New 2,2′-Substituted 6,6′-Dimethylbiphenyl Derivatives Inducing Strong Helical Twisting Power in Liquid Crystals

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New optically active tetra-*ortho*-substituted biphenyl chiral dopants for nematic liquid crystals are described. It was shown, with respect to our previous results, that biphenyl chiral dopants bearing only mesogenic residues on their 2,2′-positions and without any substituents on their 4,4′-positions gave rise to very high twisting powers in nematic liquid crystals. This powerful and unconventional chiral dopant molecular architecture allowed the design of new tetra-*ortho*-substituted biphenyl derivatives, easier to prepare in optically active form. This simplification of the molecular architecture still affords chiral dopants for nematic liquid crystals with large helical twisting powers and allows more economical large-scale preparation.

Introduction

We have recently reported[1] the synthesis and the helical twisting powers (HTPs) of new chiral biphenyls in nematic liquid crystals. We have demonstrated that the introduction of mesogenic residues at the 2,2′-positions of the chiral biphenyl produced very efficient dopants of nematic liquid crystal. The compound shown in Figure 1 is a typical example among the newly developed dopants[1] and induced a very short cholesteric pitch (1.8 μm) when dissolved in very low concentrations in nematic liquid crystals.

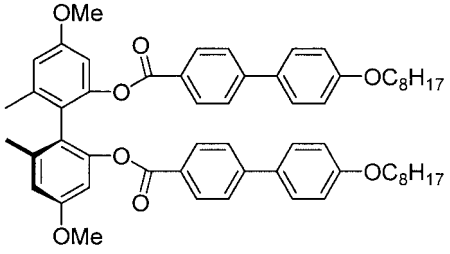
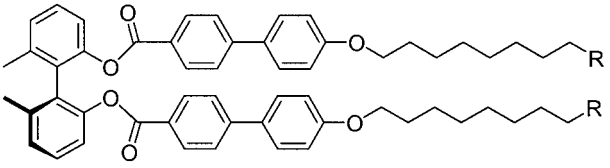


Figure 1. A biphenyl chiral dopant with a strong helical twisting power in nematic liquid crystals.

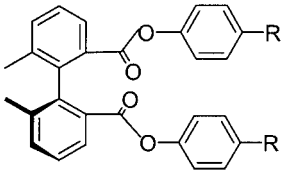
The performance of the newly discovered chiral dopants was mainly attributed to conformational stabilisation of the optically active form as a result of strong congestion of the molecular architecture. No significant drawbacks on thermotropic behaviour were observed with biphenyls bearing mesogenic residues at the unconventional 2,2′-positions instead of the 4,4′-ones. Indeed, acceptable compatibility with nematic liquid crystalline materials such as AN5, developed by Rolic for applications purposes, was obtained.

In view of the remarkable properties of these biphenyl chiral dopants and their potential use in cholesteric devices, we were interested in designing other derivatives with easier chemical access.

The use of methoxy groups at the 4,4′-positions in our former biphenyl derivatives had only been to allow for possible substitution (e.g., with mesogenic residues for increasing compatibility with liquid crystalline hosts). As acceptable compatibility was observed, the presence of the methoxy groups was no longer needed from a structural point of view. Other easily accessible biphenyl chiral dopants then become interesting to explore.



(–)-(*M*)-7



(–)-(*M*)-9

Figure 2.

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Here we present the synthesis of optically active biphenyl chiral dopants (–)-(*M*)-**7** and (–)-(*M*)-**9** (Figure 2). We demonstrate that the presence of mesogenic residues on the 2,2′-positions maintained very high helical twisting powers even in the absence of substituents in the 4,4′-positions. The synthetic route to these new molecules without substituents in the 4,4′-positions is much shorter (four steps only instead of nine previously) and should allow economical large-scale preparation.

Results and Discussion

Synthesis

The synthetic routes to the chiral dopants (–)-(*M*)-**7a**, (–)-(*M*)-**7b**, (–)-(*M*)-**9a** and (–)-(*M*)-**9b** are shown in Schemes 1 and 2.

