ (115 mg, 0.20 mmol) and tfp (93 mg, 0.40 mmol) in 9 mL THF. Purification by flash chromatography (pentane/EtOAc; 50:1) yielded **140c** (3.03 g, 92 %) as a colourless oil.

IR (ATR) $\tilde{\nu}$ (cm^{-1}): 1610, 1592, 1579, 1568, 1488, 1464, 1418, 1388, 1331, 1307, 1292, 1258, 1241, 1218, 1211, 1168, 1122, 1092, 1073, 1029, 1013, 908, 891, 856, 824, 807, 795, 736, 715.

^{1}H-NMR (300 MHz, $CDCl_3$): δ = 7.61-7.52 (m, 4H, Ar*H*), 6.97-6.79 (m, 2H, Ar*H*), 3.81 (s, 3H, CH_3).

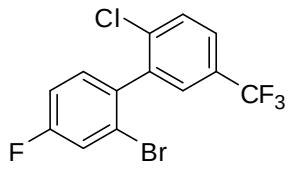
^{13}C-NMR (75 MHz, $CDCl_3$): δ = 158.8, 140.7, 139.7, 133.4, 132.2, 130.1, 129.1 (q, ^{2}J(C,F) = 33 Hz), 128.0 (q, ^{3}J(C,F) = 3.7 Hz), 126.0 (q, ^{3}J(C,F) = 3.6 Hz), 123.5 (q, ^{1}J(C,F) = 272 Hz), 116.4, 115.9, 113.7, 55.6.

^{19}F-NMR (282 MHz, $CDCl_3$): δ = –62.5.

MS (70 eV, EI): *m/z* (%) = 372 (12), 368 (27), 367 (16), 366 (100), 365 (11), 364 (75), 323 (20), 321 (15), 285 (26), 250 (24), 207 (24).

HRMS (EI): *m/z* calc. for [$C_{14}H_9BrClF_3O$] 363.9477, found: 363.9472.

Synthesis of 2-bromo-2'-chloro-4-fluoro-5'-(trifluoromethyl)biphenyl (140d)



Prepared according to **TP10** from 2-bromo-4-fluoroiodobenzene (3.01 g, 10.0 mmol) [I/Mg-exchange conditions: *i*PrMgCl·LiCl at –20 °C for 1 h], 4-chloro-3-iodobenzotrifluoride (2.76 g, 9.00 mmol), $Pd(dba)_2$ (115 mg, 0.20 mmol) and tfp (93 mg, 0.40 mmol) in 9 mL THF. Purification by flash chromatography (pentane) yielded **140d** (2.49 g, 75 %) as colourless oil.

IR (ATR) $\tilde{\nu}$ (cm^{-1}): 1599, 1581, 1558, 1497, 1470, 1409, 1330, 1286, 1265, 1199, 1169, 1126, 1088, 1069, 1045, 1015, 905, 884, 861, 824, 737, 720, 682, 674, 654.

^{1}H-NMR (300 MHz, $CDCl_3$): δ = 7.60 (d, *J* = 1.4 Hz, 2H), 7.53-7.49 (m, 1H), 7.44 (dd, *J* = 8.6 Hz, *J* = 2.9 Hz, 1H), 7.24 (dd, *J* = 8.6 Hz, *J* = 6.0 Hz, 1H), 7.16-7.09 (m, 1H).

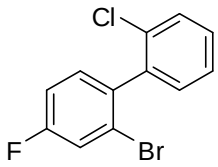
^{13}C-NMR (75 MHz, $CDCl_3$): δ = 162.3 (d, ^{1}J(C,F) = 252 Hz), 139.8, 137.6, 135.1 (d, ^{4}J(C,F) = 3.7 Hz), 131.9 (d, ^{3}J(C,F) = 8.5 Hz), 130.1, 129.2 (q, ^{2}J(C,F) = 33 Hz), 128.3 (q, ^{3}J(C,F) = 4.0 Hz), 126.3 (q, ^{3}J(C,F) = 3.7 Hz), 123.7 (d, ^{3}J(C,F) = 10.0 Hz), 123.6 (q, ^{1}J(C,F) = 272 Hz), 120.1 (d, ^{2}J(C,F) = 25 Hz), 114.7 (d, ^{2}J(C,F) = 21 Hz).

^{19}F-NMR (282 MHz, $CDCl_3$): δ = –111.0, –62.5.

MS (70 eV, EI): *m/z* (%) = 356 (22), 355 (17), 354 (98), 352 (62), 333 (10), 319 (15), 317 (10), 275 (11), 273 (60), 239 (14), 238 (100), 237 (20), 168 (13), 71 (12), 57 (18).

HRMS (EI): *m/z* calc. for [$C_{13}H_6BrClF_4$] 351.9278, found: 351.9274.

Synthesis of 2-bromo-2'-chloro-4-fluorobiphenyl (140e)



Prepared according to **TP10** from 2-bromo-4-fluoroiodobenzene (2.56 g, 8.50 mmol) [I/Mg-exchange conditions: *i*PrMgCl·LiCl at –20 °C for 1 h], 1-chloro-2-iodobenzene (1.82 g, 7.65 mmol), $Pd(dba)_2$ (98 mg, 0.17 mmol) and tfp (79 mg, 0.34 mmol) in 8 mL THF. Purification by flash chromatography (pentane) yielded **140e** (1.75 g, 80 %) as a colourless oil.

IR (ATR) $\tilde{\nu}$ (cm^{-1}): 1601, 1590, 1579, 1499, 1462, 1432, 1385, 1259, 1247, 1196, 1127, 1078, 1045, 1037, 1005, 945, 876, 858, 818, 754, 739, 732, 702, 667.

^{1}H-NMR (300 MHz, $CDCl_3$): δ = 7.55-7.49 (m, 1H, Ar*H*), 7.46 (dd, *J* = 8.3 Hz, *J* = 2.4 Hz, 1H, Ar*H*), 7.41-7.32 (m, 2H, Ar*H*), 7.31-7.22 (m, 2H, Ar*H*), 7.14 (dt, *J* = 8.3 Hz, *J* = 2.7 Hz, 1H, Ar*H*).

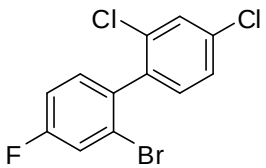
^{13}C-NMR (75 MHz, $CDCl_3$): δ = 161.9 (d, ^1J(C,F) = 251 Hz), 139.1, 136.53 (d, *J*(C,F) = 0.5 Hz), 136.48, 133.5 (d, *J*(C,F) = 0.8 Hz), 131.9 (d, ^3J(C,F) = 8.1 Hz), 131.1 (d, *J*(C,F) = 0.8 Hz), 129.5 (d, ^4J(C,F) = 3.0 Hz), 126.5, 123.8 (d, ^3J(C,F) = 9.3 Hz), 119.8 (d, ^2J(C,F) = 25 Hz), 114.4 (d, ^2J(C,F) = 21 Hz).

^{19}F-NMR (282 MHz, $CDCl_3$): δ = –112.2.

MS (70 eV, EI): *m/z* (%) = 286 (49), 284 (41), 205 (39), 170 (100), 138 (11), 120 (11), 85 (15), 70 (10), 57 (12).

HRMS (EI): *m/z* calc. for [$C_{12}H_7BrClF$] 283.9404, found: 283.9391.

Synthesis of 2-bromo-2',4'-dichloro-4-fluorobiphenyl (140f)

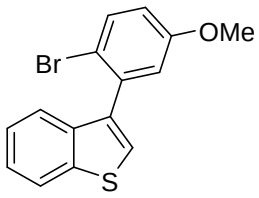


Prepared according to **TP10** from 2-bromo-4-fluoroiodobenzene (1.81 g, 6.00 mmol) [I/Mg-exchange conditions: *i*PrMgCl·LiCl at –20 °C for 1 h], 2,4-dichloroiodobenzene (1.47 g, 5.40

mmol), $Pd(dba)_2$ (69 mg, 0.12 mmol) and tfp (56 mg, 0.24 mmol) in 6 mL THF. Purification by flash chromatography (pentane) yielded **140f** (1.28 g, 74 %) as colourless oil.

IR (ATR) $\tilde{\nu}$ (cm^{-1}): 1601, 1580, 1552, 1498, 1463, 1442, 1387, 1374, 1259, 1197, 1139, 1101, 1077, 1043, 1003, 860, 815, 803, 680, 670.
^{1}H-NMR (300 MHz, $CDCl_3$): δ = 7.52 (d, *J* = 2.2 Hz, 1H), 7.44 (dd, *J* = 8.3 Hz, *J* = 2.4 Hz, 1H), 7.33 (dd, *J* = 8.3 Hz, *J* = 1.9 Hz, 1H), 7.28-7.07 (m, 3H).
^{13}C-NMR (75 MHz, $CDCl_3$): δ = 162.1 (d, ^1J(C,F) = 252 Hz), 137.6, 135.4 (d, ^4J(C,F) = 3.8 Hz), 134.7, 134.4, 132.0 (d, ^5J(C,F) = 1.0 Hz), 131.9 (d, ^3J(C,F) = 8.8 Hz), 129.4, 127.0, 123.8 (d, ^3J(C,F) = 9.3 Hz), 120.0 (d, ^2J(C,F) = 24.5 Hz), 114.5 (d, ^2J(C,F) = 21.3 Hz).
^{19}F-NMR (282 MHz, $CDCl_3$): δ = –111.5.
MS (70 eV, EI): *m/z* (%) = 322 (43), 321 (12), 320 (100), 318 (58), 285 (10), 241 (23), 239 (31), 206 (24), 205 (11), 204 (76), 169 (17), 168 (16), 103 (11), 102 (30), 84 (13).
HRMS (EI): *m/z* calc. for [$C_{12}H_6BrCl_2F$] 317.9014, found: 317.9007.

Synthesis of 3-(2-bromo-5-methoxyphenyl)-1-benzothiophene (144b)



Prepared according to **TP10** from 3-bromobenzothiophene (2.13 g, 10.0 mmol) and 1-bromo-2-iodo-4-methoxybenzene (2.82 g, 9.0 mmol). Purification by flash chromatography (pentane/EtOAc; 50:1) yielded **144b** (2.13 g, 74 %) as colourless solid.

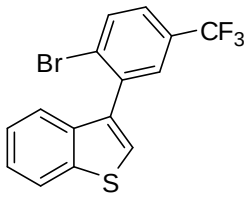
mp: 109.2 – 110.7 °C.
IR (ATR) $\tilde{\nu}$ (cm^{-1}): 1740, 1596, 1568, 1492, 1427, 1337, 1282, 1272, 1258, 1235, 1172, 1136, 1128, 1062, 1048, 1015, 879, 851, 810, 782, 765, 742, 734, 699.
^{1}H-NMR (300 MHz, $CDCl_3$): δ = 7.95-7.88 (m, 1H), 7.60 (d, *J* = 8.8 Hz, 1H), 7.57-7.52 (m, 1H), 7.43 (s, 1H), 7.40-7.32 (m, 2H), 6.96 (d, *J* = 3.0 Hz, 1H), 6.86 (dd, *J* = 8.8 Hz, *J* = 3.0 Hz, 1H), 3.80 (s, 3H, OCH_3)

^{13}C-NMR (75 MHz, $CDCl_3$): δ = 158.7, 139.7, 138.2, 137.5, 136.5, 133.7, 125.3, 124.4, 124.2, 123.3, 122.7, 117.2, 115.5, 114.4, 55.5.

MS (70 eV, EI): *m/z* (%) = 321 (19), 320 (100), 319 (18), 318 (100), 239 (28), 224 (37), 196 (31), 195 (57), 127 (17), 69 (22), 57 (37), 55 (32).

HRMS (EI): *m/z* calc. for [$C_{15}H_{11}BrOS$] 317.9714, found: 317.9708.

