

# New ABC Core for the Synthesis of Nonsymmetric Star Molecules

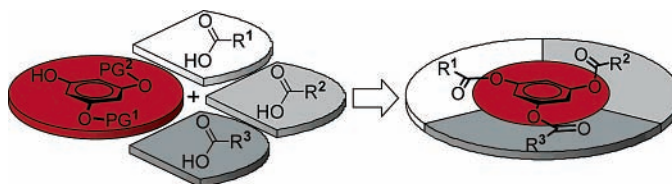
Matthias Lehmann\* and Michael Jahr

Institute of Chemistry, Chemnitz University of Technology, Strasse der Nationen 62,  
09111 Chemnitz, Germany

Matthias.Lehmann@chemie.tu-chemnitz.de

Received November 25, 2005

## ABSTRACT



An ABC core has been synthesized, with two orthogonal protecting groups (PG). This new multifunctional unit allows building of star-shaped molecules with up to three different moieties. The synthesis of a star-shaped mesogen based on an oligobenzoate scaffold with three arms of different lengths is demonstrated.

Dendritic and star-shaped molecules are recently of high interest in materials science because these multiarm compounds are applied for optoelectronic devices,<sup>1</sup> for drug delivery,<sup>2</sup> in catalysis,<sup>2,3</sup> and also in liquid crystal science.<sup>4,5</sup> Many of these materials have a 3-fold functional core with a 1,3,5-substituted benzene ring, most of them with a uniform periphery. Modification of the lateral groups has either been realized statistically, converting peripheral functional groups with a mixture of reagents,<sup>6</sup> or been more elaborated by using readily available multifunctional cores connecting different dendrons.<sup>7</sup> In this way, Janus molecules have been reported

with new amphiphilic properties.<sup>8</sup> More complex ABC star systems have been synthesized in the series of heteroarm triblock copolymers and were shown to assemble in various columnar structures.<sup>9</sup> Theoretical studies predict numerous new morphologies in such materials, if the interaction and size of the branches can be controlled.<sup>10</sup> Low molar mass star compounds related to the latter block copolymers are not known.<sup>11</sup> However, somewhat different molecules, the so-called bolaamphiphiles, with three incompatible building blocks have been shown to form many new mesophase morphologies.<sup>12</sup> The synthesis of star-shaped molecules with three dissimilar scaffolds connected to the center is highly interesting with respect to the control of their supramolecular

(1) (a) Meier, H.; Lehmann, M. In *Encyclopedia of Nanoscience and Nanotechnology*; American Scientific Publishers: Stevenson Ranch, 2004; Vol. 10, 95. (b) Pomarenko, S. A.; Kirchmeyer, S.; Elscher, A.; Huisman, B.-H.; Karbach, A.; Drechsler, D. *Adv. Funct. Mater.* **2003**, *13*, 591. (c) Percec, V.; Glodde, M.; Bera, T. K.; Miura, Y.; Shiyonovskaya, I.; Singer, K. D.; Balagurusamy, V. S. K.; Heiney, P. A.; Schnell, I.; Rapp, A.; Spiess, H. W.; Hudson, S. D.; Duan, H. *Nature* **2002**, *417*, 384.

(2) For a review, see: Bosman, A. W.; Janssen, H. M.; Meijer, E. W. *Chem. Rev.* **1999**, *99*, 1665.

(3) For a recent review, see: van Heerbeek, R.; Kamer, P. C. J.; van Leeuwen, P. W. N. M.; Reek, J. N. H. *Chem. Rev.* **2002**, *102*, 3717.

(4) For a review on unconventional mesogens, see: (a) Tschierske, C. *Annu. Rep. Prog. Chem., Sect. C* **2001**, *97*, 191. (b) Guillon, D. *Struct. Bonding* **1999**, *95*, 42. (c) Tschierske, C. *J. Mater. Chem.* **1998**, *8*, 1485.

(5) Lehmann, M.; Gearba, R. I.; Koch, M. H. J.; Ivanov, D. *Chem. Mater.* **2004**, *16*, 374.