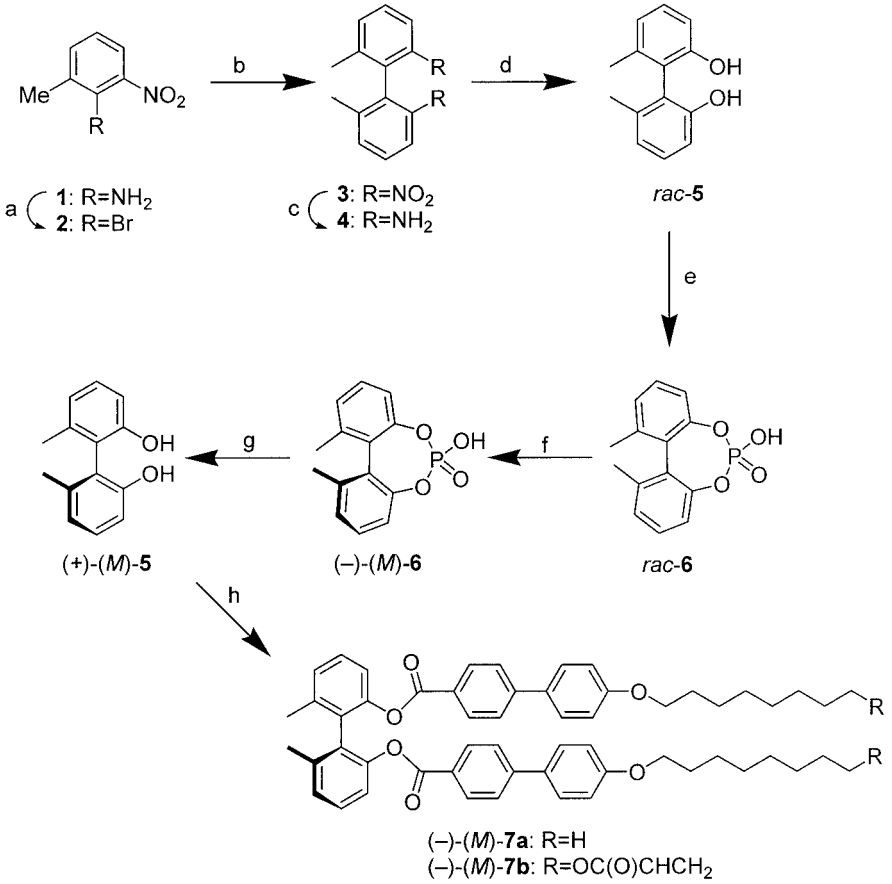
For (–)-(*M*)-**7a** and (–)-(*M*)-**7b**, Sandmeyer-type bromination[2] of 2-methyl-6-nitroaniline (93% yield) was used as the first reaction step. This was followed by Ullmann coupling (86% yield) and reduction of the nitro group to the corresponding diamine *rac*-**4** under hydrogen (99% yield), (Scheme 1). After diazotization, the resulting diazonium salt was hydrolysed [3] to afford the biphenol *rac*-**5** (50% yield).

The optical resolution of biphenol *rac*-**5** was carried out by the method described by Suda et al.[4] Compound *rac*-**5** was treated with phosphoryl chloride to afford the hydrogenphosphate *rac*-**6.** Compound *rac*-**6**, when added to one equivalent of cinchonidine in aqueous methanol, afforded the crystallisation of the diastereomerically enriched salt of (+)-(*M*)-**5**/cinchonidine (41% yield).

Treatment of the mother liquors with quinine after hydrolysis of the salts allowed the crystallisation of (–)-(*P*)-**5**/quinine salt (38% yield). Hydrolysis of the optically active salts followed by the cleavage of the hydrogenphosphate group in (–)-(*M*)-**6** and (+)-(*P*)-**6** with $LiAlH_4$ yielded the corresponding chiral biphenols (+)-(*M*)-**5** and (–)-(*P*)-**5** (95%). Finally (+)-(*M*)-**5** was esterified[5] in the presence of methanesulfonyl chloride and 4′-(octyloxy)biphenyl-4-carboxylic acid or 4′-(8-acryloyloxyoctyloxy)biphenyl-4-carboxylic acid to give the optically active dopants (–)-(*M*)-**7a** and (–)-(*M*)-**7b**, respectively.

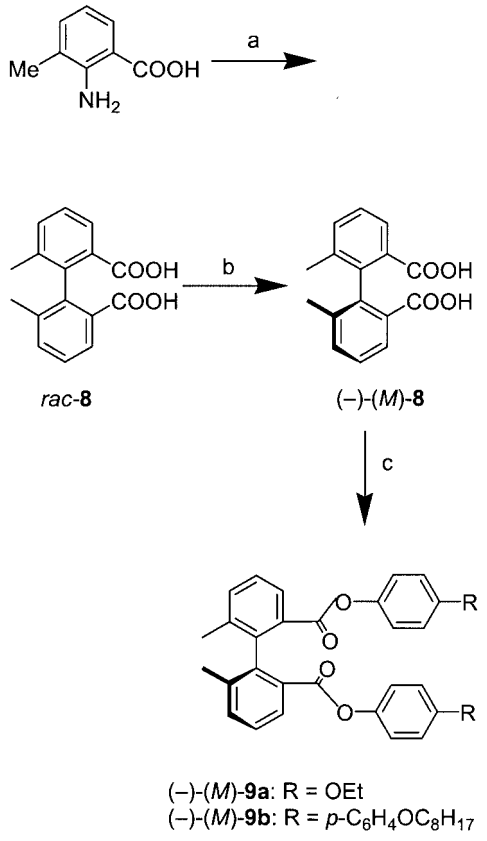
The absolute configurations of these new products, as well as their high optical purities, were deduced by comparison with the known compounds (+)-(*M*)-**5** and (–)-(*M*)-**6**.[4]