Synthesis of 3-[2-bromo-5-(trifluoromethyl)phenyl]-1-benzothiophene (144c)



Prepared according to **TP10** from 3-bromobenzothiophene (2.13 g, 10.0 mmol) and 1-bromo-2-iodo-4-(trifluoromethyl)benzene (3.16 g, 9.0 mmol). Purification by flash chromatography (pentane) yielded **144c** (2.29 g, 71 %) as colourless oil.

IR (ATR) $\tilde{\nu}$ (cm^{-1}): 1604, 1577, 1523, 1458, 1429, 1343, 1317, 1281, 1255, 1204, 1166, 1120, 1078, 1062, 1031, 965, 906, 845, 825, 797, 758, 743, 732, 708, 688, 656, 642.

^{1}H-NMR (300 MHz, $CDCl_3$): δ = 7.97-7.91 (m, 1H), 7.86 (d, *J* = 8.4 Hz, 1H), 7.68 (d, *J* = 2.2 Hz, 1H), 7.54 (dd, *J* = 8.4 Hz, *J* = 2.2 Hz, 1H), 7.49-7.36 (m, 4H).

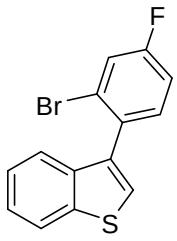
^{13}C-NMR (75 MHz, $CDCl_3$): δ = 139.8, 137.8, 137.7, 135.1, 133.8, 130.0 (q, ^{2}J(C,F) = 33 Hz), 128.7 (q, ^{3}J(C,F) = 3.7 Hz), 128.1, (q, ^{4}J(C,F) = 1.7 Hz), 126.1, 126.0 (q, ^{3}J(C,F) = 3.7 Hz), 124.7, 124.5, 123.7 (q, ^{1}J(C,F) = 272 Hz), 122.9, 122.8.

^{19}F-NMR (282 MHz, $CDCl_3$): δ = –62.6.

MS (70 eV, EI): *m/z* (%) = 359 (17), 358 (100), 357 (16), 356 (95), 276 (12), 232 (43), 208 (13).

HRMS (EI): *m/z* calc. for [$C_{15}H_8BrF_3S$] 355.9482, found: 355.9475.

Synthesis of 3-(2-bromo-4-fluorophenyl)-1-benzothiophene (144d)



Prepared according to **TP10** from 3-bromobenzothiophene (1.61 g, 7.56 mmol), and 2-bromo-4-fluoroiodobenzene (2.03 g, 6.75 mmol), $Pd(dba)_2$ (87 mg, 0.15 mmol) and tfp (70mg, 0.30 mmol) in 7 mL THF. Purification by flash chromatography (pentane) yielded **144d** (1.31 g, 63 %) as colourless oil.

IR (ATR) $\tilde{\nu}$ (cm^{-1}): 1597, 1575, 1528, 1472, 1456, 1426, 1382, 1342, 1318, 1255, 1222, 1191, 1144, 1062, 1033, 1022, 943, 867, 860, 816, 788, 758, 731, 698, 673, 628.

^{1}H-NMR (300 MHz, $CDCl_3$): δ = 7.95-7.89 (m, 1H), 7.51-7.45 (m, 2H), 7.42-7.31 (m, 4H), 7.13 (td, *J* = 8.1 Hz, *J* = 2.6 Hz, 1H).

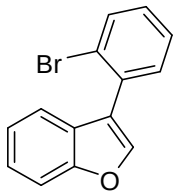
^{13}C-NMR (75 MHz, $CDCl_3$): δ = 162.0 (d, ^1J(C,F) = 251 Hz), 139.7, 138.3, 135.5, 132.79, 132.77 (d, ^3J(C,F) = 8.3 Hz), 125.6, 124.5, 124.3, 124.2 (d, ^3J(C,F) = 9.7 Hz), 123.0, 122.7, 120.4 (d, ^2J(C,F) = 24 Hz), 114.5 (d, ^2J(C,F) = 21 Hz).

^{19}F-NMR (282 MHz, $CDCl_3$): δ = –112.1.

MS (70 eV, EI): *m/z* (%) = 309 (15), 308 (100), 307 (15), 306 (97), 226 (21), 183 (65), 114 (10), 113 (10).

HRMS (EI): *m/z* calc. for [$C_{14}H_8BrFS$] 305.9514, found: 305.9509.

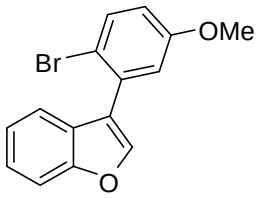
Synthesis of 3-(2-bromophenyl)-1-benzofuran (144e)



Prepared according to **TP10** from 3-bromobenzofuran (4.29 g, 21.7 mmol) [Br/Mg-exchange conditions: *i*PrMgCl·LiCl at –55 °C for 24 h], 1-bromo-2-iodobenzene (5.83 g, 20.6 mmol), $Pd(dba)_2$ (250 mg, 0.43 mmol) and tfp (201 mg, 0.87 mmol) in 20 mL THF. Purification by flash chromatography (pentane) yielded **144e** (4.27 g, 76 %) as colourless oil.

IR (ATR) $\tilde{\nu}$ (cm^{-1}): 1616, 1597, 1569, 1477, 1465, 1450, 1433, 1424, 1333, 1249, 1215, 1106, 1093, 1049, 1026, 1008, 965, 856, 811, 772, 760, 740, 720, 711, 651.
^{1}H-NMR (300 MHz, $CDCl_3$): δ = 7.85 (s, 1H), 7.77 (dd, *J* = 8.3 Hz, *J* = 1.2 Hz, 1H), 7.62-7.50 (m, 3H), 7.46-7.26 (m, 4H).
^{13}C-NMR (75 MHz, $CDCl_3$): δ = 155.0, 143.2, 133.5, 132.7, 131.7, 129.2, 127.4, 127.1, 124.5, 123.7, 122.8, 121.0, 120.8, 111.7.
MS (70 eV, EI): *m/z* (%) = 275 (15), 274 (99), 273 (15), 272 (100), 165 (59), 164 (14), 163 (18), 83 (20).
HRMS (EI): *m/z* calc. for [$C_{14}H_9BrO$] 271.9837, found: 271.9820.

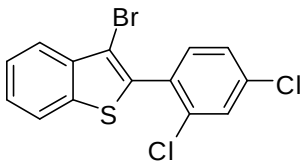
Synthesis of 3-(2-bromo-5-methoxyphenyl)-1-benzofuran (144f)



Prepared according to **TP10** from 3-bromobenzofuran (1.28 g, 6.00 mmol) [Br/Mg-exchange conditions: *i*PrMgCl·LiCl at –55 °C for 24 h], 1-bromo-2-iodo-4-methoxybenzene (1.69 g, 5.40 mmol), $Pd(dba)_2$ (69 mg, 0.12 mmol) and tfp (56 mg, 0.24 mmol) in 6 mL THF. Purification by flash chromatography (pentane/EtOAc; 50:1) yielded **144f** (1.31 g, 80 %) as colourless oil. The product was obtained as an inseparable mixture containing the desired product in 90% purity. The product was analyzed by GC-MS and was used without further purifications.

MS (70 eV, EI): *m/z* (%) = 304 (99), 303 (22), 302 (100), 261 (10), 195 (16), 180 (11), 152 (23).
HRMS (EI): *m/z* calc. for [$C_{15}H_{11}BrO_2$] 301.9942, found: 301.9956.

Synthesis of 3-bromo-2-(2,4-dichlorophenyl)-1-benzothiophene (147)



Prepared according to **TP10** from 3-bromo-2-iodo-1-benzothiophene (2.37 g, 7.00 mmol) [I/Mg-exchange conditions: *i*PrMgCl·LiCl at –40 °C for 1 h], 2,4-dichloroiodobenzene (1.72 g, 6.3 mmol), $Pd(dba)_2$ (81 mg, 0.14 mmol) and tfp (65 mg, 0.28 mmol) in 7 mL THF. Purification by flash chromatography (pentane) yielded **147** (1.86 g, 82 %) as a colourless solid.

mp: 127.9 – 128.6 °C.

IR (ATR) $\tilde{\nu}$ (cm^{-1}): 1587, 1547, 1534, 1465, 1428, 1372, 1300, 1246, 1159, 1144, 1102, 1061, 895, 879, 834, 757, 726, 716, 704.

^{1}H-NMR (300 MHz, $CDCl_3$): δ = 7.90-7.81 (m, 2H), 7.56 (dd, *J* = 1.9 Hz, *J* = 0.5 Hz, 1H), 7.53-7.33 (m, 4H).

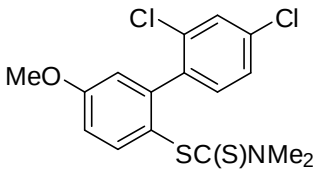
^{13}C-NMR (75 MHz, $CDCl_3$): δ = 138.5, 137.9, 135.9, 135.4, 134.3, 133.4, 130.6, 129.9, 127.1, 125.9, 125.3, 123.7, 122.3, 109.0.

MS (70 eV, EI): *m/z* (%) = 360 (45), 359 (14), 38 (100), 356 (54), 244 (13), 242 (34).

HRMS (EI): *m/z* calc. for [$C_{14}H_7BrCl_2S$] 355.8829, found: 355.8819.

9.3 Preparation of Dithiocarbamates

Synthesis of 2',4'-dichloro-5-methoxybiphenyl-2-yl dimethyldithiocarbamate (142b)



Prepared according to **TP11** from 2'-bromo-2,4-dichloro-5'-methoxybiphenyl (1.82 g, 5.47 mmol) [exchange conditions: *n*BuLi at –95 °C for 0.5 h and subsequent transmetalation

with $MgCl_2 \cdot LiCl$] and tetramethylthiuram disulfide (1.18 g, 4.92 mmol). Purification by flash chromatography (pentane/EtOAc; 9:1) yielded **142b** (1.48 g, 81 %) as yellow solid.

mp: 133.3 – 134.6 °C

IR (ATR) $\tilde{\nu}$ (cm^{-1}): 1599, 1568, 1486, 1411, 1372, 1300, 1288, 1238, 1212, 1182, 1139, 1098, 1064, 1029, 1014, 970, 879, 822, 816, 786, 650.

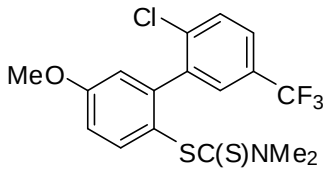
^{1}H-NMR (300 MHz, $CDCl_3$): δ = 7.46 (d, *J* = 8.6 Hz, 1H, Ar*H*), 7.42 (d, *J* = 2.1 Hz, 1H, Ar*H*), 7.38 (d, *J* = 8.2 Hz, 1H, Ar*H*), 7.20 (dd, *J* = 8.2 Hz, *J* = 2.1 Hz, 1H, Ar*H*), 7.01 (dd, *J* = 8.8 Hz, *J* = 2.0 Hz, 1H, Ar*H*), 6.82 (d, *J* = 2.8 Hz, 1H, Ar*H*), 3.84 (s, 3H, OCH_3), 3.43 (s, 3H, CH_3), 3.28 (s, 3H, CH_3).

^{13}C-NMR (75 MHz, $CDCl_3$): δ = 198.0, 161.1, 145.3, 140.0, 138.0, 133.91, 133.88, 132.0, 128.6, 126.4, 122.2, 116.2, 114.8, 55.4, 45.6, 41.9.

MS (70 eV, EI): *m/z* (%) = 355 (9), 338 (11), 336 (24), 248 (116), 233 (11), 205 (20), 88 (100), 72 (60).

HRMS (EI): *m/z* calc. for [$C_{16}H_{15}Cl_2NOS_2$] 370.9972, found: 370.9966.