(6) (a) Barberá, J.; Donnio, B.; Gehringer, L.; Guillon, D.; Marcos, M.; Omenat, A.; Serrano, J. L. *J. Mater. Chem.* **2005**, *15*, 4093. (b) Martín-Rapún, R.; Marcos, M.; Omenat, A.; Serrano, J. L.; Luckhurst, G. R.; Mainal, A. *Chem. Mater.* **2004**, *16*, 4969.

(7) (a) Grayson, S. M.; Fréchet, J. M. J. *Chem. Rev.* **2001**, *101*, 3819. (b) Grayson, S. M.; Fréchet, J. M. J. *J. Am. Chem. Soc.* **2000**, *122*, 10335.

(8) (a) Saez, I. M.; Goodby, J. W. *J. Mater. Chem.* **2005**, *15*, 26–40. (b) Saez, I. M.; Goodby, J. W. *Chem.–Eur. J.* **2003**, *9*, 4869.

(9) (a) Hückstädt, H.; Göpfert, A.; Abetz, V. *Macromol. Chem. Phys.* **2000**, *201*, 296–307. (b) Sioula, S.; Hadjichristidis, N.; Thomas, E. L. *Macromolecules* **1998**, *31*, 8429. (c) Wei, J.; Huang, J. *Macromolecules* **2005**, *38*, 1107.

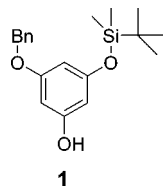
(10) Tang, P.; Qiu, F.; Zhang, H.; Yang, Y. *J. Phys. Chem. B* **2004**, *108*, 8434.

(11) To the best of our knowledge, no star-shaped mesogens with three different arms related to terblockcopolymer are known today, except compounds synthesized in our group (see ref 13).

(12) Cheng, X.; Prehm, M.; Das, M. K.; Kain, J.; Baumeister, U.; Diele, S.; Leine, D.; Blume, A.; Tschierske, C. *J. Am. Chem. Soc.* **2003**, *125*, 10977.

arrangement in columnar self-assemblies. Mesogens with three differently substituted oligobenzoate arms have been synthesized using a 2-fold benzyl-protected phloroglucinol.<sup>13</sup> The second arm has been coupled by stoichiometric control yielding only small amounts of target molecules. In a different context, dendritic molecules based on aromatic ether scaffolds with up to four arms have been synthesized; however, arm components have been attached early in the multistep synthesis, affording only low overall yields. Thus, dendrons previously synthesized were lost during these procedures.<sup>14</sup> The drawbacks can be overcome with a strategy using orthogonal protecting groups, prior to the coupling of arm scaffolds. These protecting groups have to be introduced and cleaved successively, without influencing each other or the attached benzoate scaffold. An ABC moiety based on phloroglucinol has been synthesized earlier;<sup>15</sup> however, in conditions where one of the applied protecting groups, i.e., the benzenesulfonyl group, deprotects, benzoate functions cleave, too. Thus, for an efficient synthesis of nonsymmetric star oligobenzoates, a new ABC phloroglucinol derivative should be designed. Promising phenol protecting groups for phloroglucinol are the benzyl and the *tert*-butyldimethylsilyl group, which can be cleaved individually without effect upon the benzoate units.<sup>16</sup>

To build up the target ABC core, **1** (Figure 1), as a key compound for the preparation of star-shaped or dendritic molecules with different arms or dendrons, either the protecting groups have to be attached stepwise or a protecting group has to be removed from a 3-fold protected phloroglucinol. The latter strategy turned out to be the most efficient



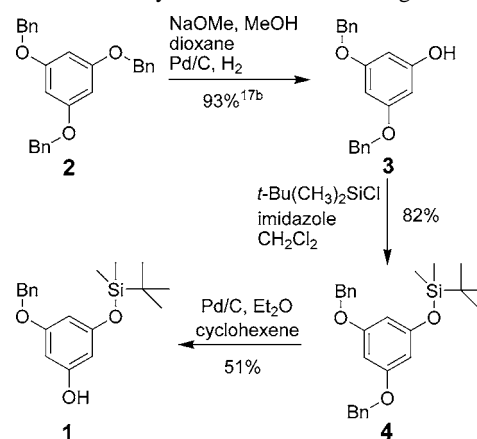
**Figure 1.** New ABC building block; a phloroglucinol core with 2-fold orthogonal protected phenolic OH groups (Bn = benzyl).