Compounds (–)-(*M*)-**9a** and (–)-(*M*)-**9b** were prepared by homocoupling of the freshly prepared diazonium salt of commercially available 3-methylanthranilic acid[6] (72% yield, Scheme 2). Optical resolution of the resulting biphen-



Scheme 1. Reagents and conditions: a) HBr, $NaNO_2$, 0 °C, CuBr, 0 °C to 60 °C. b) Cu, 200 °C, 2 h. c) MeOH, Pd, H_2. d) H_2SO_4, $NaNO_2$, 0 °C, H_2SO_4, 110 °C. e) $POCl_3$, H_2O, THF. f) Cinchonidine, MeOH, H_2O, HCl. g) $LiAlH_4$, THF. h) **7a**: 4′-(octyloxy)biphenyl-4-carboxylic acid, THF, CH_3SO_2Cl, Et_3N, –25 °C; **7b**: 4′-(8-acryloyloxyoctyloxy)biphenyl-4-carboxylic acid, THF, CH_3SO_2Cl, Et_3N, –25 °C.

yldicarboxylic acid *rac*-**8** was achieved by diastereoselective crystallisation of the corresponding brucine salt,[7] and the acid (–)-(*M*)-**8** was obtained in 32% yield. Finally, esterification with *p*-ethoxyphenol or 4′-(octyloxy)biphenyl-4-ol in the presence of methanesulfonyl chloride gave (–)-(*M*)-**9a** (45% yield) or (–)-(*M*)-**9b** (52% yield), respectively. The absolute configurations of these new products as well as their high optical purities were deduced by comparison with the known compound carboxylic acid (–)-(*M*)-**8**. [7]



Scheme 2. Reagents and conditions: a) $NaNO_2$, NaOH, 0 °C, HCl, NH_4OH, $CuSO_4$, $(NH_2OH)_2{\cdot}H_2SO_4$, 0 °C. b) Brucine, acetone, MeOH, HCl. c) **9a**: *p*-ethoxyphenol, THF, CH_3SO_2Cl, Et_3N, –25 °C; **9b**: 4′-(octyloxy)biphenyl-4-ol; THF, CH_3SO_2Cl, Et_3N, –25 °C.

Helical Twisting Power Measurements

The HTPs (= 1/*px*, where *p* is the pitch in μm and *x* is the mol fraction) of the newly prepared optically active biphenyls are listed in Table 1. Measurement were performed in the nematic mixture ROTN 3010 (from Rolic Technology, Allschwil, Switzerland).

A global analysis of the results shows relatively high HTPs for these new 2,2′-substituted optically active biphenyls as chiral dopants. By increasing the length of the mesogenic residues and varying the nature of their linking groups to the chiral residue it was possible to achieve HTPs of up to 42 $g{\cdot}\mu m^{-1}{\cdot}mmol^{-1}$ in the nematic host ROTN 3010. This confirms our assumption relating to chiral dopant intramolecular congestion[1,8] as an efficient molecular architecture concept for achieving high HTPs.

Table 1. Helical twisting powers of chiral biphenyls in ROTN3010.

Compound	Pitch[a] [μm]	HTP [$g{\cdot}\mu m^{-1}{\cdot}mmol^{-1}$]	Screw sense
(–)-(*M*)-**7a**	2.1	42	right
(+)-(*P*)-**7a**	2.0	42	left
(–)-(*M*)-**7b**	2.4	41	right
(+)-(*P*)-**7b**	2.1	46	left
(–)-(*M*)-**9a**	10.2	5.1	right
(–)-(*M*)-**9b**	3.9	21	right

[a] The pitch was measured in a solution of 1% of dopant in nematic ROTN3010.

This efficiency of biphenyl chiral dopants allows consideration of their application in modern cholesteric devices: namely, reflective and transflective cholesteric films. For this purpose optically active biphenyl derivatives bearing polymerisable acrylic groups at the ends of the mesogenic residues were prepared. The presence of acrylic groups allows the chiral dopant to be crosslinked with polymerisable nematic. The specific cholesteric properties induced at the monomeric scale are then frozen into the sample by photochemical radical polymerisation.

The introduction of the polymerisable group had no significant influence on the measured HTPs, which varied between 41 and 46 $g{\cdot}\mu m^{-1}{\cdot}mmol^{-1}$ for the polymerizable optically active dopant **7b** and around 42 $g{\cdot}\mu m^{-1}{\cdot}mmol^{-1}$ for the nonpolymerizable dopant **7a**.

Furthermore, consistently with our expectations we confirmed that compound (–)-(*M*)-**9b**, with a longer side chain containing a rigid biphenyl core, induces a higher HTP than compound (–)-(*M*)-**9a** with an ethoxyphenyl group.