Synthesis of 2'-chloro-5-methoxy-5'-(trifluoromethyl)biphenyl-2-yl dimethyldithiocarbamate (142c)



Prepared according to **TP11** from 2-bromo-2'-chloro-5-methoxy-5'-(trifluoromethyl)biphenyl (2.20 g, 6.00 mmol) [exchange conditions: *n*BuLi at –95 °C for 30 min and subsequent transmetalation with $MgCl_2 \cdot LiCl$] and tetramethylthiuram disulfide (1.30 g, 5.4 mmol). Purification by flash chromatography (pentane/EtOAc; 9:1) yielded **142c** (1.75 g, 80 %) as a colourless solid.

mp: 142.4 – 144.0 °C.

IR (ATR) $\tilde{\nu}$ (cm^{-1}): 1598, 1568, 1472, 1424, 1333, 1299, 1263, 1247, 1212, 1167, 1131, 1102, 1080, 1061, 1023, 972, 893, 836, 809, 763, 721.

^{1}H-NMR (300 MHz, $CDCl_3$): δ = 7.78 (m, 1H, Ar*H*), 7.53 (s, 1H, Ar*H*), 7.51 (dd, *J* = 8.0 Hz, *J* = 0.4 Hz, 2H, Ar*H*), 7.04 (dd, *J* = 8.6 Hz, *J* = 2.6 Hz, 1H, Ar*H*), 6.88 (d, *J* = 2.6 Hz, 1H, Ar*H*), 3.86 (s, 3H, OCH_3), 3.41 (s, 3H, CH_3), 3.22 (s, 3H, CH_3).

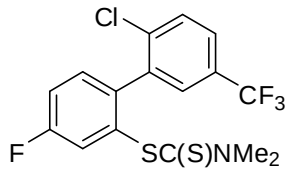
^{13}C-NMR (75 MHz, $CDCl_3$): δ = 197.6, 161.1, 144.8, 140.2, 140.1, 137.0, 129.4, 128.4 (q, ^{3}J(C,F) = 3.9 Hz), 128.3 (q, ^{2}J(C,F) = 33.0 Hz), 125.5 (q, ^{3}J(C,F) = 3.9 Hz), 123.7 (q, ^{1}J(C,F) = 272 Hz), 122.2, 116.3, 114.9, 55.5, 45.5, 41.8.

^{19}F-NMR (282 MHz, $CDCl_3$): δ = –62.5.

MS (70 eV, EI): *m/z* (%) = 405 (9), 370 (13), 239 (11), 88 (100).

HRMS (EI): *m/z* calc. for [$C_{17}H_{15}ClF_3NOS_2$] 405.0236, found: 405.0231.0779.

Synthesis of 2'-chloro-4-fluoro-5'-(trifluoromethyl)biphenyl-2-yl dimethyldithiocarbamate (142d)



Prepared according to **TP11** from 2-bromo-2'-chloro-4-fluoro-5'-(trifluoromethyl)biphenyl (2.04 g, 5.54 mmol) [exchange conditions: *n*BuLi at –95 °C for 0.5 h and subsequent transmetalation with $MgCl_2$·LiCl] and tetramethylthiuram disulfide (1.20 g, 4.99 mmol). Purification by flash chromatography (pentane/EtOAc; 9:1) yielded **142d** (1.65 g, 84 %) as light yellow solid.

mp: 66.6 – 68.5 °C.

IR (ATR) $\tilde{\nu}$ (cm^{-1}): 1596, 1575, 1495, 1469, 1405, 1375, 1329, 1285, 1258, 1245, 1198, 1161, 1135, 1116, 1092, 1069, 1052, 1017, 982, 906, 901, 873, 834.

^{1}H-NMR (300 MHz, $CDCl_3$): δ = 7.75 (s, 1H, Ar*H*), 7.57-7.54 (m, 2H, Ar*H*), 7.40-7.27 (m, 3H, Ar*H*), 3.42 (br. s, 3H, CH_3), 3.24 (br. s, 3H, CH_3).

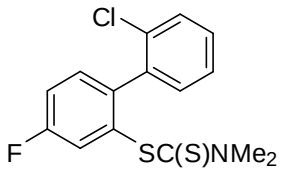
^{13}C-NMR (75 MHz, $CDCl_3$): δ = 195.2, 162.2 (d, ^{1}J(C,F) = 251 Hz), 139.3 (d, ^{4}J(C,F) = 3.7 Hz), 139.2, 137.3, 133.1 (d, ^{3}J(C,F) = 8.5 Hz), 131.9 (d, ^{3}J(C,F) = 8.3 Hz), 129.5, 128.6 (dq, ^{3}J(C,F) = 3.7 Hz, ^{4}J(C,F) = 0.9 Hz), 128.5 (q, ^{2}J(C,F) = 33 Hz), 125.7 (q, ^{3}J(C,F) = 3.9 Hz), 125.5 (d, ^{2}J(C,F) = 22 Hz), 123.7 (q, ^{1}J(C,F) = 272 Hz), 117.7 (d, ^{2}J(C,F) = 21 Hz), 45.4, 42.0.

^{19}F-NMR (282 MHz, $CDCl_3$): δ = –111.9, –62.6.

MS (70 eV, EI): *m/z* (%) = 358 (27), 270 (17), 251 (10), 88 (100).

HRMS (EI): *m/z* calc. for [$C_{16}H_{12}ClF_4NS_2$] 393.0036, found: 393.0036.

Synthesis of 2'-chloro-4-fluorobiphenyl-2-yl dimethyldithiocarbamate (142e)



Prepared according to **TP11** from 2-bromo-2'-chloro-4-fluorobiphenyl (1.43 g, 5.00 mmol) [exchange conditions: *n*BuLi at –95 °C for 30 min and subsequent transmetalation with $MgCl_2$·LiCl] and tetramethylthiuram disulfide (1.14 g, 4.75 mmol). Purification by flash chromatography (pentane/EtOAc; 9:1) yielded **142e** (1.46 g, 94 %) as colourless solid.

mp: 111.3 – 113.1 °C.

IR (ATR) $\tilde{\nu}$ (cm^{-1}): 1589, 1494, 1464, 1430, 1369, 1246, 1195, 1145, 1081, 1053, 982, 946, 896, 862, 821, 757, 739, 730.

^{1}H-NMR (300 MHz, $CDCl_3$): δ = 7.45-7.20 (m, 7H, Ar*H*), 3.43 (br. s, 3H, CH_3), 3.26 (br. s, 3H, CH_3).

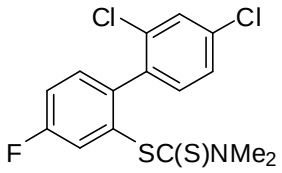
^{13}C-NMR (75 MHz, $CDCl_3$): δ = 196.0, 161.9 (d, ^1J(C,F) = 250 Hz), 140.8 (d, ^4J(C,F) = 3.4 Hz), 138.6, 133.4, 133.1 (d, ^3J(C,F) = 8.5 Hz), 131.9 (d, ^3J(C,F) = 8.0 Hz), 131.4, 129.0, 128.8, 126.1, 125.0 (d, ^2J(C,F) = 22.5 Hz), 117.5 (d, ^2J(C,F) = 21.4 Hz), 45.4, 42.1.

^{19}F-NMR (282 MHz, $CDCl_3$): δ = –113.1.

MS (70 eV, EI): *m/z* (%) = 325 (1), 290 (50), 202 (39), 88 (100).

HRMS (EI): *m/z* calc. for [$C_{15}H_{13}ClFNS_2$] 325.0162, found: 325.0157.

Synthesis of 2',4'-dichloro-4-fluorobiphenyl-2-yl dimethyldithiocarbamate (142f)



Prepared according to **TP11** from 2-bromo-2',4'-dichloro-4-fluorobiphenyl (960 mg, 3.00 mmol) [exchange conditions: *n*BuLi at –95 °C for 30 min and subsequent transmetalation with $MgCl_2 \cdot LiCl$] and tetramethylthiuram disulfide (649 mg, 2.70 mmol). Purification by flash chromatography (pentane/EtOAc; 9:1) yielded **142f** (825 mg, 85 %) as a colourless solid.

mp: 146.3 – 148.0 °C.

IR (ATR) $\tilde{\nu}$ (cm^{-1}): 1582, 1495, 1462, 1446, 1374, 1248, 1196, 1143, 1130, 1102, 1081, 1054, 1006, 982, 970, 894, 872, 829, 821, 799.

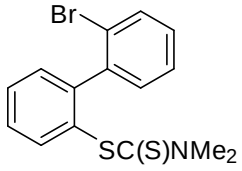
^{1}H-NMR (300 MHz, $CDCl_3$): δ = 7.43 (d, *J* = 2.2 Hz, 1H), 7.35 (d, *J* = 8.3 Hz, 1H), 7.34-7.30 (m, 1H), 7.29-7.20 (m, 3H), 3.43 (s, 3H), 3.29 (s, 3H).

^{13}C-NMR (75 MHz, $CDCl_3$): δ = 195.7, 162.1 (d, ^1J(C,F) = 251 Hz), 139.8, 137.1, 134.23, 134.17, 133.1 (d, ^3J(C,F) = 8.7 Hz), 132.3 (d, ^4J(C,F) = 0.8 Hz), 131.9 (d, ^3J(C,F) = 8.2 Hz), 128.7, 126.5, 125.2 (d, ^2J(C,F) = 22.3 Hz), 117.7 (d, ^2J(C,F) = 21.3 Hz), 45.4, 42.1.

MS (70 eV, EI): *m/z* (%) = 326 (12), 325 (6), 323 (30), 236 (13), 88 (100).

HRMS (EI): *m/z* calc. for [$C_{15}H_{12}Cl_2FNS_2$] 358.9772, found: 358.9775.

Synthesis of 2'-bromobiphenyl-2-yl dimethyldithiocarbamate (142g)



Prepared according to **TP11** from 2,2'-dibromobiphenyl (1.56 g, 5.00 mmol) [exchange conditions: *n*BuLi at –95 °C for 30 min and subsequent transmetalation with $MgCl_2 \cdot LiCl$] and

tetramethylthiuram disulfide (1.08 g, 4.50 mmol). Purification by flash chromatography (pentane/Et_2O; 2:1) yielded **142g** (1.20 g, 76 %) as a light yellow solid.

mp: 140.6 – 142.4 °C.

IR (ATR) $\tilde{\nu}$ (cm^{-1}): 1498, 1454, 1416, 1375, 1244, 1145, 1114, 1055, 1025, 1000, 980, 962, 944, 860, 765, 752, 720, 693, 667, 656, 613.

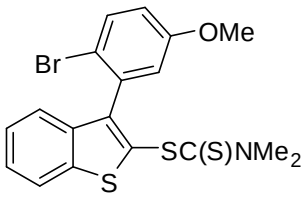
^{1}H-NMR (300 MHz, $CDCl_3$): δ = 7.63-7.41 (m, 5H, ArH), 7.33-7.16 (m, 3H, ArH), 3.41 (s, 3H, CH_3), 3.24 (s, 3H, CH_3).

^{13}C-NMR (75 MHz, $CDCl_3$): δ = 197.0, 146.4, 141.4, 138.4, 131.8, 131.1, 131.1, 130.6, 130.2, 128.9, 128.7, 126.6, 123.6, 45.3, 42.0.

MS (70 eV, EI): *m/z* (%) = 350 (0.07), 273 (13), 272 (70), 184 (54), 152 (11), 139 (11), 88 (100), 72 (11).

HRMS (EI): *m/z* calc. for [$C_{15}H_{14}BrNS_2$] 350.9751, found: 350.9745.

Synthesis of 3-(2-bromo-5-methoxyphenyl)-1-benzothien-2-yl dimethyldithiocarbamate (145b)



Prepared according to **TP12** from 3-(2-bromo-5-methoxyphenyl)-1-benzothiophene (1.28 g, 4.00 mmol) [deprotonation conditions: TMPMgCl·LiCl at 0 °C for 2.5 h] and tetramethylthiuram disulfide (865 mg, 3.60 mmol). Purification by flash chromatography (pentane/EtOAc; 4:1) yielded **145b** (1.42 g, 90 %) as a yellow solid.

mp: 130.5 – 132.0 °C.