because selective coupling of one or two protecting groups to phloroglucinol affords mixtures of compounds which are difficult to separate. For 1,3,5-trisbenzyloxybenzene, various selective monodeprotection procedures are known<sup>17</sup> and thus it has been chosen as starting material. However, it should be noted that its synthesis is not straightforward because

direct 3-fold O-benylation leads to a minimum of 10% of an additional Friedel–Crafts C-benzylated product, which can be removed only with difficulty and in small amounts of material by chromatography.<sup>18</sup> Recently, Kawamoto and co-workers developed a synthetic route to a pure 3-fold O-benzylated phloroglucinol, which can be applied for large-scale production.<sup>19</sup> Here, the electron-rich benzene ring of phloroglucinol could be deactivated vs Friedel–Crafts reactions by 3-fold O-acetylation. Subsequent ester cleavage in the presence of benzyl chloride led to the analytically pure 1,3,5-trisbenzyloxybenzene as starting material for the synthesis of **1**.

The synthetic route toward ABC core **1**, starting with 1,3,5-trisbenzyloxybenzene **2**, is outlined in Scheme 1.

**Scheme 1.** Synthesis of ABC Building Block **1**



Selective monodebenzylation was first achieved by the method of Curtis et al.<sup>17b</sup> A subsequent etherification with *tert*-butyldimethylsilyl chloride afforded the silyl ether **4** in excellent yields. In the following debenylation step, basic conditions have to be avoided to not cleave the just introduced silyl ether function. Thus, cyclohexene is employed as a hydrogen donor,<sup>17c</sup> which permits the controlled monodeprotection in good yields. If the reaction is stopped at the appropriate time, the single second compound isolated apart from the target molecule is the unreacted starting material, which can be reused in the deprotection procedure. Reaction times that are too long result in a mixture with the additional 2-fold deprotected product.

Key compound **1** can be used to introduce three different arms by subsequent selective esterification and deprotection procedures (Scheme 2). The conditions are optimized for benzoate scaffolds.<sup>5,20</sup> Esterification of the phenolic hydroxy group with 3,4,5-tridodecyloxybenzoic acid provides compound **5** in excellent yields. The silyl ether function is cleaved by tetra-*n*-butylammonium fluoride with a small amount of acetic acid to not provoke a transesterification process by

(13) Lehmann, M.; Gearba, R. I.; Koch, M. J. H.; Ivanov, D. *Mol. Cryst. Liq. Cryst.* **2004**, *411*, 397.

(14) (a) Peerlings, H. W. I.; Struijk, M. P.; Meijer, E. W. *Chirality* **1998**, *10*, 46. (b) Kremers, J. A.; Meijer, E. W. *J. Org. Chem.* **1994**, *59*, 4262.

(15) Wolff, S.; Hoffmann, H. M. R. *Synthesis* **1988**, 760.

(16) Green, T. W.; Wuts, P. G. M. *Protecting Groups in Organic Synthesis*, 3rd ed.; Wiley: New York, 1999.

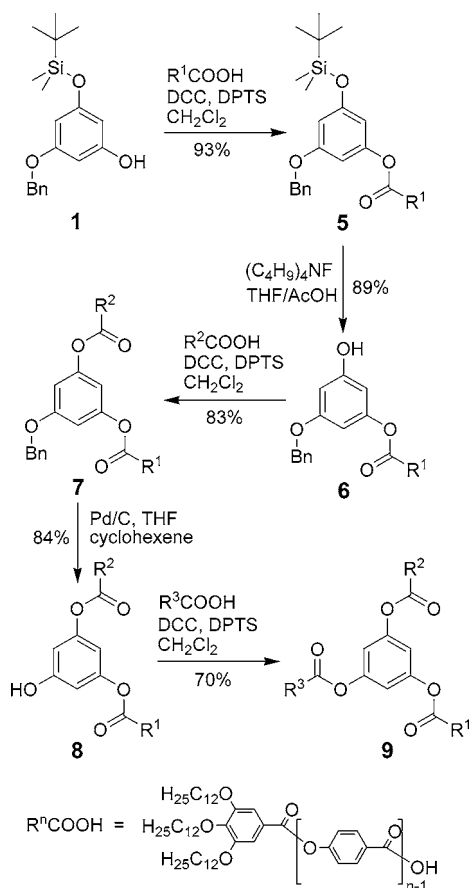
(17) (a) Chow, H.-F.; Wang, Z.-Y.; Lau, Y.-F. *Tetrahedron* **1998**, *54*, 13813. (b) Curtis, W. D.; Stoddart, J. F.; Jones, G. H. *J. Chem. Soc., Perkin I*, **1977**, *7*, 785. (c) Nithyanandhan, J.; Jayaraman, N. *J. Org. Chem.* **2002**, *67*, 6282.