We observed that the crosslinkable compound (–)-(*M*)-**7b** with an acrylic group at the end of the side chain has about the same helical twisting power as compound (–)-(*M*)-**7a**.

Conclusions

We have demonstrated that chiral biphenyls with appropriate molecular architecture are able to induce large HTPs in nematic liquid crystals. We thus confirmed the validity of molecular congestion around the chiral group as an efficient molecular architecture concept for chiral dopant development. Chiral biphenyls based on this concept and characterised by very easy chemical access were developed and offer potential application in various modern and classic cholesteric devices regarding the high efficiency of both polymerisable and nonpolymerisable forms.

Experimental Section

General Remarks: ^1H and ^{13}C NMR spectra were recorded at 200 and 50 MHz on a Bruker AC 200 instrument. Chemical shifts are reported relative to $CHCl_3$. Infrared spectra were recorded on a Perkin–Elmer Spectrum One instrument. Optical rotations were measured on a Perkin–Elmer 241 MC Polarimeter. Melting points

are uncorrected. Tetrahydrofuran and diethyl ether were distilled from benzophenone. Dichloromethane was distilled from P_2O_5. Hexane and dimethylformamide were dried over 4-Å molecular sieves. Flash chromatography was performed on Merck silica gel Si 60 (40–63 μm). Elemental analyses were performed at the Service Central de Microanalyse at the CNRS, Institut de Chimie, Strasbourg, France. Pitches were determined by Grandjean–Cano method with use of an Olympus BH-2 microscope.

2-Bromo-3-nitrotoluene (2): $Na_2S_2O_5$ (12 g), dissolved in water (120 mL), was added over 5 minutes to a warm (60 °C) solution of $CuSO_4$ (45 g, 0.18 mol) and NaBr (19 g, 0.19 mol) in water (150 mL). The mixture was allowed to cool down to room temp. and the solid was decanted. The solid was washed with water (3 × 100 mL) and dissolved in aqueous HBr (48%, 30 mL).

Aqueous HBr (48%, 85 mL) was added over 20 minutes to a solution of 2-methyl-6-nitroaniline (**1**, 25 g, 0.16 mol) at reflux in water (150 mL) and dioxane (75 mL). After a further 15 minutes at reflux the mixture was cooled down to 0 °C and a solution of $NaNO_2$ (11.3 g, 0.16 mol) in water (100 mL) was added dropwise. The temperature was still maintained at 0 °C and the mixture was poured over freshly prepared CuBr and stirred for further 15 minutes, and was then heated to 60 °C for 15 minutes and finally stirred at room temp. overnight. The product was extracted with diethyl ether, the organic layer was dried ($MgSO_4$) and filtered, and the solvent was evaporated to afford compound **2** (32.9 g, 93%, 0.15 mmol). ^{1}H NMR ($CDCl_3$): δ = 2.50 (s, 3 H), 7.32 (dd, J = 7.8 and 7.5 Hz, 1 H), 7.43 (ddd, J = 7.5, 1.9 and 0.8 Hz, 1 H), 7.50 (ddd, J = 7.8, 1.9 and 0.5 Hz, 1 H) ppm. ^{13}C NMR ($CDCl_3$): δ = 23.6, 115.8, 122.2, 126.7, 127.5, 133.5, 141.2 ppm. IR (KBr): $\tilde{\nu}$ = 696, 790, 804, 1038, 1326–1381, 1454, 1529 cm^{-1}.

2,2′-Dimethyl-6,6′-dinitrobiphenyl (3): 2-Bromo-3-nitrotoluene (**2**, 30 g, 0.14 mol) and freshly activated copper powder[9] (30 g) were heated under inert atmosphere to 200 °C for 2 hours. The mixture was filtered through celite and washed thoroughly with diethyl ether. After evaporation of the solvent, biphenol **3** (16.4 g, 86%, 60 mmol) was obtained. – m.p. 100–102 °C. ^{1}H NMR ($CDCl_3$): δ = 1.98 (s, 6 H), 7.47 (dd, J = 8.0 and 7.5 Hz, 2 H), 7.58 (ddd, J = 7.4, 0.9 and 0.5 Hz, 2 H), 7.99 (ddd, J = 8.0, 0.9 and 0.5 Hz, 2 H) ppm. ^{13}C NMR ($CDCl_3$): δ = 19.9, 122.4, 128.6, 131.5, 135.2, 138.3, 148.1 ppm. IR (KBr): $\tilde{\nu}$ = 743, 799, 811, 1217, 1351, 1455, 1518, 1738, 2864–3087 cm^{-1}.