IR (ATR) $\tilde{\nu}$ (cm^{-1}): 1589, 1574, 1494, 1455, 1421, 1373, 1336, 1292, 1240, 1142, 1027, 1011, 970, 879, 812, 761, 734.

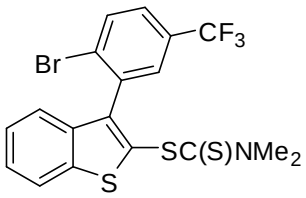
^{1}H-NMR (300 MHz, $CDCl_3$): δ =7.86 (dt, *J* = 7.9 Hz, *J* = 0.9 Hz, 1H, Ar*H*), 7.55 (d, *J* = 8.8 Hz, 1H, Ar*H*), 7.45-7.30 (m, 3H, Ar*H*), 7.20 (d, *J* = 3.2 Hz, 1H, Ar*H*), 6.87 (dd, *J* = 7.8 Hz, *J* = 3.0 Hz, 1H, Ar*H*), 3.73 (s, 3H, OCH_3), 3.48 (s, 3H, CH_3), 3.37 (s, 3H, CH_3).

^{13}C-NMR (75 MHz, $CDCl_3$): δ = 195.3, 158.5, 145.3, 142.6, 138.5, 136.2, 133.0, 128.1, 125.9, 124.6, 124.4, 122.3, 117.1, 116.5, 114.4, 55.7, 45.7, 42.1.

MS (70 eV, EI): *m/z* (%) = 436 (0.2), 358 (37), 271 (10), 270 (47), 227 (45), 88 (100).

HRMS (EI): *m/z* calc. for [$C_{18}H_{16}BrNOS_3$] 436.9577, found: 436.9576.

Synthesis of 3-[2-bromo-5-(trifluoromethyl)phenyl]-1-benzothien-2-yl dimethyldithiocarbamate (145c)



Prepared according to **TP12** from 3-[2-bromo-5-(trifluoromethyl)phenyl]-1-benzothiophene (1.43 g, 4.01 mmol) [deprotonation conditions: TMPMgCl·LiCl at 0 °C for 2.5 h] and tetramethylthiuram disulfide (868 mg, 3.61 mmol). Purification by flash chromatography (pentane/EtOAc; 4:1) yielded **145c** (1.47 g, 86 %) as a yellow solid.

mp: 148.3 – 149.6 °C.

IR (ATR) $\tilde{\nu}$ (cm^{-1}): 1603, 1506, 1428, 1374, 1339, 1312, 1241, 1167, 1125, 1083, 1074, 1015, 968, 917, 829, 764, 732, 713, 694, 636.

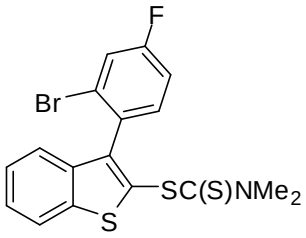
^{1}H-NMR (300 MHz, $CDCl_3$): δ = 7.92-7.81 (m, 3H), 7.58-7.52 (m, 1H), 7.47-7.40 (m, 1H), 7.38-7.31 (m, 2H), 3.46 (s, 3H), 3.35 (s, 3H).

^{13}C-NMR (75 MHz, $CDCl_3$): δ = 194.3, 143.6, 142.7, 138.1, 136.5, 133.2, 129.6 (q, ^2J(C,F) = 32.8 Hz), 129.4, 129.3 (q, ^3J(C,F) = 3.9 Hz), 128.3 (q, ^4J(C,F) = 1.4 Hz), 126.4 (q, ^3J(C,F) = 3.7 Hz), 126.1, 124.6, 124.2, 123.7 (q, ^1J(C,F) = 273 Hz), 122.4, 45.7, 42.0.

MS (70 eV, EI): *m/z* (%) = 477 (3), 475 (3), 310 (7), 309 (11), 308 (63), 88 (100)

HRMS (EI): *m/z* calc. for [$C_{18}H_{13}BrF_3NS_3$] 474.9346, found: 474.9332.

Synthesis of 3-(2-bromo-4-fluorophenyl)-1-benzothien-2-yl dimethyldithiocarbamate (145d)



Prepared according to **TP12** from 3-(2-bromo-5-fluorophenyl)-1-benzothiophene (922 mg, 3.00 mmol) [deprotonation conditions: TMPMgCl·LiCl at 0 °C for 2.5 h] and tetramethylthiuram disulfide (649 mg, 2.70 mmol). Purification by flash chromatography (pentane/EtOAc; 4:1) yielded **145d** (916 mg, 80 %) as a yellow solid.

mp: 152.6 – 153.7 °C.

IR (ATR) $\tilde{\nu}$ (cm^{-1}): 1594, 1496, 1473, 1379, 1316, 1251, 1240, 1215, 1178, 1150, 1039, 964, 951, 909, 866, 825, 791, 766, 734.

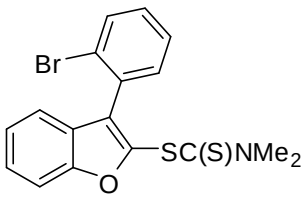
^{1}H-NMR (300 MHz, $CDCl_3$): δ = 7.90 (d, *J* = 8.2 Hz, 1H, Ar*H*), 7.62-7.30 (m, 5H, Ar*H*), 7.14 (dt, *J* = 8.4 Hz, *J* = 2.4 Hz, 1H, Ar*H*), 3.62-3.38 (m, 6H, 2 x CH_3).

^{13}C-NMR (75 MHz, $CDCl_3$): δ = 194.9, 162.3 (d, ^{1}J(C,F) = 252 Hz), 144.4, 142.6, 138.6, 133.3 (d, ^{3}J(C,F) = 8.5 Hz), 131.5 (d, ^{4}J(C,F) = 3.6 Hz), 128.8, 126.0, 124.5, 124.3, 123.3, 122.4, 119.8 (d, ^{2}J(C,F) = 24.5 Hz), 114.6 (d, ^{2}J(C,F) = 21.1 Hz), 45.7, 42.0.

MS (70 eV, EI): *m/z* (%) = 427 (6), 425 (5), 346 (36), 258 (32), 88 (100).

HRMS (EI): *m/z* calc. for [$C_{17}H_{13}BrFNS_3$] 424.9378, found: 424.9373.

Synthesis of 3-(2-bromophenyl)-1-benzofuran-2-yl dimethyldithiocarbamate (145e)



Prepared according to **TP12** from 3-(2-bromophenyl)-1-benzofuran (2.73 g, 10.0 mmol) [deprotonation conditions: TMPMgCl·LiCl at 0 °C for 2 h] and tetramethylthiuram disulfide

(2.28 g, 9.50 mmol). Purification by flash chromatography (pentane/Et_2O; 2:1) yielded **145e** (3.26 g, 87 %) as a yellow solid.

mp: 108.9 – 110.6 °C.

IR (ATR) $\tilde{\nu}$ (cm^{-1}): 1511, 1443, 1434, 1410, 1381, 1342, 1243, 1234, 1148, 1126, 1096, 1054, 1026, 1007, 978, 963, 902, 859, 828, 760, 752, 720, 669, 652.

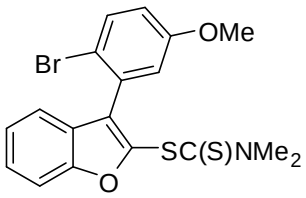
^{1}H-NMR (300 MHz, $CDCl_3$): δ = 7.71 (dd, *J* = 7.8 Hz, *J* = 1.5 Hz, 1H), 7.66-7.56 (m, 2H), 7.45-7.35 (m, 3H), 7.34-7.23 (m, 2H), 3.49 (s, 3H, C*H*$_3$), 3.40 (s, 3H, C*H*$_3$).

^{13}C-NMR (75 MHz, $CDCl_3$): δ = 192.9, 156.3, 141.9, 132.8, 132.6, 132.3, 131.8, 129.9, 128.1, 127.4, 126.2, 124.1, 123.0, 121.7, 111.8, 45.4, 42.3.

MS (70 eV, EI): *m/z* (%) = 393 (2), 391 (2), 225 (17), 224 (98), 196 (14), 195 (17), 152 (27), 88 (100).

HRMS (EI): *m/z* calc. for [$C_{17}H_{14}BrNOS_2$] 390.9700, found: 390.9680.

Synthesis of 3-(2-bromo-5-methoxyphenyl)-1-benzofuran-2-yl dimethyldithiocarbamate (145f)



Prepared according to **TP12** from 3-(2-bromo-5-methoxyphenyl)-1-benzofuran (1.00 g, 3.30 mmol) [deprotonation conditions: TMPMgCl·LiCl at 0 °C for 2 h] and tetramethylthiuram disulfide (714 mg, 2.970 mmol). Purification by flash chromatography (pentane/EtOAc; 4:1) yielded **145f** (1.02 g, 81 %) as a yellow solid.

mp: 148.8 – 150.5 °C.

IR (ATR) $\tilde{\nu}$ (cm^{-1}): 1597, 1579, 1500, 1458, 1448, 1439, 1401, 1377, 1340, 1294, 1244, 1231, 1127, 1118, 1096, 1017, 966, 878, 847, 812, 761, 751, 713, 621, 612.

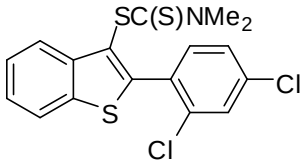
^{1}H-NMR (300 MHz, $CDCl_3$): δ = 7.60-7.54 (m, 2H, Ar*H*), 7.47-7.36 (m, 2H, Ar*H*), 7.30-7.24 (m, 2H, Ar*H*), 6.86 (dd, *J* = 9.1 Hz, *J* = 3.3 Hz, 1H, Ar*H*), 3.75 (s, 3H, OC*H*$_3$), 3.49 (s, 3H, C*H*$_3$), 3.42 (s, 3H, C*H*$_3$).

^{13}C-NMR (75 MHz, $CDCl_3$): δ = 193.0, 158.7, 156.3, 141.8, 133.4, 133.3, 131.9, 127.9, 126.3, 123.0, 121.8, 116.92, 116.89, 114.3, 111.8, 55.7, 45.5, 42.4.

MS (70 eV, EI): *m/z* (%) = 342 (19), 254 (28), 211 (14), 88 (100).

HRMS (EI): *m/z* calc. for [$C_{18}H_{16}BrNO_2S_2$] 420.9806, found: 420.9804.

Synthesis of 2-(2,4-dichlorophenyl)-1-benzothien-3-yl dimethyldithiocarbamate (148)



A dry and argon-flushed Schlenk-flask, equipped with a magnetic stirring bar and a septum, was charged with 3-bromo-2-(2,4-dichlorophenyl)-1-benzothiophene (1.43 mg, 4.00 mmol) and 4 mL THF. After cooling to –5 °C, *i*PrMgCl·LiCl (3.56 mL, 1.24 M in THF, 4.4 mmol) was added dropwise and stirred for 18 h. Then, a solution of tetramethylthiuram disulfide (865 mg, 3.60 mmol) in CH_2Cl_2 (7 mL) was added and the mixture was gradually warmed up to 25 °C within 1 h. The crude reaction mixture was quenched by the addition of sat. NH_4Cl solution (10 mL) and extracted with CH_2Cl_2 (3 x 40 mL). The combined organic layers were dried ($MgSO_4$), filtered, and concentrated under reduced pressure. Purification by flash chromatography (pentane/EtOAc; 4:1) yielded **148** (1.09 g, 76 %) as a yellow solid.

mp: 174.9 – 176.4 °C.

