A New Family of Enantiomerically Pure Smectic C* Liquid Crystals with a Bridged Chiral Biphenyl Core

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Abstract. The synthesis of enantiomerically pure bridged biphenyl compounds, (−)-(*R*)-3,9-bis(4-(dodecyloxy)benzoyloxy)-5,7-dihydro-1,11-dimethyldibenzo[*c*,*e*]thiepine, **13**, and (−)-(*R*)-3,9-bis(4-(dodecyloxy)benzoyloxy)-5,7-dihydro-1,11-dimethyldibenzo[*c*,*e*]-thiepin dioxide, **14**, is described. This is the first report of smectic C* mesophases with a rigid twisted biphenyl core and axial chirality.

We have recently reported[1] a new family of enantiomerically pure liquid crystals of type **A** and **B** showing that molecules containing a rigid twisted biphenyl core and axial chirality can give cholesteric mesophase (Figure 1). This result has confirmed our previous findings[2] which showed that the mesomorphic character of substituted stilbenes was maintained when stilbenes were converted to their epoxide, meaning therefore that the planarity of the central aromatic core was not required for mesomorphic behavior. In the oxepines **A** and **B**, the presence of a bridge between the two aromatic rings is certainly an important factor controlling particularly the dihedral angle between the two aromatic rings (torsional angle of 56°). It is well-known that in unbridged biphenyls the introduction of ortho-substituents decreases strongly the mesophase thermal stability with disappearance of the mesomorphic character[3] as in the case of tetra-*o*-chloro substituted biphenyls in which the torsional angle is close to 90°. However, the size as well as the polarity of the substituent may play a significant role, since it was reported recently that *o*-fluorine substituents in octafluorobiphenyl derivatives do not prevent the formation of mesomorphic compounds, a nematic phase in this specific case.[4]

We report now in this paper the first examples of smectic C* liquid crystals having the bridged enantiomerically pure biphenyl structures **13** and **14**. The synthesis of the optically active targets **13** and **14** was based on Ullmann coupling reaction of the chiral oxazoline (−)-(*S*)-**4** (Scheme 1), a method developed by A. Meyers.[6,7]

The synthesis of the diastereomeric oxazoline derivatives **5** and **6** started from 4-bromo-3,5-dimethylmethoxybenzene (**1**) by selective bromination with NBS of one methyl group, calcium carbonate[5] hydrolysis to the corresponding benzylic alcohol, and permanganate oxidation to the carboxylic acid **3** which was then transformed into the chiral oxazoline (−)-(*S*)-**4**, using the method described by Meyers.[6] Compound **4** was dimerized by the Ullmann reaction with activated copper, affording a 58/42 mixture of diastereomers **5** and **6**. Meyers[7] reported that the Ullmann dimerization of chiral oxazoline of type **4**, could give, under thermodynamic equilibrating conditions, a diastereomeric enhancement and afford mainly one diastereomer of the resulting biphenyl. When we carried out the Ullmann dimerization of **4** in the conditions described by Meyers we obtained indeed a nearly 1 to 1 mixture of the two diastereomers **5** and **6**. We could, however, separate these two diastereomers, (+)-(*S*,*S*,*S*)-**5** and (−)-(*R*,*S*,*S*)-**6**, by silica gel chromatography in high yield[1,8] (Scheme 1).

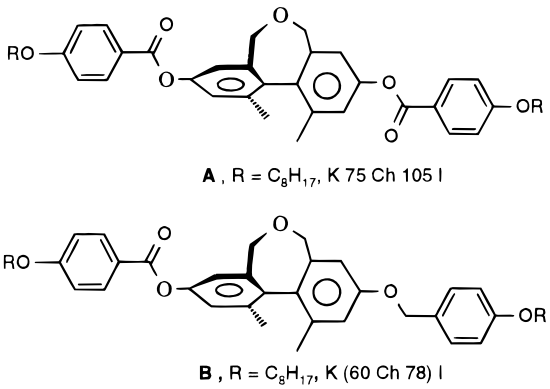

Figure 1.