6,6′-Dimethylbiphenyl-2,2′-diamine (4): A catalytic amount of Pd (5% on carbon) in a solution of dinitrobiphenyl **3** (3.0 g, 11 mmol) in methanol (50 mL) was stirred at room temp. under hydrogen atmosphere (30–50 bar) for 5 hours. Filtration of the mixture over silica gel, followed by evaporation of the solvent, afforded diamine **4** (2.31 g, 99%, 10.9 mmol). ^{1}H NMR ($CDCl_3$): δ = 1.98 (s, 6 H), 3.46 (broad s, 4 H), 6.65 (dd, J = 7.8 and 0.7 Hz, 2 H), 6.73 (ddd, J = 7.5, 7.2 and 0.7 Hz, 2 H), 7.09 (dd, J = 7.8 and 7.5 Hz, 2 H) ppm. ^{13}C NMR ($CDCl_3$): δ = 19.5, 113.2, 120.5, 122.3, 128.6, 138.2, 144.5 ppm. IR (KBr): $\tilde{\nu}$ = 746, 779, 787, 1297, 1460, 1581, 1607, 3345, 3421, 3440 cm^{-1}.

6,6′-Dimethylbiphenyl-2,2′-diol (*rac*-5): A solution of $NaNO_2$ (3.38 g, 49 mmol) in water (50 mL) was added slowly at 0 °C to a solution of diamine **4** (5.2 g, 25 mmol) in concentrated H_2SO_4 (17 mL) and water (150 mL). The mixture was stirred for a further 10 minutes at 0 °C and was then added dropwise at 105–110 °C to a solution of H_2SO_4 (50%, 450 mL). As soon as the addition had been finished the mixture was cooled to r.t. and extracted with diethyl ether. The desired biphenol was extracted from the organic phase with NaOH (1 M); this aqueous phase was acidified by addition of H_2SO_4 (1 M) in order to precipitate biphenol **5**. The solid was dissolved in diethyl ether, washed with brine (2 × 50 mL), dried over $MgSO_4$, and evaporated in vacuo to afford biphenol **5** (2.64 g, 50%, 12 mmol). – m.p. 159–160 °C. ^{1}H NMR ($CDCl_3$): δ = 2.00 (s, 6 H), 4.73 (s, 2 H), 6.8–6.9 (m, 4 H), 7.25 (dd, J = 7.9 and 7.6 Hz, 2 H) ppm. ^{13}C NMR ($CDCl_3$): δ = 19.5, 113.2, 119.5, 122.6, 130.1, 138.9, 153.8 ppm. IR (KBr): $\tilde{\nu}$ = 739, 782, 1162, 1176, 1259, 1281, 1461, 1574, 3409, 3463 cm^{-1}.

6-Hydroxy-1,11-dimethyl-6λ^5-dibenzo[*d*,*f*][1,3,2]dioxaphosphepin-6-one (*rac*-6): Phosphoryl chloride (0.63 mL, 6.8 mmol) was added to a solution of biphenol **5** (1.22 g, 5.69 mmol) in CH_2Cl_2 (20 mL). Et_3N (1.93 mL, 13.7 mmol) was added slowly and the mixture was kept at reflux for 30 minutes. The obtained chlorophosphate was extracted with CH_2Cl_2 (2 × 25 mL) and hydrolysed by heating in a mixture of water/THF (1:1) at 50 °C for 1 h. The THF was evaporated and the obtained hydrogen phosphate *rac*-**6** was recrystallised from aqueous methanol. Yield: 1.4 g (87%, 4.9 mmol). ^{1}H NMR ($(CD_3)_2CO$): δ = 2.20 (s, 6 H), 4.90 (broad s, 1 H), 7.1-7.4 (m, 6 H) ppm. ^{31}P NMR ($(CD_3)_2CO$): δ = 0.30 (s, 1 P) ppm.

6-Hydroxy-1,11-dimethyl-6λ^5-dibenzo[*d*,*f*][1,3,2]dioxaphosphepin-6-one [(–)-(*M*)-6 and (+)-(*P*)-6]: Hydrogenphosphate *rac*-**6** (1.16 g, 4.20 mmol) and cinchonidine (1.28 g, 4.30 mmol) were dissolved in methanol (9.5 mL) at reflux. Water (1.9 mL) was added to the hot solution and the mixture was then allowed to cool down slowly. The cinchonidine salt crystals, $[\alpha]_D^{20}$ = –153 (c = 0.5, MeOH), recovered after filtration were hydrolysed by shaking with HCl (20%, 15 mL). The mixture was extracted with EtOAc (2 × 20 mL) and the combined organic phases were dried over $MgSO_4$, filtered and evaporated in vacuo to afford (–)-(*M*)-**6** (0.45 g, 39%, 1.6 mmol), $[\alpha]_D^{20}$ = –168 (c = 0.5, MeOH), (ref.[4] –179 (c = 0.5, MeOH).

The mother liquor was hydrolysed in HCl (20%) and the recovered hydrogenphosphate was added to 1 equivalent of quinine dissolved in aqueous methanol in order to precipitate the corresponding quinine salt $[\alpha]_D^{20}$ = –42 (c = 0.5, MeOH). The salt was hydrolysed by shaking in HCl (20%) and the desired atropisomer was extracted with EtOAc (2 × 20 mL), dried over $MgSO_4$, filtered and evaporated in vacuo to afford (+)-(*P*)-**6** (0.41 g, 35%, 1.5 mmol), $[\alpha]_D^{20}$ = +162 (c = 0.5, MeOH). – NMR spectra were identical to those of *rac*-**6**.

