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An Easy and Multigram-Scale Synthesis of Versatile AA- and AB-Type *m*-Terphenylenes as Building Blocks for Kinked Polyphenylenes

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A set of *m*-terphenylenes having a readily functionalizable hydroxy group as well as either symmetric AA-type or unsymmetric AB-type halide termini have been prepared on a several-gram scale. The synthesis was carried out on the basis of the Suzuki–Miyaura cross-coupling in combination with a TMS masking strategy.

Introduction

Oligo- and polyphenylenes attract increasing interest not only in academic research but also for industrial applications due to their useful mechanical and optoelectronic properties.[1] These properties are largely attributed to the structure of the main chains, which are potentially conjugated, inherently stiff and also chemically stable. We here report an easy and scalable synthesis of *m*-terphenylenes having a readily functionalizable benzylic OH group as well as symmetric AA-type and unsymmetric AB-type halide termini (Figure 1). Due to their kinked shape, *m*-terphenylenes are a key motif particularly in the skeletons of phenylene-based macrocycles,[2] foldamers[3] as well as tough amorphous polymers,[4] etc. For polymer synthesis, they have additional potential as monomers for the Suzuki polycondensation (SPC).[1,5]

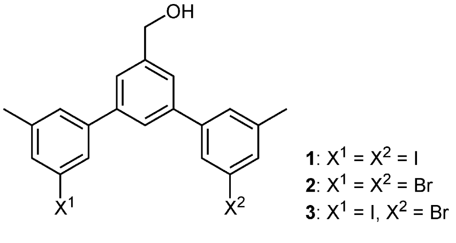

Figure 1. Target *m*-terphenylene structures possessing a free benzylic OH group as well as symmetric AA-type (**1** and **2**) or unsymmetric AB-type (**3**) termini.

Results and Discussion

Building blocks for the central part of the *m*-terphenylenes **1**–**3** (Figure 1) were **5** (for symmetric **1** and **2**) and **6** (for unsymmetric **3**) and prepared according to a known procedure[6] adjusted to the present large-scale synthesis (Scheme 1a). Starting from the commercially available compound **4**, product **5** was obtained by bromination, deamination, and then reduction of the benzoate to the corresponding benzylic alcohol. Note that each of these steps proceeded nearly quantitative, and the products were easily separated by recrystallization without any chromatographic purification. This facilitated the synthesis and obtainment of analytically pure **5** on a large scale (50 g). A portion of **5** was further converted to **6**, which was needed for the synthesis of the unsymmetric **3**.[7] The synthesis of **6** involved subsequently protection of benzylic OH with the tetrahydro-2*H*-pyran-2-yl (THP) group, silylation at one of the brominated carbon atoms, and borylation at the other one. Analytically pure **6** was obtained on a 25 g scale.

On the other hand, "cornerstones" **9** (for **1**–**3**) and **10** (for **3**) were prepared according to rather simple procedures (Scheme 1b). First, an efficient silylation took place at one of the brominated carbon atoms of the commercially available dibromo compound **7**. This was achieved through lithiation and subsequent quenching with trimethylsilyl chloride (TMSCl). For **10**, this TMS group was further replaced to afford the corresponding iodide (14 g) by reaction with iodine monochloride (ICl).[2] Product **9** (37 g) was prepared by borylation at the remaining bromide of **8** through lithiation.

The obtained building blocks **5**, **6**, **9**, and **10** were assembled into the *m*-terphenylenes **1**–**3** by using the Suzuki–Miyaura cross-coupling (SMC) protocol. For the symmetric **1** (Scheme 2a), compound **5** was subjected to a double SMC with 2 equiv. of **9** to afford **11** (21 g) very efficiently. Product **11** was also found to be recrystallizable from hexane. A por-