The determination of the absolute configuration of **5** and **6** was achieved by chemical correlation[1] of the diastereomer (−)-(*R*,*S*,*S*)-**6** to the known (+)-(*R*)-2,2′-dihydroxy-4,4′-dimethoxy-6,6′-dimethylbiphenyl.[9]

The oxazoline (−)-(*R*,*S*,*S*)-**6** was then hydrolyzed with trifluoroacetic anhydride and acetylated to the diester (−)-(*R*,*S*,*S*)-**7** following the procedure of A. I. Meyers,[6b] and reduced with $LiAlH_4$ to the (+)-(*R*)-diol **8**. Swern oxidation to the (+)-(*R*)-dialdehyde **9**, followed by hydrolysis of the methoxy groups with boron tribromide,

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(3) Byron, D. J.; Gray, W. G.; Worrall, B. M. *J. Chem. Soc.* **1965**, 3706.
(4) Byron, D. J.; Matharu, A. S.; Wilson. R. C. *Liq. Cryst.* **1995**, *19*, 39−45.
(5) Smith, J. G.; Dibble, P. W.; Sandborn, R. E. *J. Org. Chem.* **1986**, *51*, 3762−3768.
(6) (a) Nelson, T. D.; Meyers, A. I. *J. Org. Chem.* **1994**, *59*, 2577−80. (b) Meyers, A. I.; Meier, A.; Rawson, D. J. *Tetrahedron Lett.* **1992**, *33*, 853−856.
(7) Nelson, T. D.; Meyers, A. I. *Tetrahedron Lett.* **1994**, *35*, 3259−62.
(8) We already reported in a short paper[1] the chromatographic separation of the biphenyloxazolines diastereomers **5** and **6**. Unfortunately in this paper the references to the pioneering work of Al Meyers were accidently omitted. The authors apologize for this.
(9) Musso, H.; Steckelberg, W. *Chem. Ber.* **1968**, *101*, 1510−18.

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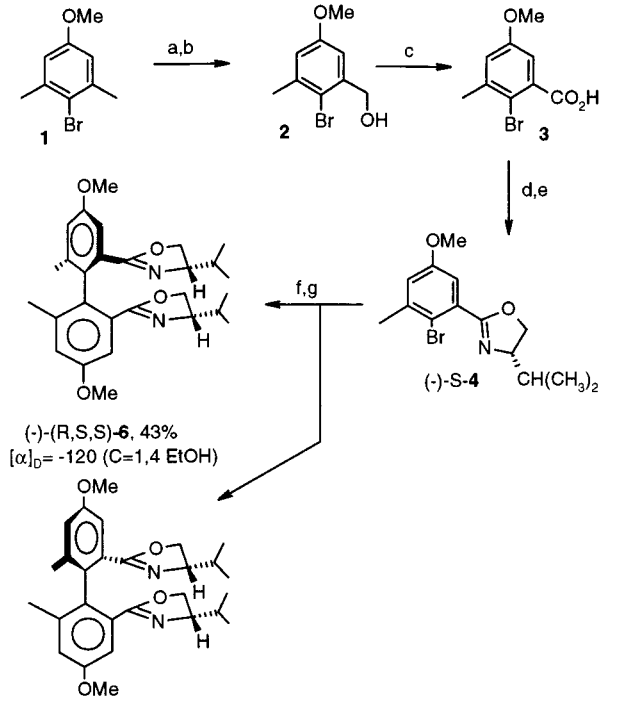
Scheme 1



a) NBS, CCl_4, AIBN, Δ, 85%;b) $CaCO_3$, H_2O, dioxane, 90%; c) $KMnO_4$, acetone, 91%;d) $SOCl_2$, benzene, Δ, then L-valinol, 84%;e) $SOCl_2$, CH_2Cl_2, 98%; f) Cu, DMF, Δ, 73%; g) silica gel chromatographic separation.

afforded the (+)-(*R*)-diphenol **10**, which was esterified with 4-(dodecyloxy)benzoyl chloride to the (+)-(*R*)-diester **11** (Scheme 2).