IR (ATR) $\tilde{\nu}$ (cm^{-1}): 1582, 1548, 1505, 1463, 1428, 1411, 1375, 1247, 1143, 1104, 1075, 1059, 994, 970, 913, 878, 865, 809, 772, 748, 725, 709, 632.

^{1}H-NMR (300 MHz, $CDCl_3$): δ = 7.90-7.76 (m, 2H), 7.67-7.59 (m, 1H), 7.50 (d, *J* = 1.9 Hz, 1H), 7.48-7.38 (m, 2H), 7.34-7.27 (m, 1H), 3.47 (s, 6H).

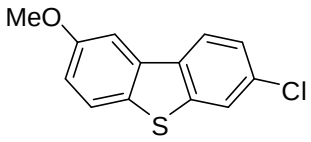
^{13}C-NMR (75 MHz, $CDCl_3$): δ = 194.6, 146.8, 139.7, 139.0, 135.6, 135.0, 133.4, 130.8, 129.3, 126.9, 125.4, 125.1, 123.5, 122.4, 122.1, 45.5, 42.1.

MS (70 eV, EI): *m/z* (%) = 397 (11), 361 (12), 274 (13), 88 (100).

HRMS (EI): *m/z* calc. for [$C_{17}H_{13}Cl_2NS_3$] 396.9587, found: 396.9584.

9.4 Ring-Closing Reactions

Synthesis of 7-chloro-2-methoxydibenzo[*b*,*d*]thiophene (134b)



Prepared according to **TP13** from 2',4'-dichloro-5-methoxybiphenyl-2-yl dimethyldithiocarbamate (372 mg, 1.00 mmol) and KO*t*Bu (337 mg, 3.00 mmol) at 50 °C for 18 h. Purification by flash chromatography (pentane/EtOAc; 50:1) yielded **134b** (205 mg, 81 %) as a colourless solid.

mp: 74.5 – 75.4 °C.

IR (ATR) $\tilde{\nu}$ (cm^{-1}): 1602, 1587, 1568, 1474, 1461, 1434, 1393, 1303, 1291, 1233, 1215, 1179, 1138, 1102, 1059, 1030, 879, 869, 859, 837, 807, 788, 668, 647, 605.

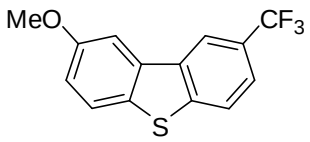
^{1}H-NMR (300 MHz, CDCl$_3$): δ = 7.96 (d, *J* = 8.6 Hz, 1H, Ar*H*), 7.78 (d, *J* = 1.9 Hz, 1H, Ar*H*), 7.68 78 (d, *J* = 8.6 Hz, 1H, Ar*H*), 7.53 (d, *J* = 2.4 Hz, 1H, Ar*H*), 7.38 (dd, *J* = 8.6 Hz, *J* = 2.1 Hz, 1H, Ar*H*), 7.09 (dd, *J* = 8.8 Hz, *J* = 2.4 Hz, 1H, Ar*H*), 3.92 (s, 3H, OC*H*$_3$).

^{13}C-NMR (75 MHz, CDCl$_3$): δ = 157.8, 141.7, 135.7, 133.9, 132.4, 131.2, 124.8, 123.4, 122.5, 122.2, 116.0, 104.9, 55.7.

MS (70 eV, EI): *m/z* (%) = 250 (34), 249 (14), 248 (100), 235 (20), 233 (51), 207 (20), 205 (53), 170 (12).

HRMS (EI): *m/z* calc. for [$C_{13}H_9ClOS$] 248.0063, found: 248.0058.

Synthesis of 2-methoxy-8-(trifluoromethyl)dibenzo[*b*,*d*]thiophene (134c)



Prepared according to **TP13** from 2'-chloro-5-methoxy-5'-(trifluoromethyl)biphenyl-2-yl dimethyldithiocarbamate (406 mg, 1.00 mmol) and KO*t*Bu (337 mg, 3.00 mmol) at 50 °C for

4 h. Purification by flash chromatography (pentane/EtOAc; 20:1) yielded **134c** (271 mg, 96 %) as a colourless solid.

mp: 77.5 – 78.3 °C.

IR (ATR) $\tilde{\nu}$ (cm^{-1}): 1601, 1479, 1450, 1431, 1329, 1319, 1282, 1260, 1236, 1211, 1174, 1136, 1102, 1076, 1055, 1031, 1017, 887, 837, 806, 709, 668.

^{1}H-NMR (300 MHz, $CDCl_3$): δ = 8.31 (s, 1H, Ar*H*), 7.90 (dd, *J* = 8.4 Hz, *J* = 0.7 Hz, 1H, Ar*H*), 7.72 (d, *J* = 8.6 Hz, 1H, Ar*H*), 7.65 (dd, *J* = 8.6 Hz, *J* = 1.9 Hz, 1H, Ar*H*), 7.61 (d, *J* = 2.6 Hz, 1H, Ar*H*), 7.14 (dd, *J* = 8.6 Hz, *J* = 2.4 Hz, 1H, Ar*H*), 3.95 (s, 3H, CH_3).

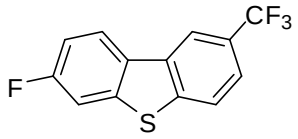
^{13}C-NMR (75 MHz, $CDCl_3$): δ = 158.0, 144.0, 135.8, 135.4, 131.7, 126.6 (q, ^{2}J(C,F) = 33 Hz), 124.6 (q, ^{1}J(C,F) = 272 Hz), 123.5, 123.3, 122.9 (q, ^{3}J(C,F) = 3.4 Hz), 118.5 (q, ^{3}J(C,F) = 4.0 Hz), 117.1, 104.8, 55.7.

^{19}F-NMR (282 MHz, $CDCl_3$): δ = –61.4.

MS (70 eV, EI): *m/z* (%) = 283 (15), 282 (100), 267 (46), 239 (47).

HRMS (EI): *m/z* calc. for [$C_{14}H_9F_3OS$] 282.0326, found: 282.0307.

Synthesis of 7-fluoro-2-(trifluoromethyl)dibenzo[*b*,*d*]thiophene (134d)



Prepared according to **TP13** from 2'-chloro-4-fluoro-5'-(trifluoromethyl)biphenyl-2-yl dimethyldithiocarbamate (355 mg, 0.90 mmol) and KO*t*Bu (303 mg, 2.80 mmol) at 50 °C for 4 h. Purification by flash chromatography (pentane) yielded **134d** (197 mg, 81 %) as a colourless solid.

mp: 101.4 – 102.8 °C.

IR (ATR) $\tilde{\nu}$ (cm^{-1}): 1600, 1563, 1484, 1423, 1337, 1274, 1240, 1194, 1183, 1139, 1103, 1082, 1066, 1052, 1013, 895, 863, 842, 807, 730, 711, 642.

^{1}H-NMR (300 MHz, $CDCl_3$): δ = 8.29 (s, 1H), 8.10 (dd, *J* = 8.8 Hz, *J* = 5.1 Hz, 1H), 7.90 (d, *J* = 8.5 Hz, 1H), 7.66 (dd, *J* = 8.5 Hz, *J* = 1.5 Hz, 1H), 7.53 (dd, *J* = 8.5 Hz, *J* = 2.2 Hz, 1H), 7.22 (dt, *J* = 8.2 Hz, *J* = 2.2 Hz, 1H).

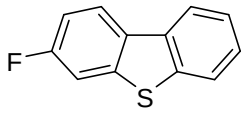
^{13}C-NMR (75 MHz, $CDCl_3$): δ = 162.2 (d, *J*(C,F) = 248 Hz), 142.6 (q, *J*(C,F) = 1.4 Hz), 141.1 (d, *J*(C,F) = 10.4 Hz), 134.7 (d, *J*(C,F) = 0.8 Hz), 131.1 (d, *J*(C,F) = 2.0 Hz), 127.3 (q, *J*(C,F) = 33.1 Hz), 123.2 (q, *J*(C,F) = 272 Hz), 123.1 (d, *J*(C,F) = 0.6 Hz), 122.9 (d, ^{1}J(C,F) = 9.3 Hz), 122.7 (dq, *J*(C,F) = 3.7 Hz, *J*(C,F) = 0.8), 118.2 (dq, *J*(C,F) = 4.1 Hz, *J*(C,F) = 0.8), 113.5 (d, *J*(C,F) = 23.8 Hz), 109.4 (d, *J*(C,F) = 25.5 Hz).

^{19}F-NMR (282 MHz, $CDCl_3$): δ = –61.5, –112.6.

MS (70 eV, EI): *m/z* (%) = 271 (17), 270 (100), 269 (11), 251 (21), 220 (15).

HRMS (EI): *m/z* calc. for [$C_{13}H_6F_4S$] 270.0126, found: 270.0112.

Synthesis of 3-fluorodibenzo[*b*,*d*]thiophene (134e)



Prepared according to **TP13** from 2'-chloro-4-fluorobiphenyl-2-yl dimethyldithiocarbamate (326 mg, 1.00 mmol) and KO*t*Bu (337 mg, 3.00 mmol) at 90 °C for 45 min using microwave irradiation. Purification by flash chromatography (pentane/Et_2O; 15:1) yielded **134e** (145 mg, 72 %) as a colourless solid.

mp: 104.5 – 105.6 °C.

IR (ATR) $\tilde{\nu}$ (cm^{-1}): 1602, 1582, 1566, 1478, 1440, 1396, 1310, 1239, 1184, 1127, 1049, 1021, 892, 840, 817, 752, 732.

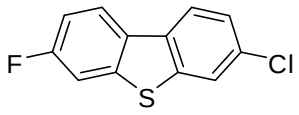
^{1}H-NMR (300 MHz, $CDCl_3$): δ = 8.11-8.04 (m, 2H), 7.86-7.80 (m, 1H), 7.53 (dd, *J* = 8.4 Hz, *J* = 2.4 Hz, 1H), 7.50-7.40 (m, 2H), 7.18 (dt, *J* = 8.8 Hz, *J* = 2.4 Hz, 1H).

^{13}C-NMR (75 MHz, $CDCl_3$): δ = 161.8 (d, ^{1}J(C,F) = 246 Hz), 140.7 (d, ^{3}J(C,F) = 9.8 Hz), 139.2 (d, ^{4}J(C,F) = 2.0 Hz), 134.8, 131.9, 126.3, 124.6, 122.7, 122.5 (d, ^{3}J(C,F) = 9.3 Hz), 121.2, 112.8 (d, ^{2}J(C,F) = 23.8 Hz), 109.2 (d, ^{2}J(C,F) = 25.5 Hz).

MS (70 eV, EI): *m/z* (%) = 203 (18), 202 (62), 199 (34), 155 (25), 127 (42), 123 (30), 114 (29), 111 (28), 97 (52), 85 (41), 83 (58), 71 (46), 70 (29), 69 (82), 57 (91), 56 (100).

HRMS (EI): *m/z* calc. for [$C_{12}H_7FS$] 202.0252, found: 202.0148.

Synthesis of 3-chloro-7-fluorodibenzo[*b*,*d*]thiophene (134f)



Prepared according to **TP13** from 2',4'-dichloro-4-fluorobiphenyl-2-yl dimethyldithiocarbamate (360 mg, 1.00 mmol) and KO*t*Bu (337 mg, 3.00 mmol) at 90 °C for 45 min using microwave irradiation. Purification by flash chromatography (pentane) yielded **134f** (185 mg, 78 %) as a colourless solid.

mp: 108.3 – 109.4 °C.

IR (ATR) $\tilde{\nu}$ (cm^{-1}): 1583, 1478, 1453, 1385, 1315, 1245, 1232, 1192, 1097, 1059, 891, 847, 793, 694.