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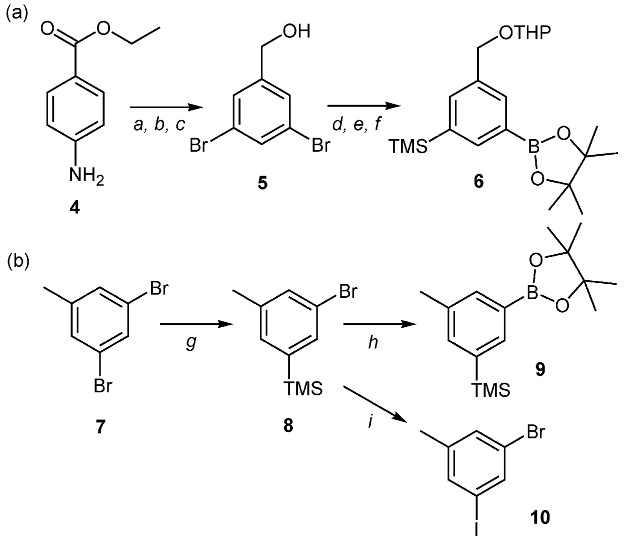
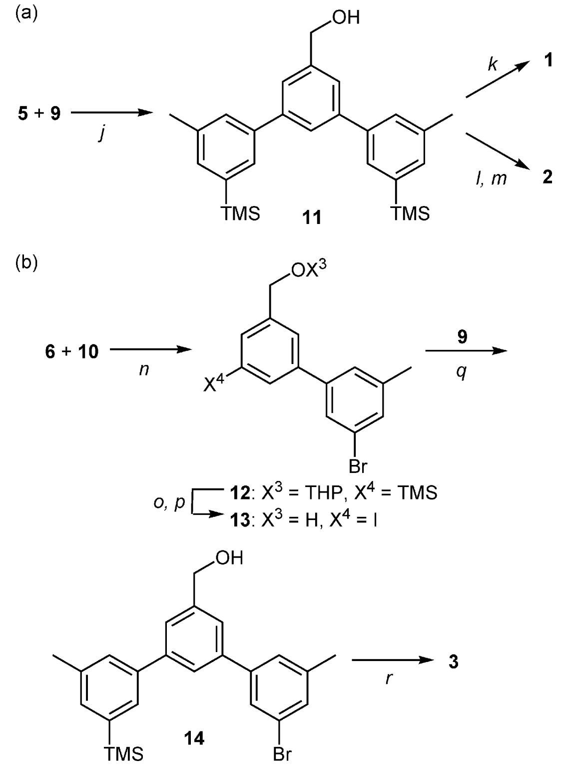


Scheme 1. Synthetic procedure to prepare building blocks for (a) the central parts, **5** (for symmetric **1** and **2**) and **6** (for unsymmetric **3**), as well as those for (b) the side parts, **9** (for **1**–**3**) and **10** (for **3**). *a*: Br_2, AcOH, 88%; *b*: $NaNO_2$, H_2SO_4, 69%; *c*: $LiAlH_4$, ether, 87%; *d*: 3,4-dihydro-2*H*-pyran, TsOH, dichloromethane, 98%; *e*: 1) BuLi, diethyl ether, 2) TMSCl, 93%; *f*: 1) BuLi, THF/diethyl ether, 2) B(O*i*Pr)$_3$, 3) pinacol, toluene, 65%; *g*: 1) BuLi, THF, 2) TMSCl. 93%; *h*: 1) BuLi, THF/diethyl ether, 2) B(OMe)$_3$, 3) pinacol, toluene, 67%; *i*: ICl, dichloromethane, 95%.

tion of **11** was then converted into the corresponding diiodide to obtain **1** by reaction with a stoichiometric amount of ICl. Note that the benzylic OH group was kept unprotected here for the ease of synthesis. However, it could be replaced with chloride in varying degrees particularly when excess amounts of ICl were used. During the conversion of **11** to **2** with *N*-bromosuccinimide/NaBr,[8] the oxidation of the alcohol functionality to the corresponding aldehyde could be observed. To retard this side reaction, the benzylic OH group was acetylated prior to the TMS/Br exchange, while the acetyl group was incidentally removed to afford **2** directly.[9] Thus, analytically pure products **1** and **2** were obtained on 7 g and 4 g scales, respectively, by recrystallization from ethyl acetate.