The aldehyde groups were then selectively reduced with sodium borohydride into the diol (+)-(*R*)-**12**. Subsequent iodination with chlorotrimethylsilane and sodium iodide and reaction with lithium sulfide gave the target thiepine (−)-(*R*)-**13**. Finally the sulfur atom of **13** was oxidized with *N*-methyl-1,2-epoxy-1,2,3,4-tetrahydroisoquinolinium tetrafluoborate[10] to the sulfone (−)-(*R*)-**14** (Scheme 3).

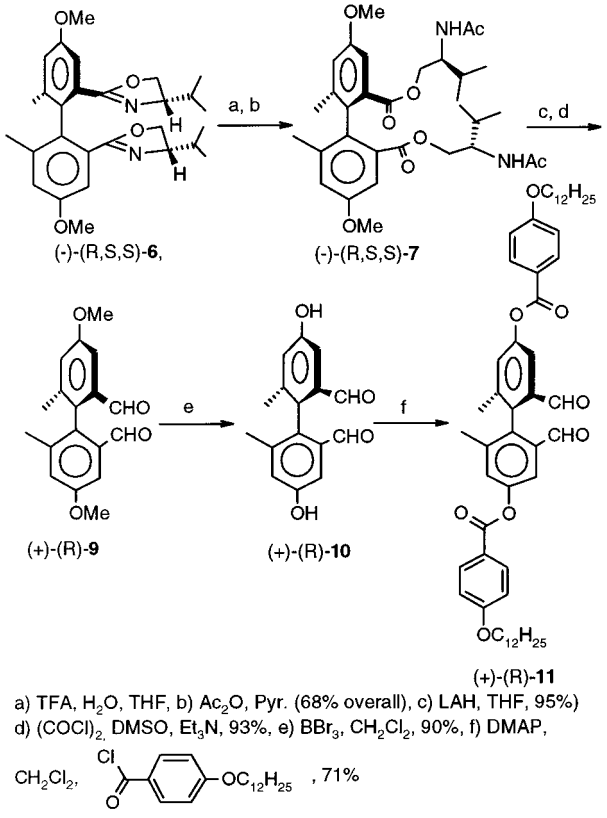
The phase transition temperatures (Table 1) of the synthesized products were measured by differential scanning calorimetry. The observed mesophases were identified by optical microscopy and X-ray diffraction.

We reported for comparison the liquid crystal properties of the oxepines **A** and **B**[1] (Table 1). We also made by the same procedure two other oxepines with a para-substituted C-12 chain on the aromatic rings instead of a C-8 chain. This is usually an efficient way to obtain smectic phases. As it is shown in the table we only got lower cholesteric transition (enantiotropic mesophase for **A** and monotropic for **B**).

In sharp contrast enantiomerically pure thiepine **13** and the corresponding sulfone **14** both displayed a smectic C* phase. This is the first report of smectic C* phases obtained from such twisted biphenyl structures. The identification of these mesophases was made by X-ray diffraction. Only the sulfur-bridged biphenyl

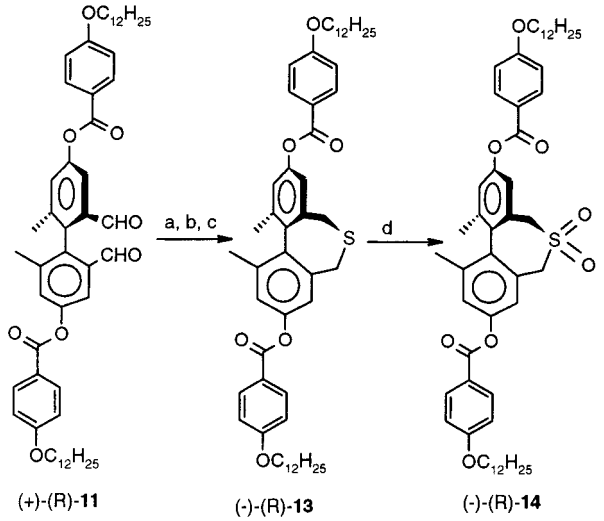
(10) Hanquet, G.; Lusinchi, X. *Tetrahedron Lett.* **1993**, *34*, 5299. This oxidation failed with most of the usual oxidants.