(18) Deme, E. *J. Org. Chem.* **1976**, *41*, 3769.

(19) Kawamoto, H.; Nakatsubo, F.; Murakami, K. *Synth. Commun.* **1996**, *26*, 531.

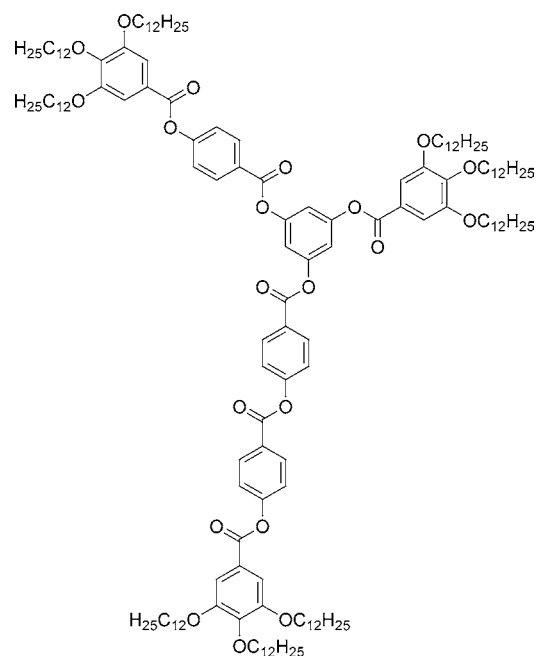
(20) Wang, Q. M.; Bruce, D. W. *Angew. Chem., Int. Ed. Engl.* **1997**, *36*, 150.

**Scheme 2.** Preparation of a Nonsymmetric Star-Shaped Molecule **9** with Three Different Benzoate Arms Attached to the Phloroglucinol Core



generation of a phenolate anion. By this procedure, compound **6** with a phenolic OH group is obtained in high yield and purity. A second benzoate arm can then be attached, and the final phenolic hydroxy group is deprotected in quantitative yields by hydrogenation to obtain molecule **8**. Finally, the third benzoate arm  $R^3\text{COOH}$  is coupled to the center to give target molecule **9** (Figure 2). By this strategy, three different arms can be built around a central benzene core, in high overall yields of up to 40% (five steps).

The arms of the resulting star-shaped compound **9** distinguish only in the length of the benzoate scaffold. Interestingly, molecules **9** self-assemble in a liquid crystal phase with a clearing temperature at 50.6 °C (onset, 2nd heating), which is essentially the same temperature as that observed for the clearing of the columnar hexagonal phase formed from the symmetric mesogen with the same number



**Figure 2.** Star-shaped mesogen **9** with three benzoate arms of different lengths.

of benzoate units.<sup>5</sup> The remarkable difference in mesogenic behavior compared to that of symmetric mesogens will be published in detail elsewhere. The synthesis of unsymmetrical compounds will be extended to chemically and physically different arms and dendrons in future work.

In summary, the new ABC building block **1** opens up the possibility to synthesize new nonsymmetric star-shaped or dendritic compounds, where three joined arm components may distinguish in size or function and consequently lead to new functional tripodic materials.

**Acknowledgment.** We thank Prof. H. Meier, A. Oehlhof, and Dr. N. Hanold for the elemental analysis and FD mass spectra completed at the University of Mainz. The Deutsche Forschungsgemeinschaft (DFG) and the Bundesministerium für Bildung und Forschung (BMBF) are gratefully acknowledged for their financial support.

**Supporting Information Available:** Detailed experimental procedures and characterization data of all compounds. This material is available free of charge via the Internet at <http://pubs.acs.org>.

OL0528585