For the synthesis of **3** with its more complex unsymmetric structure, a stepwise procedure was employed (Scheme 2b).[10] Compound **6** was first subjected to SMC with **10** to afford **12** (14 g). Note that this reaction selectively proceeded to give **12** by exploiting the significant reactivity difference between iodo and bromo aromatics in palladium-mediated cross-coupling.[10] This was followed successively by deprotection of the THP group and TMS/I exchange using a stoichiometric amount of ICl. Product **13** was then subjected to a second SMC with **9** to furnish **14** followed by iodation again with a stoichiometric amount of ICl. The unsymmetric **3** with AB-type termini was obtained on a 4 g scale. Note that **3** was also found to be recrystallizable from ethyl acetate, which guaranteed a purity high enough (> 99%) for these compounds to be considered as monomers for SPC.[1a]



Scheme 2. Synthesis of the target *m*-terphenylenes **1**–**3** from the building blocks **5**, **6**, **9**, **10** by using the Suzuki–Miyaura cross-coupling in combination with a TMS masking strategy. *j*: Pd(PPh$_3$)$_4$, Na_2CO_3, toluene/water, 97%; *k*: ICl, dichloromethane, 87%; *l*: Ac_2O, pyridine, dichloromethane, 92%; *m*: NBS, NaBr, methanol, 76%; *n*: Pd(PPh$_3$)$_4$, Na_2CO_3, TBAB, toluene/water, 75%; *o*: TsOH, MeOH/dichloromethane, 98%; *p*: ICl, dichloromethane, 93%; *q*: Pd(PPh$_3$)$_4$, Na_2CO_3, TBAB, toluene/water, 42%;[12] *r*: ICl, dichloromethane, 80%.

Conclusions

A set of *m*-terphenylenes **1**–**3**, which are equipped with either symmetric AA-type or unsymmetric AB-type termini have been prepared. These compounds are considered to be used for novel polymer synthesis: the former can copolymerize with other BB-type monomers having e.g. diboron functionalities, whereas the latter can serve as a precursor of monomers having e.g. one bromo and one boron functionality which are able to homopolymerize by SPC.[11] The synthesis of **1**–**3** was carried out by using the SMC in combination with a TMS masking strategy,[2] and the target compounds have been obtained on multigram scales eventually. These compounds also carry a free benzylic OH group, which opens a variety of options for further functionalizations. Investigations aiming at polymer synthesis are now in progress.[5]

Supporting Information (see footnote on the first page of this article): All experimental procedures and NMR and MS data.

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(ETH Zurich) for mass measurements, and Dr. T. Wigglesworth (ETH Zurich) for drawing our attention to ref.[8] Financial support by the ETH Zurich grant (TH-05 07-1) is gratefully acknowledged.

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[5] Polymer synthesis with these compounds as monomers is to be published elsewhere.

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[9] The acetyl protection actually helped to retard the oxidation to achieve an improved yield of the desired product **2**, while the formation of the aldehyde was not fully suppressed nevertheless. However, this side product can be reduced back to **2** by treatment with $NaBH_4$ (see ref.[12]).

[10] See for example: a) D. M. Opris, P. Franke, A. D. Schlüter, *Eur. J. Org. Chem.* **2005**, 822–837; b) J. Sakamoto, A. D. Schlüter, *Eur. J. Org. Chem.* **2007**, 2700–2712.

[11] Selective borylation at the iodated terminus is feasible.

[12] This rather low yield of **14** is presumably due to an aged catalyst batch which happened to be used for this particular experiment. This caused unexpected oxidation at the benzyl alcohol as detrimental side reaction. However, the resultant aldehyde was quantitatively reduced back to **14** by treatment with $NaBH_4$ in a mixed solvent of ethanol/THF (1:1).

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