^{1}H-NMR (300 MHz, $CDCl_3$): δ = 8.00 (dd, *J* = 8.8 Hz, *J* = 5.1 Hz, 1H), 7.93 (d, *J* = 8.5 Hz, 1H), 7.78 (d, *J* = 1.7 Hz, 1H), 7.49 (dd, *J* = 8.5 Hz, *J* = 2.2 Hz, 1H), 7.39 (dd, *J* = 8.5 Hz, *J* = 1.9 Hz, 1H), 7.17 (dd, *J* = 8.8 Hz, *J* = 2.2 Hz, 1H).

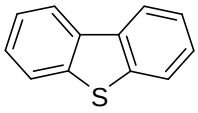
^{13}C-NMR (75 MHz, $CDCl_3$): δ = 161.9 (d, ^{1}J(C,F) = 247 Hz), 140.6 (d, ^{3}J(C,F) = 10.1 Hz), 140.4 (d, ^{5}J(C,F) = 1.9 Hz), 133.3 , 132.2 (d, ^{5}J(C,F) = 1.6 Hz), 131.1 (d, ^{4}J(C,F) = 2.2 Hz), 125.3, 122.6 (d, ^{3}J(C,F) = 9.3 Hz), 122.4 , 121.9, 113.2 (d, ^{2}J(C,F) = 24.0 Hz), 109.3 (d, ^{2}J(C,F) = 25.6 Hz).

^{19}F-NMR (282 MHz, $CDCl_3$): δ = –113.7.

MS (70 eV, EI): *m/z* (%) = 238 (31), 237 (12), 236 (100), 201 (10), 157 (12).

HRMS (EI): *m/z* calc. for [$C_{12}H_6ClFS$] 235.9863, found: 235.9856.

Synthesis of dibenzo[*b*,*d*]thiophene (134g)

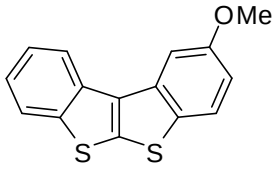


Prepared according to **TP14** from 2'-bromobiphenyl-2-yl dimethyldithiocarbamate (176 mg, 0.50 mmol) and *n*BuLi (0.23 mL, 2.44 M in hexane, 0.5 mmol). Purification by flash

chromatography (pentane/Et_2O; 9:1) yielded **134g** (82 mg, 89 %) as a colourless solid. The spectroscopic data match with the literature.[97]

^{1}H-NMR (300 MHz, $CDCl_3$): δ = 8.19-8.14 (m, 2H), 7.89-7.83 (m, 2H), 7.49-7.44 (m, 4H).
^{13}C-NMR (75 MHz, $CDCl_3$): δ = 139.4, 135.5, 126.7, 124.3, 122.8, 121.5.

Synthesis of 2-methoxy[1]benzothieno[2,3-*b*][1]benzothiophene (135b)

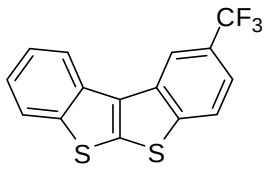


Prepared according to **TP14** from 3-(2-bromo-5-methoxyphenyl)-1-benzothien-2-yl dimethyldithiocarbamate (438 mg, 1.00 mmol) and *n*BuLi (0.42 mL, 2.48 M in hexane, 1.05 mmol). Purification by flash chromatography (pentane/EtOAc; 50:1) yielded **135b** (242 mg, 90 %) as a colourless solid.

mp: 108.7 – 109.6 °C.
IR (ATR) $\tilde{\nu}$ (cm^{-1}): 1597, 1588, 1562, 1554, 1482, 1461, 1444, 1426, 1397, 1312, 1281, 1275, 1255, 1226, 1220, 1145, 1130, 1124, 1052, 1030, 1021, 851, 842, 825, 811, 794, 758, 753, 724, 657, 625.
^{1}H-NMR (300 MHz, $CDCl_3$): δ = 8.24 (d, *J* = 8.0 Hz, 1H, Ar*H*), 7.86 (d, *J* = 8.0 Hz, 1H, Ar*H*), 7.76 (d, *J* = 2.4 Hz, 1H, Ar*H*), 7.72 (d, *J* = 8.8 Hz, 1H, Ar*H*), 7.50 (ddd, *J* = 7.3 Hz, *J* = 7.1 Hz, *J* = 1.1 Hz, 1H, Ar*H*), 7.37 (ddd, *J* = 7.3 Hz, *J* = 7.3 Hz, *J* = 1.3 Hz, 1H, Ar*H*), 7.02 (dd, *J* = 8.8 Hz, *J* = 2.4 Hz, 1H, Ar*H*), 3.97 (s, 3H, OCH_3).
^{13}C-NMR (75 MHz, $CDCl_3$): δ = 157.9, 143.5, 141.1, 135.5, 134.7, 134.4, 133.4, 124.8, 123.8, 123.7, 123.3, 120.9, 112.6, 105.1, 55.7.
MS (70 eV, EI): *m/z* (%) = 272 (10), 271 (18), 270 (100), 227 (54).
HRMS (EI): *m/z* calc. for [$C_{15}H_{10}OS_2$] 270.0173, found: 270.1063.

[97] G. K. S. Prakash, C. Weber, S. Chacko, G. A. Olah, *Org. Lett.* **2007**, *9*, 1863.

Synthesis of 2-(trifluoromethyl)[1]benzothieno[2,3-*b*][1]benzothiophene (135c)



Prepared according to **TP14** from 3-[2-bromo-5-(trifluoromethyl)phenyl]-1-benzothien-2-yl dimethyldithiocarbamate (477 mg, 1.00 mmol) and *n*BuLi (0.42 mL, 2.48 M in hexane, 1.05 mmol). Purification by flash chromatography (pentane) yielded **135c** (239 mg, 78 %) as a colourless solid.

mp: 130.5 – 132.0 °C.

IR (ATR) $\tilde{\nu}$ (cm^{-1}): 1489, 1479, 1437, 1323, 1312, 1271, 1253, 1170, 1139, 1107, 1069, 1053, 956, 874, 845, 816, 810, 757, 729, 720, 713, 703, 628.

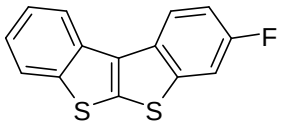
^{1}H-NMR (400 MHz, d8-THF): δ = 8.65 (s, 1H), 8.45 (d, J = 8.0 Hz, 1H), 8.16 (d, J = 8.4 Hz, 1H), 7.97 (dt, J = 8.2 Hz, J = 1.0 Hz, 1H), 7.69 (ddd, J = 8.6 Hz, J = 1.8 Hz, J = 0.6 Hz, 1H), 7.55 (ddd, J = 7.2 Hz, J = 1.2 Hz, 1H), 7.42 (ddd, J = 7.2 Hz, J = 1.2 Hz, 1H).

^{13}C-NMR (100 MHz, d8-THF): δ = 148.1 (d, ^{4}J(C,F) = 1.3 Hz), 144.6, 143.0, 135.4, 134.0, 133.8, 128.1 (d, ^{2}J(C,F) = 32 Hz), 126.0, 125.8 (d, ^{1}J(C,F) = 272 Hz), 125.3, 124.9, 124.2, 122.2, 121.0 (d, ^{3}J(C,F) = 3.7 Hz), 118.7 (d, ^{3}J(C,F) = 4.3 Hz),

MS (70 eV, EI): *m/z* (%) = 310 (11), 309 (19), 308 (100), 289 (6), 154 (6).

HRMS (EI): *m/z* calc. for [$C_{15}H_7F_3S_2$] 307.9941, found: 307.9935.

Synthesis of 3-fluoro[1]benzothieno[2,3-*b*][1]benzothiophene (135d)



Prepared according to **TP14** from 3-(2-bromo-5-fluorophenyl)-1-benzothien-2-yl dimethyldithiocarbamate (426 mg, 1.00 mmol) and *n*BuLi (0.42 mL, 2.48 M in hexane, 1.05 mmol). Purification by flash chromatography (pentane) yielded **135d** (214 mg, 83 %) as a colourless solid.

mp: 171.5 – 172.3 °C.

IR (ATR) $\tilde{\nu}$ (cm^{-1}): 1606, 1566, 1482, 1459, 1420, 1380, 1303, 1267, 1250, 1206, 1175, 1156, 1127, 1051, 1038, 1017, 939, 880, 852, 839, 809, 797, 751, 724, 715, 707, 647, 628.

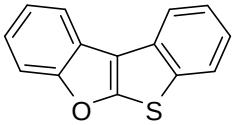
^{1}H-NMR (400 MHz, d8-THF): δ = 8.43 (m, 2H), 7.95 (ddd, *J* = 8.0 Hz, *J* = 0.8 Hz, 1H), 7.77 (dd, *J* = 9.0 Hz, *J* = 2.5 Hz, 1H), 7.51 (td, *J* = 7.2 Hz, *J* = 1.2 Hz, 1H), 7.39 (td, *J* = 7.2 Hz, *J* = 1.2 Hz, 1H), 7.32 (td, *J* = 8.8 Hz, *J* = 2.5 Hz, 1H).

^{13}C-NMR (100 MHz, d8-THF): δ = 161.0 (d, ^{1}J(C,F) = 243 Hz), 145.7 (d, ^{3}J(C,F) = 10.1 Hz), 144.6, 140.2 (d, ^{4}J(C,F) = 2.7 Hz), 135.2, 134.0, 131.0 (d, ^{1}J(C,F) = 2.0 Hz), 125.8, 124.9, 124.1, 122.9 (d, ^{3}J(C,F) = 9.0 Hz), 121.9, 114.0 (d, ^{2}J(C,F) = 23.8 Hz), 110.6 (d, ^{2}J(C,F) = 26.1 Hz),

MS (70 eV, EI): *m/z* (%) = 260 (10), 259 (15), 258 (100), 181 (9).

HRMS (EI): *m/z* calc. for [$C_{14}H_7FS_2$] 257.9973, found: 257.9969.

Synthesis of [1]benzothieno[2,3-*b*][1]benzofuran (136a)



Prepared according to **TP14** from 3-(2-bromophenyl)-1-benzofuran-2-yl dimethyldithiocarbamate (392 mg, 1.00 mmol) and *n*BuLi (0.49 mL, 2.14 M in hexane, 1.05

mmol). Purification by flash chromatography (pentane) yielded **136a** (167 mg, 74 %) as a colourless solid.

mp: 76.4 – 77.2 °C.

IR (ATR) $\tilde{\nu}$ (cm^{-1}): 1595, 1561, 1490, 1443, 1429, 1402, 1333, 1309, 1264, 1246, 1192, 1159, 1146, 1094, 1056, 1018, 1010, 964, 928, 758, 741, 723, 689.

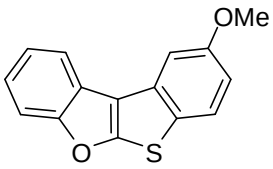
^{1}H-NMR (300 MHz, CDCl$_3$): δ = 8.05 (ddd, *J* = 7.8 Hz, *J* = 1.2 Hz, *J* = 0.7 Hz, 1H), 7.91 (ddd, *J* = 7.1 Hz, *J* = 1.9 Hz, *J* = 1.0 Hz, 1H), 7.82 (ddd, *J* = 8.3 Hz, *J* = 1.2 Hz, *J* = 0.7 Hz, 1H), 7.61 (ddd, *J* = 7.8 Hz, *J* = 1.7 Hz, *J* = 1.0 Hz, 1H), 7.50 (ddd, *J* = 8.0 Hz, *J* = 7.3 Hz, *J* = 1.2 Hz, 1H), 7.42-7.30 (m, 3H).

^{13}C-NMR (75 MHz, CDCl$_3$): δ = 160.6, 159.1, 138.3, 130.5, 125.3, 124.0, 123.9, 123.7, 123.6, 123.5, 121.4, 119.9, 119.1, 111.9.

MS (70 eV, EI): *m/z* (%) = 225 (14), 224 (100), 196 (11), 195 (12), 152 (19).

HRMS (EI): *m/z* calc. for [$C_{14}H_8OS$] 224.0296, found: 224.0292.