Scheme 2



a) TFA, H_2O, THF, b) Ac_2O, Pyr. (68% overall), c) LAH, THF, 95%) d) $(COCl)_2$, DMSO, Et_3N, 93%, e) BBr_3, CH_2Cl_2, 90%, f) DMAP, CH_2Cl_2, , 71%

Scheme 3



a) $NaBH_4$, EtOH, 81%, b) $ClSiMe_3$, NaI, 98%, c) LiS, CH_3CN, THF, 65%, d) N-methyl-1,2-epoxy-1,2,3,4-tetrahydroisoquinolinium tetrafluoroborate, CH_2Cl_2, 96%.

compounds **13** and **14** show a sharp Bragg reflection at small angles which is characteristic of smectic layers. The layer spacing determined by X-ray diffraction was 30.7 Å for **13** and 37.7 Å for **14**. The length of the molecules in their most extended conformations has been estimated by molecular modeling (MOPAC software CAChe work station from Oxford Molecular) to be about 52.6 Å for **13** and 52.2 Å for **14**, these values being greater than the layer spacing. Moreover, the layer spacing increased with temperature, and it could be concluded that the molecules are tilted in a smectic C* phase.

Table 1. Transition Temperatures of the Liquid Crystals

R	absol config	transition temp (deg)[a]	biphenyl dihedral angle, deg	$[\alpha]_D$ (acetone)
A, C_8H_{17}	*R*	C 75 Ch 105 I	56	+24 ($c = 1.6$)
A, $C_{12}H_{25}$	*R*	C 70 Ch 94 I	56	+20 ($c = 1.6$)
B, C_8H_{17}	*R*	C (Ch 60) 78 I	56	−10 ($c = 2.0$)
B, $C_{12}H_{25}$	*R*	C (Ch49) 58 I	56	−10 ($c = 2.0$)
13, $C_{12}H_{25}$	*R*	C 71 Sc* 90 Ch 106 I	63	−74 ($c = 2.0$)
14, $C_{12}H_{25}$	*R*	C 37 Sc* 42 Ch 46 I	58	−45 ($c = 0.5$)

[a] C, Sc*, Ch, and I indicate crystal, smectic C, cholesteric phases, and isotropic solution. Numbers are the transition temperatures, and numbers in parentheses indicate a monotropic transition which can be observed only in cooling the sample.

Using MOPAC molecular modeling software, we determined the dihedral angle of the bridged biphenyl moiety in the minimum energy conformation: an angle of 56° was already obtained for oxepines **A** and **B**; 63° was calculated for the thiepine **13** and 58° for thiepine dioxide **14**.

In conclusion, these new results confirmed that rigid nonplanar and enantiomerically pure biphenyl derivatives of type **A** or **B** can show liquid crystal properties. It is clear at this point of our studies that an oxygen atom on the bridge joining the two aromatic rings lead essentially to cholesteric phases while a sulfur and a sulfonyl group on the bridge lead to smectic C* phases. This is probably the result of a higher transversal polarization in the case of the sulfur compounds. This was confirmed by the calculation of the dipolar moments of the molecules containing only *p*-methoxy substituents on the biphenyl core which gave 4.8 D for the cyclic sulfone, 2.6 D for the thiepine, and only 1.9 D for the oxepine. Moreover, a dihedral angle between 56° and 63° seems to be an important factor for the mesomorphic behavior.

Experimental Section

2-Bromo-3-methyl-5-methoxybenzyl Alcohol, 2. A mixture of 4-bromo-3,5-dimethylanisole (**1**)[11] (86 g, 0.4 mol), *N*-bromosuccinimide (71.2 g, 0.4 mol) and AIBN (0.2 g) was refluxed in CCl_4 (500 mL) for 4 h. The cooled reaction mixture was washed with sat. $NaHCO_3$, dried ($MgSO_4$), and filtered, and the solvent was evaporated to give crude 2-bromo-5-methoxy-3-methylbenzylic bromide as a yellow solid (117.2 g, 85% yield determined by ^{1}H NMR) which was used in the next step without further purification. An analytical pure sample was obtained by flash chromatography on silica gel (eluent: hexane/ether: 80/20); mp 75 °C; ^{1}H NMR (200 MHz, $CDCl_3$) δ 6.85 (d, $J = 3$ Hz, 1H), 6.77 (d, $J = 3$ Hz, 1H), 4.61 (s, 2H), 3.80 (s, 3H), 2.41 (s, 3H); ^{13}C NMR (50 MHz, $CDCl_3$) δ 158.4, 140.4, 138.0, 117.6, 117.0, 114.0, 55.6, 34.8, 24.0.