6,6′-Dimethylbiphenyl-2,2′-diol [(+)-(*M*)-5 and (–)-(*P*)-5]: $LiAlH_4$ (20 mg, 0.5 mmol) was added to a solution of the hydrogenphosphate (–)-(*M*)-**6** or (+)-(*P*)-**6** (50 mg, 0.18 mmol) in THF (5 mL) at 0 °C. The mixture was heated at reflux for 3 h and was then hydrolysed with HCl (20%, 1 mL) and extracted with EtOAc. The organic layer was washed with brine, dried over $MgSO_4$ and filtered, and the solvent was evaporated under vacuum to provide the desired atropisomer (38 mg, 99%, 0.18 mmol). (+)-(*M*)-**5**: $[\alpha]_D^{20}$ = +84 (c = 1, EtOH), (ref.[4] +91 (c = 0.5, MeOH). (–)-(*P*)-**5:** $[\alpha]_D^{20}$ = –83 (c = 1, EtOH). – m.p. 159–160 C. IR and NMR spectra were identical to those of *rac*-**5**.

6,6′-Dimethylbiphenyl-2,2′-diyl Bis[4′-(octyloxy)biphenyl-4-carboxylate] [(–)-(*M*)-7a and (+)-(*P*)-7a]: A solution of 4′-(octyloxy)biphenyl-4-carboxylic acid (165 mg, 0.50 mmol), triethylamine (0.13 mL, 0.92 mmol) and methanesulfonyl chloride (35 μL, 0.45 mmol) in THF (2 mL) was stirred between –25 °C and –35 °C for 1 h. Biphenol (+)-(*M*)-**5** or (–)-(*P*)-**5** (40 mg, 0.19 mmol) and DMAP (4 mg) dissolved in THF (1 mL) were added. The mixture was stirred at room temperature for 5 days, filtered through celite and purified by preparative TLC (ethyl acetate/hexane, 20:80) to provide 75 mg (0.09 mmol, 48%) of (–)-(*M*)-**7a**: $[\alpha]_D^{20}$ = –211 (c = 1, CH_2Cl_2); pitch = +2.1 μm (1% in ROTN 3010) or (+)-(*P*)-**7a**: $[\alpha]_D^{20}$ = +208 (c = 1, CH_2Cl_2); pitch = –2.0 μm (1% in ROTN 3010). – m.p. 52–54 °C; ^{1}H NMR ($CDCl_3$): δ = 0.91 (t, J = 5.5 Hz,

6 H), 1.2–1.9 (m, 24 H), 2.15 (s, 6 H), 4.00 (t, J = 6.4 Hz, 4 H), 6.98 (d, J = 8.6 Hz, 4 H), 7.1–7.3 (m, 6 H), 7.55 (2d, J = 8.6 Hz, 8 H), 7.88 (d, J = 8.3 Hz, 4 H) ppm. ^{13}C NMR ($CDCl_3$): δ = 14.1, 19.5, 22.6, 26.0, 29.2, 29.3, 29.4, 31.8, 68.1, 114.8, 119.8, 126.3, 127.3, 127.5, 128.3, 129.0, 130.4, 132.0, 138.7, 145.5, 148.7, 159.4, 164.7 ppm. IR (KBr): $\tilde{\nu}$ = 826, 1077, 1182, 1220, 1247, 1264, 1465, 1497, 1604, 1732, 2855, 2924 cm^{-1}.