Synthesis of 9-methoxy[1]benzothieno[2,3-*b*][1]benzofuran (136b)



Prepared according to **TP14** from 3-(2-bromo-5-methoxyphenyl)-1-benzofuran-2-yl dimethyldithiocarbamate (422 mg, 1.00 mmol) and *n*BuLi (0.49 mL, 2.14 M in hexane, 1.05 mmol). Purification by flash chromatography (pentane/EtOAc; 25:1) yielded **136b** (193 mg, 76 %) as a colourless solid.

mp: 121.8 – 122.9 °C.

IR (ATR) $\tilde{\nu}$ (cm^{-1}): 1594, 1561, 1518, 1491, 1457, 1440, 1414, 1381, 1333, 1288, 1269, 1225, 1192, 1179, 1125, 1096, 1024, 1012, 920, 838, 827, 811, 800, 736, 715, 649.

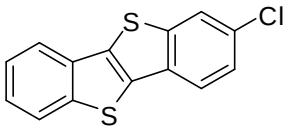
^{1}H-NMR (300 MHz, CDCl$_3$): δ = 7.90-7.85 (m, 1H), 7.67 (d, *J* = 8.8 Hz, 1H), 7.62-7.57 (m, 1H), 7.51 (d, *J* = 2.7 Hz, 1H), 7.41-7.29 (m, 2H), 6.97 (dd, *J* = 8.8 Hz, *J* = 2.4 Hz, 1H), 3.94 (s, 3H).

^{13}C-NMR (75 MHz, $CDCl_3$): δ = 160.5, 160.2, 158.2, 131.4, 130.0, 124.5, 123.9, 123.48, 123.45, 119.8, 118.9, 112.1, 111.9, 105.6, 55.7.

MS (70 eV, EI): *m/z* (%) = 255 (17), 254 (100), 211 (29), 139 (13).

HRMS (EI): *m/z* calc. for [$C_{15}H_{10}O_2S$] 254.0402, found: 254.0386.

Synthesis of 2-chloro[1]benzothieno[3,2-*b*][1]benzothiophene (137)



Prepared according to **TP13** from 2-(2,4-dichlorophenyl)-1-benzothien-3-yl dimethyldithiocarbamate (398 mg, 1.00 mmol) and KO*t*Bu (337 mg, 3.00 mmol) at 50 °C for 24 h. Purification by flash chromatography (pentane) yielded **137** (200 mg, 73 %) as a colourless solid.

mp: 208.9 – 209.4 °C.

IR (ATR) $\tilde{\nu}$ (cm^{-1}): 1538, 1426, 1343, 1332, 1286, 1251, 1242, 1133, 1096, 1052, 950, 864, 804, 774, 746, 724, 707, 683.

^{1}H-NMR (400 MHz, d8-THF): δ = 8.07 (dd, *J* = 2.0 Hz, *J* = 0.6 Hz, 1H, Ar*H*), 8.01-7.97 (m, 1H, Ar*H*), 7.95-7.88 (m, 2H, Ar*H*), 7.50-7.40 (m, 3H, Ar*H*).

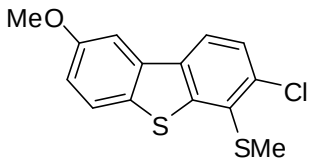
^{13}C-NMR (100 MHz, d8-THF): δ = 144.4, 143.3, 134.8, 133.8, 133.7, 132.6, 131.7, 126.5, 126.3, 126.0, 124.9, 124.6, 123.2, 122.3.

MS (70 eV, EI): *m/z* (%) = 276 (38), 275 (15), 274 (100), 239 (7), 195 (9), 137 (9),

HRMS (EI): *m/z* calc. for [$C_{14}H_7ClS_2$] 273.9678, found: 273.9671.

9.5 Metalation of Functionalized Dibenzothiophens

Synthesis of 7-chloro-2-methoxy-6-(methylthio)dibenzo[*b*,*d*]thiophene (151a)



A dry and argon-flushed Schlenk-flask, equipped with a magnetic stirring bar and a septum, was charged with 7-chloro-2-methoxydibenzo[*b*,*d*]thiophene (75 mg, 0.30 mmol) and 1.2 mL THF. After cooling to –78 °C, *n*BuLi (0.15 mL, 2.14 M in hexane, 0.32 mmol) was added dropwise and stirred for 1 h. Then, dimethyl disulfide (34 mg, 0.36 mmol) was added and the resulting mixture was gradually warmed up to 25 °C within 12 h. Thereafter, the crude reaction mixture was concentrated under reduced pressure. Purification by flash chromatography (pentane/Et_2O; 9:1) yielded **151a** (72 mg, 81 %) as a colourless solid.

mp: 130.8 – 132.3 °C.

IR (ATR) $\tilde{\nu}$ (cm^{-1}): 1608, 1561, 1541, 1463, 1449, 1429, 1365, 1305, 1288, 1242, 1216, 1177, 1155, 1139, 1037, 1022, 972, 964, 875, 823, 793, 785, 642, 627.

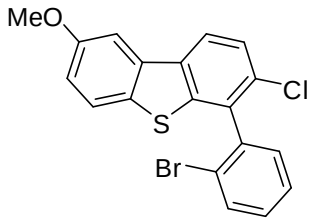
^{1}H-NMR (300 MHz, $CDCl_3$): δ = 7.93 (d, *J* = 8.4 Hz, 1H, Ar*H*), 7.72 (dd, *J* = 8.8 Hz, *J* = 0.6 Hz, 1H, Ar*H*), 7.52-7.49 (m, 2H, Ar*H*), 7.10 (dd, *J* = 8.8 Hz, *J* = 2.5 Hz, 1H, Ar*H*), 3.92 (s, 3H, CH_3), 2.53 (s, 3H, CH_3).

^{13}C-NMR (75 MHz, $CDCl_3$): δ = 157.8, 149.3, 137.3, 136.8, 134.1, 132.0, 128.1, 126.2, 123.5, 122.2, 116.2, 105.0, 55.7, 17.9.

MS (70 eV, EI): *m/z* (%) = 296 (42), 295 (18), 294 (100), 281 (18), 279 (43), 251 (14), 201 (17).

HRMS (EI): *m/z* calc. for [$C_{14}H_{11}ClOS_2$] 293.9940, found: 293.9934

Synthesis of 6-(2-bromophenyl)-7-chloro-2-methoxydibenzo[*b*,*d*]thiophene (151b)



A dry and argon-flushed Schlenk-flask, equipped with a magnetic stirring bar and a septum, was charged with 7-chloro-2-methoxydibenzo[*b*,*d*]thiophene (995 mg, 4.00 mmol) and 16 mL THF. After cooling to –78 °C, *n*BuLi (2.00 mL, 2.14 M in hexane, 4.40 mmol) was added dropwise and stirred for 1 h. Then, $ZnCl_2 \cdot 2LiCl$ (4.4 mL, 1.00 M in THF, 4.40 mmol) was added and the resulting mixture was warmed up to –20 °C and stirred for 30 min. A dry and argon flushed Schlenk-flask, equipped with a magnetic stirring bar and septum was charged with 1-bromo-2-iodobenzene (1.36 g, 4.8 mmol), $Pd(dba)_2$ (92 mg, 0.16 mmol) and tfp (74 mg, 0.32 mmol) in 5 mL THF. The zinc reagent was added dropwise over 90 min at 50 °C and the resulting mixture was stirred for additional 12 h at 50 °C. The crude reaction mixture was cooled to 25 °C, quenched with sat. NH_4Cl solution (50 mL) and extracted with CH_2Cl_2 (3 x 100 mL). The combined organic layer was dried ($MgSO_4$), filtered, and concentrated under reduced pressure. Purification by flash chromatography (pentane/EtOAc; 20:1) yielded **151b** (1.02 g, 63 %) as a colourless solid.

mp: 151.9 – 152.8 °C.

IR (ATR) $\tilde{\nu}$ (cm^{-1}): 1602, 1561, 1483, 1466, 1434, 1371, 1328, 1295, 1276, 1249, 1228, 1218, 1177, 1137, 1129, 1046, 1024, 1010, 907, 810, 800, 750, 725, 699, 669, 651, 640.

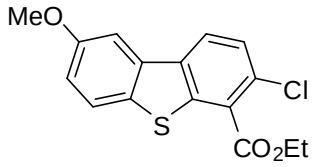
^{1}H-NMR (300 MHz, $CDCl_3$): δ = 8.04 (d, *J* = 8.6 Hz, 1H, Ar*H*), 7.80-7.75 (m, 1H, Ar*H*), 7.61 (d, *J* = 7.4 Hz, 1H, Ar*H*), 7.59 (s, 1H, Ar*H*), 7.57 (d, *J* = 8.4 Hz, 1H, Ar*H*), 7.51-7.44 (m, 1H, Ar*H*), 7.40-7.33 (m, 2H, Ar*H*), 7.08 (dd, *J* = 8.8 Hz, *J* = 2.6 Hz, 1H, Ar*H*), 3.94 (s, 3H, CH_3).

^{13}C-NMR (75 MHz, $CDCl_3$): δ = 157.9, 143.0, 138.6, 136.3, 134.23, 134.16, 133.1, 131.9, 131.6, 130.8, 130.2, 127.8, 125.7, 123.6, 123.4, 121.8, 116.1, 105.0, 55.7.

MS (70 eV, EI): *m/z* (%) = 406 (24), 405 (19), 404 (100), 403 (14), 402 (70), 389 (14), 387 (11), 361 (13), 359 (11), 323 (17), 288 (10), 245 (24).

HRMS (EI): *m/z* calc. for [$C_{19}H_{12}BrClOS$] 401.9481, found: 401.9474.

Synthesis of ethyl 3-chloro-8-methoxydibenzo[*b,d*]thiophene-4-carboxylate (151c)



A dry and argon-flushed Schlenk-flask, equipped with a magnetic stirring bar and a septum, was charged with 7-chloro-2-methoxydibenzo[*b,d*]thiophene (75 mg, 0.30 mmol) and 1.2 mL THF. After cooling to –78 °C, *n*BuLi (0.15 mL, 2.14 M in hexane, 0.32 mmol) was added dropwise and stirred for 1 h. Then, ethyl chloroformat (39 mg, 0.36 mmol) was added and the resulting mixture was gradually warmed up to 25 °C within 1 h. Thereafter, the crude reaction mixture was concentrated under reduced pressure. Purification by flash chromatography (pentane/Et_2O; 9:1) yielded **151c** (80 mg, 83 %) as a colourless solid.

mp: 111.5 – 112.7 °C.

IR (ATR) $\tilde{\nu}$ (cm^{-1}): 1680, 1607, 1564, 1550, 1466, 1437, 1375, 1358, 1317, 1304, 1287, 1271, 1240, 1221, 1166, 1154, 1115, 1052, 1025, 1015, 867, 827, 788, 642, 618.

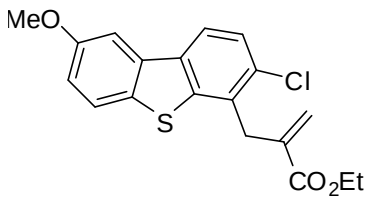
^{1}H-NMR (300 MHz, $CDCl_3$): δ = 8.02 (d, *J* = 8.5 Hz, 1H, Ar*H*), 7.69 (d, *J* = 8.8 Hz, 1H, Ar*H*), 7.50 (d, *J* = 2.4 Hz, 1H, Ar*H*), 7.47 (d, *J* = 8.5 Hz, 1H, Ar*H*), 7.10 (dd, *J* = 8.8 Hz, *J* = 2.4 Hz, 1H, Ar*H*), 4.54 (q, *J* = 7.1 Hz, 2H, CH_2CH$_3$), 3.91 (s, 3H, OCH_3), 1.50 (t, *J* = 7.1 Hz, 3H, CH$_2$CH_3).