6,6′-Dimethylbiphenyl-2,2′-diyl Bis[4′-(8-acryloyloxyoctyloxy)biphenyl-4-carboxylate] [(–)-(*M*)-7b and (+)-(*P*)-7b]: A solution of 4′-(8-acryloyloxyoctyloxy)biphenyl-4-carboxylic acid (600 mg, 1.45 mmol), triethylamine (0.38 mL, 2.7 mmol) and methanesulfonyl chloride (100 μL, 1.33 mmol) in THF (7 mL) was stirred between –25 °C and –35 °C for 1 h. Biphenol (+)-(*M*)-**5** or (–)-(*P*)-**5** (130 mg, 0.6 mmol) and DMAP (15 mg) dissolved in THF (7 mL) were added. The mixture was stirred at room temperature for 4 days, filtered through celite and purified by preparative TLC (ethyl acetate/hexane, 50:50) to provide 115 mg (0.12 mmol, 20%) of (–)-(*M*)-**7b**: $[\alpha]_D^{20}$ = –216 (c = 1, CH_2Cl_2); pitch = +2.4 μm (1% in ROTN 3010) or (+)-(*P*)-**7b**: $[\alpha]_D^{20}$ = +212 (c = 1, CH_2Cl_2); pitch = –2.1 μm (1% in ROTN 3010). ^{1}H NMR ($CDCl_3$): δ = 1.3–1.9 (m, 24 H), 2.13 (s, 6 H), 4.00 (t, J = 6.5 Hz, 4 H), 4.16 (t, J = 6.7 Hz, 4 H), 5.82 (B of ABX, J = 10.2 and 1.6 Hz, 2 H), 6.30 (X of ABX, J = 17.5 and 10.2 Hz, 2 H), 6.41 (A of ABX, J = 17.2 and 1.6 Hz, 2 H), 6.97 (d, J = 8.9 Hz, 4 H), 7.1–7.4 (m, 6 H), 7.53 (d, J = 8.9 Hz, 4 H), 7.55 (d, J = 8.6 Hz, 4 H), 7.86 (d, J = 8.7 Hz, 4 H) ppm. ^{13}C NMR ($CDCl_3$): δ = 19.5, 25.8, 25.9, 28.5, 29.1, 29.2, 64.6, 68.0, 114.8, 119.8, 126.3, 127.3, 128.3, 128.6, 130.4, 127.5, 128.9, 130.5, 132.0, 138.7, 145.4, 148.6, 159.4, 164.6, 166.3 ppm. IR (KBr): $\tilde{\nu}$ = 829, 1084, 1187, 1222, 1249, 1269, 1295, 1604, 1732, 2857, 2933 cm^{-1}. $C_{62}H_{66}O_{10}$ (971.2): calcd. C 76.7, H 6.9; found C 76.4, H 6.8.

6,6′-Dimethylbiphenyl-2,2′-dicarboxylic Acid (*rac*-8): $NaNO_2$ (7.8 g, 113 mmol) was added at 0 °C to a solution of 3-methylanthranylic acid (17 g, 113 mmol) in aqueous NaOH (10%, 60 mL) and the mixture was stirred for 30 minutes. HCl (4 M, 240 mL) was added slowly, the temperature being kept below +7 °C. In another flask $(NH_2OH)_2{\cdot}H_2SO_4$ (17.6 g, 107 mmol) was added at 0 °C to a solution of concentrated ammonia (55 mL, 0.35 mol) and $CuSO_4{\cdot}5H_2O$ (28 g, 0.11 mol) in water (90 mL) and stirring was continued for 30 minutes at 0 °C.

The freshly prepared solution containing the diazonium salt was added to this mixture by addition funnel, the temperature being kept between 0 and +10 °C. As soon as the addition was finished the mixture was heated at reflux for 30 minutes. It was then allowed to cool down to r.t., concentrated HCl (75 mL) was added, and stirring was continued for 12 h. Filtration of the mixture over celite, followed by washing of the organic layer with water and brine, drying over $MgSO_4$ and evaporation of the solvent, afforded diacid *rac*-**8** (11 g, 72%, 44 mmol); m.p. 236–237 °C. ^{1}H NMR ($CDCl_3$): δ = 1.83 (s, 6 H), 7.29(dd, J = 7.5 Hz, 2 H), 7.43 (d, J = 7.5 Hz, 2 H), 7.91 (d, J = 7.5 Hz, 2 H) ppm. ^{13}C NMR ($CDCl_3$): δ = 20.0, 126.8, 127.5, 129.0, 134.6, 136.2, 142.3, 172.6 ppm. IR (KBr): $\tilde{\nu}$ = 753, 1158, 1186, 1271, 1295, 1402, 1689, 2558, 1654, 2500–3200 cm^{-1}.

6,6′-Dimethylbiphenyl-2,2′-dicarboxylic Acid [(+)-(*P*)-8 and (–)-(*M*)-8]: Diacid *rac*-**8** (3.22 g, 11.9 mmol) and brucine (4.71 g, 11.9 mmol) were dissolved at reflux in a mixture of methanol (5 mL) and acetone (10 mL). The solution was allowed to cool down slowly to r.t. and the ((+)-(*P*)-**8**)-brucine salt crystallised (3.1 g, 39%) $[\alpha]_D^{20}$ = +38 (c = 1, MeOH). The mother liquor was evaporated and the residue was dissolved at a minimum of acetone at reflux. After cooling down to r.t. the crystallised ((–)-(*M*)-**8**)-brucine salt (2.6 g, 33%) $[\alpha]_D^{20}$ = –38 (c = 1, MeOH) was obtained. The two obtained salts were each hydrolysed by shaking in a mixture of EtOAc/HCl (1 M, 1:1) in a separation funnel. The organic layer was washed with saturated aqueous $NaHCO_3$ and brine, dried over $MgSO_4$ and filtered, and the solvent was evaporated under vacuum to afford the desired atropisomers. (+)-(*P*)-**8**: 1.4 g (38%, 3.5 mmol) $[\alpha]_D^{20}$ = +21 (c = 1, MeOH), (ref.[7] +22, c = 1, MeOH); (–)-(*M*)-**8**: 1.1 g (32%, 3.4 mmol) $[\alpha]_D^{20}$ = –20 (c = 1, MeOH) of the desired atropisomer (99%, 0.18 mmol); m.p. 208–210 °C. IR and NMR spectra were identical to those of *rac*-**8**.

Bis(4-ethoxyphenyl) 6,6′-Dimethylbiphenyl-2,2′-dicarboxylate [(–)-(*M*)-9a]: A solution of diacid (–)-(*M*)-**8** (257 mg, 0.95 mmol), triethylamine (0.56 mL, 4.0 mmol) and methanesulfonyl chloride (0.15 mL, 1.9 mmol) in THF (4 mL) was stirred between –25 °C and –35 °C for 1 h. *p*-Ethoxyphenol (276 mg, 2.0 mmol) and DMAP (5 mg) dissolved in THF (2 mL) were added. The mixture was stirred at room temperature for 5 days, filtered through celite and purified by preparative TLC (ethyl acetate/hexane, 50:50) to provide (–)-(*M*)-**9a** as a viscous liquid (220 mg, 0.43 mmol, 45%). $[\alpha]_D^{20}$ = –111 (c = 1, CH_2Cl_2); pitch = +10.2 μm (1% in ROTN 3010). ^{1}H NMR ($CDCl_3$): δ = 1.37 (t, J = 7.0 Hz, 6 H), 2.02 (s, 6 H), 3.96 (q, J = 7.0 Hz, 4 H), 6.76 (d, J = 3.0 Hz, 8 H), 7.38 (dd, J = 7.5 Hz, 2 H), 7.49 (d, J = 7.0 Hz, 2 H), 8.00 (d, J = 7.2 Hz, 2 H) ppm. ^{13}C NMR ($CDCl_3$): δ = 14.7, 20.1, 63.7, 114.8, 122.1, 127.2, 128.1, 129.3, 134.0, 136.9, 140.9, 143.9, 156.4, 166.1 ppm. IR (KBr): $\tilde{\nu}$ = 761, 1116, 1192, 1247, 1282, 1506, 1744, 2927, 2980, 3066 cm^{-1}. $C_{32}H_{30}O_6$ (510.6): calcd. C 75.3, H 5.9; found C 74.6, H 6.3.

Bis[4′-(octyloxy)biphenyl-4-yl] 6,6′-Dimethylbiphenyl-2,2′-dicarboxylate [(–)-(*M*)-9b]: A solution of diacid (–)-(*M*)-**8** (129 mg, 0.48 mmol), triethylamine (0.28 mL, 2.0 mmol) and methanesulfonyl chloride (74 μL, 0.95 mmol) in THF (2 mL) was stirred between –25 °C and –35 °C for 1 h. 4′-Octyloxy-biphenyl-4-ol (300 mg, 1.0 mmol) and DMAP (7 mg) dissolved in THF (2 mL) were added. The mixture was stirred at room temperature for 4 days, filtered through celite and purified by preparative TLC (ethyl acetate/hexane, 50:50) to provide (–)-(*M*)-**9b** (210 mg, 0.25 mmol, 52%). $[\alpha]_D^{20}$ = –154 (c = 1, CH_2Cl_2). pitch = +3.9 μm (1% in ROTN 3010). m.p. 56–64 °C. ^{1}H NMR ($CDCl_3$): δ = 0.91 (t, J = 6.5 Hz, 6 H), 1.1–1.5 (m, 20 H), 1.7–1.9 (m, 4 H), 2.02 (s, 6 H), 3.99 (t, J = 6.4 Hz, 4 H), 7.93 (2×d, J = 8.0 Hz, 8 H), 7.4–7.6 (m, 12 H), 8.01 (d, J = 7.5 Hz, 2 H) ppm. ^{13}C NMR ($CDCl_3$): δ = 14.1, 20.2, 22.6, 26.0, 29.2, 29.7, 31.8, 68.0, 114.7, 121.6, 127.4, 127.6, 128.0, 128.3, 129.1, 132.8, 134.2, 137.0, 138.5, 141.1, 149.5, 158.7, 165.9 ppm. IR (KBr): $\tilde{\nu}$ = 759, 1001, 1114, 1167, 1203, 1246, 1268, 1497, 1609, 1745, 2855, 2926 cm^{-1}. $C_{56}H_{62}O_6$ (831.1): calcd. C 80.9, H 7.5; found C 80.8, H 8.2.

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[9] Activation of copper powder: Prior to use the copper powder (10 g) was stirred in a solution of iodine (2 g) in acetone (50 mL). As soon as the mixture became colourless the liquid was decanted and the copper powder was washed once with a mixture of acetone/$HCl_{concd.}$ (1:1, 50 mL), and then with acetone (5 × 50 mL). The copper powder was dried in vacuo at 170 °C for 2 hours.

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