^{13}C-NMR (75 MHz, $CDCl_3$): δ = 165.3, 157.8, 143.4, 134.98, 134.95, 132.8, 132.6, 127.20, 127.19, 124.3, 123.1, 116.5, 104.6, 62.1, 55.7, 14.3.

MS (70 eV, EI): *m/z* (%) = 322 (38), 321 (19), 320 (100), 294 (14), 292 (33), 279 (11), 277 (31), 275 (18), 249 (18), 247 (12).

HRMS (EI): *m/z* calc. for [$C_{16}H_{13}ClO_3S$] 320.0274, found: 320.0262.

Synthesis of ethyl 2-[(3-chloro-8-methoxydibenzo[*b,d*]thien-4-yl)methyl]acrylate (151d)



A dry and argon-flushed Schlenk-flask, equipped with a magnetic stirring bar and a septum, was charged with 7-chloro-2-methoxydibenzo[*b*,*d*]thiophene (75 mg, 0.30 mmol) and 1.2 mL THF. After cooling to –78 °C, *n*BuLi (0.15 mL, 2.14 M in hexane, 0.32 mmol) was added dropwise and stirred for 1 h. Then, $ZnCl_2 \cdot 2LiCl$ (0.33 mL, 1.00 M in THF, 0.33 mmol) was added and the resulting mixture was warmed up to –20 °C and stirred for 30 min. Thereafter, CuCN·2LiCl (0.03 mL, 1.00 M in THF, 0.03 mmol) and ethyl 2-(bromomethyl)acrylate (69 mg, 0.36 mmol) were added and the resulting mixture was gradually warmed up to 25 °C within 1 h. The crude reaction mixture was concentrated under reduced pressure. Purification by flash chromatography (pentane/Et_2O; 9:1) yielded **151d** (102 mg, 94 %) as a colourless solid.

mp: 72.0 – 73.1 °C.

IR (ATR) $\tilde{\nu}$ (cm^{-1}): 1701, 1632, 1601, 1459, 1439, 1387, 1369, 1294, 1276, 1225, 1207, 1173, 1136, 1093, 1060, 1050, 1023, 955, 939, 853, 817, 803, 791, 773, 640.

^{1}H-NMR (300 MHz, $CDCl_3$): δ = 7.92 (d, *J* = 8.5 Hz, 1H, Ar*H*), 7.67 (dd, *J* = 8.7 Hz, *J* = 0.5 Hz, 1H, Ar*H*), 7.55 (d, *J* = 2.4 Hz, 1H, Ar*H*), 7.47 (d, *J* = 8.5 Hz, 1H, Ar*H*), 7.08 (dd, *J* = 8.8 Hz, *J* = 2.4 Hz, 1H, Ar*H*), 6.21-6.19 (m, 1H), 5.10-5.08 (m, 1H), 4.30 (q, *J* = 7.3 Hz, 2H, C*H*$_2$CH$_3$), 4.04 (t, *J* = 1.9 Hz, 2H, C*H*$_2$), 3.92 (s, 3H, OC*H*$_3$), 1.35 (t, *J* = 7.3 Hz, 3H, CH$_2$C*H*$_3$).

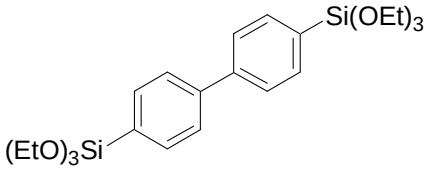
^{13}C-NMR (75 MHz, $CDCl_3$): δ = 166.7, 157.9, 143.0, 136.5, 135.8, 134.4, 132.8, 131.3, 130.4, 126.0, 125.1, 123.5, 120.8, 116.1, 105.0, 61.0, 55.7, 34.4, 14.2.

MS (70 eV, EI): *m/z* (%) = 362 (39), 361 (22), 360 (100), 325 (32), 297 (46), 296 (15), 288 (13), 286 (36), 279 (27), 253 (10), 252 (24), 251 (29), 237 (10), 209 (14), 208 (11).

HRMS (EI): *m/z* calc. for [$C_{19}H_{17}ClO_3S$] 360.0587, found: 360.0575.

10. Synthesis of Bis(trialkoxysilyl)biphenyls as Precursors for Periodic Mesopourous Silica

Synthesis of biphenyl-4,4'-diylbis(triethoxysilane) (155a)



A dry and argon-flushed Schlenk-flask, equipped with a magnetic stirring bar and a septum, was charged with 4,4'-diiodobiphenyl (8.12 g, 20.0 mmol) and 40 mL THF. After cooling to 0 °C, *i*PrMgCl·LiCl (33.2 mL, 1.32 M in THF, 44 mmol) was added dropwise and stirred for 45 min. Then, the reaction mixture was cannulated under argon to neat $Si(OEt)_4$ (20.8 g, 100 mmol) at 0 °C. The mixture was allowed to warm up to 25 °C within 1.5 h. The crude reaction mixture was diluted with pentane (250 mL) and washed with NH_4Cl solution (5 %; 100 mL). The organic layer was dried ($MgSO_4$), filtered, and concentrated under reduced pressure. Purification by flash chromatography (pentane/Et_2O; 9:1) yielded **155a** (3.92 g, 41 %) as a colourless oil.

IR (ATR) $\tilde{\nu}$ (cm^{-1}): 2974, 2925, 2886, 1600, 1389, 1295, 1165, 1128, 1094, 1070, 1004, 956, 807, 776, 732.

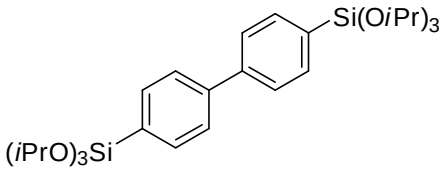
^{1}H-NMR (300 MHz, $CDCl_3$): δ = 7.74 (d, *J* = 8.3 Hz, 4H, Ar*H*), 7.62 (d, *J* = 8.3 Hz, 4H, Ar*H*), 3.89 (q, *J* = 7.0 Hz, 12H, 6 x C*H*$_2$CH$_3$), 1.26 (q, *J* = 7.0 Hz, 18H, 6 x CH$_2$C*H*$_3$).

^{13}C-NMR (75 MHz, $CDCl_3$): δ = 142.7, 135.3, 129.9, 126.6, 58.8, 18.3.

MS (70 eV, EI): *m/z* (%) = 480 (13), 479 (30), 478 (87), 433 (25), 406 (14), 405 (40), 377 (17), 361 (33), 343 (18), 271 (16), 253 (14), 194 (16), 187 (16), 181 (16), 163 (39), 147 (100), 130 (19), 119 (35), 118 (17).

HRMS (EI): *m/z* calc. for [$C_{24}H_{38}O_6Si_2$] 478.2207, found: 478.2202

Synthesis of biphenyl-4,4'-diylbis(triisopropoxysilane) (155b)



A dry and argon-flushed Schlenk-flask, equipped with a magnetic stirring bar and a septum, was charged with 4,4'-diiodobiphenyl (20.3 g, 50.0 mmol) and 100 mL THF. After cooling to 0 °C, *i*PrMgCl·LiCl (90 mL, 1.22 M in THF, 110 mmol) was added dropwise and stirred for 45 min. Then, the reaction mixture was cannulated under argon to neat $SiCl_4$ (34.0 g, 200 mmol) at 0 °C. The mixture was allowed to warm up to 25 °C within 1.5 h. All solvents were removed under vacuum to complete dryness. The mixture was redissolved in THF (200 mL) and was added dropwise to a solution of *i*PrOH (34.5 g, 600 mmol) and NEt_3 (58.3 g, 600 mmol) in 120 mL dry THF. After complete addition, the reaction mixture was warmed up to 25 °C and stirred for additional 2 h. The crude reaction mixture was diluted with Et_2O (400 mL) and washed with sat. NaCl solution (150 mL). The aqueous layer was reextracted with Et_2O (2 x 100 mL). The combined organic layers were dried ($MgSO_4$), filtered, and concentrated under reduced pressure. Purification by flash chromatography (pentane/Et_2O; 20:1) yielded **155b** (16.1 g, 57 %) as a colourless solid.

mp: 76.4 – 77.2 °C.

IR (ATR) $\tilde{\nu}$ (cm^{-1}): 2966, 1749, 1716, 1597, 1463, 1447, 1380, 1367, 1220, 1171, 1114, 1021, 1000, 887, 871, 809, 768, 752, 721.

^{1}H-NMR (300 MHz, $CDCl_3$): δ = 7.75 (d, *J* = 7.9 Hz, 4H, Ar*H*), 7.61 (d, *J* = 7.9 Hz, 4H, Ar*H*), 4.29 (sept, *J* = 6.0 Hz, 6H, C*H*(CH_3)$_2$), 1.23 (d, *J* = 6.0 Hz, 36H, CH(C*H*$_3$)$_2$).

^{13}C-NMR (75 MHz, $CDCl_3$): δ = 142.4, 135.4, 131.8, 126.4, 65.5, 25.6.

MS (70 eV, EI): *m/z* (%) = 563 (13), 562 (29), 547 (10), 503 (16), 489 (10), 420 (20), 419 (64), 335 (11), 293 (12), 275 (12), 205 (19), 204 (68), 202 (19), 190 (19), 189 (72), 181 (16), 162 (11), 161 (20), 146 (11), 139 (23), 138 (100).

HRMS (EI): *m/z* calc. for [$C_{30}H_{50}O_6Si_2$] 562.3146, found: 562.3142

D

APPENDIX

1. Curriculum Vitae

Marcel Patrik Kienle

Personal informations

*2.1.1981	in Stuttgart-Bad Cannstatt
Citizenship:	German
Maritial Status:	married

Education

1987-1991	Primary school (Johannes-Keppler-Schule), Magstadt
1991-2000	High school “Stiftgymnasium” Sindelfingen
06/2000	Graduation (Abitur; main subjects: mathematics/chemistry; grade: 1.5)
07/2000-05/2001	alternative civilian service
10/2001-01/2006	Studies in Chemistry at the Universität Stuttgart, diploma examinations 09/2005-01/2006
02/2006-08/2006	Diploma thesis on “Aerobic oxidations using flavin mimetica” in the group of Prof. Dr. S. Laschat. (Allover diploma average grade: 1.2)
09/2006-03/2010	PhD thesis in the group of Prof. Dr. P. Knochel on “Oxidative and Transition-Metal Catalyzed Cross-Coupling Reactions, Preparation and Coupling of S-Heterocycles”

Languages

German	mother tongue
English	fluently
Swedish	basic

Work experience and internships

10/2004-03/2005	Organisch-Chemisches Fortgeschrittenen Praktikum with Prof. Dr. P. Somfai (Royal Institute of Technology, Stockholm, Sweden).

Awards

2007	Römer Fellowship

Extracrricular Activities

Interests	Skiing, reading, traveling

Publications

1 "1,3-Dipolar Cycloadditions of Carbonyl Ylides to Aldimines: A Three Component Approach to *syn*-α-Hydroxy-β-Amino Esters"
S. Torssell, **M. Kienle**, P. Somfai, *Angew. Chem. Int. Ed*. **2005**, *44*, 3096.

2 "A Practical Synthetic Procedure for the Preparation of Tertiary Amines via the Oxidative Coupling of Polyfunctional Aryl and Heteroaryl Amidocuprate"
M. Kienle, S. R. Dubbaka, V. del Amo, P. Knochel, *Synthesis*, **2007**, 1272.

3 "Modern Amination Reactions"
M. Kienle, S. R. Dubbaka, K. Brade, P. Knochel, *Eur. J. Org. Chem.* **2007**, 4166.

4 "Copper(I)-Mediated Oxidative Cross-Coupling Between Polyfunctional Alkynyllithium and Arylmagnesium Reagents"
S. R. Dubbaka, **M. Kienle**, H. Mayr, P. Knochel, *Angew. Chem. Int. Ed.* **2007**, *46*, 9093.

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