To a solution of the preceding bromide (60 g) in 1,4-dioxane (500 mL) were added water (500 mL) and $CaCO_3$ (100 g) and the mixture refluxed for 12 h. After cooling, filtration of the excess of $CaCO_3$, and dioxane evaporation, CH_2Cl_2 (500 mL) was added as well as diluted HCl to dissolve all the solids. The organic layer was separated, washed with sat. $NaHCO_3$, dried ($MgSO_4$), and filtered. After evaporation of the solvent, the product was distilled under vacuum to give 36 g of **2** (90% yield): mp 52 °C; ^{1}H NMR (200 MHz, $CDCl_3$) δ 6.9 (d, $J = 3$ Hz, 1H), 6.74 (d; $J = 3$ Hz, 1H), 4.72 (s, 2H), 3.8 (s, 3H), 2.39 (s, 3H); ^{13}C NMR (50 MHz, $CDCl_3$) δ 158.7, 141.1, 139.3, 115.6, 111.4; 65.4, 55.5, 23.5.

2-Bromo-5-methoxy-3-methylbenzoic Acid, 3. To a boiling solution of alcohol **2** (18 g, 78 mmol) in acetone (450 mL) was added dropwise a solution of $KMnO_4$ (16,6 g, 105 mmol) in water (350 mL) in 30 min, and heating was continued for another 0.5 h. The cooled, dark brown mixture was acidified (few drops of HCl) and then cleared by $NaHSO_3$ solution. After addition of excess of NH_4OH, the mixture was passed through a short silica gel column to remove brown precipitates, acidified with concentrated HCl, and extracted with ether. After drying, the solvent was removed affording 16.4 g of acid **3** (86%): mp 129 °C; ^{1}H NMR (200 MHz, $CDCl_3$) δ 10.3 (broad s, 1H), 7.25 (d, $J = 2.6$ Hz, 1H), 6.98 (d, $J = 2.6$ Hz, 1H), 3.82 (s, 3H), 2.45 (s, 3H); ^{13}C NMR (50 MHz, DMSO-d_6) δ 167.95, 157.79, 139.89, 136.28, 118.19, 112.24, 111.65, 55.62, 23.13. Anal. Calcd for $C_9H_9BrO_3$: C, 44.08; H, 3.67. Found: C, 44.36; H, 3.70.

(−)-(*S*)-4,5-Dihydro-2-(2-bromo-3-methyl-5-methoxyphenyl)-4-isopropyl-1,3-oxazole, 4. A mixture of the bromobenzoic acid **3** (6 g, 24.5 mmol) and thionyl chloride (4.4 g,36.7 mmol) in benzene (50 mL) was heated under reflux for 3 h. The solvent and the excess of $SOCl_2$ were removed in vacuo, and the residue was dissolved in 50 mL of CH_2Cl_2 and added to a cooled (0 °C) solution of (L)-valinol (2.8 g, 26.9 mmol), Et_3N (10 mL), and CH_2Cl_2 (50 mL). The mixture was stirred at room temperature overnight and washed with HCl (2 M) and a saturated sodium bicarbonate solution. After drying over sodium sulfate, the solvent was removed in vacuo and the resulting solid purified by flash chromatography (ethyl acetate/hexane: 8/2) to afford 6.78 g (20.6 mmol, 84%) of the amide (*S*): mp 127 °C; ^{1}H NMR (200 MHz, $CDCl_3$) δ 6.83 (s, 2H), 6.2 (broad d, 1H), 3.9 (m, 3H), 3.78 (s, 3H), 2.4 (s, 3H), 2.0 (m, 1H), 1.0 (dd, J: 6.8 Hz, J: 1.4 Hz, 6H); ^{13}C NMR (50 MHz, $CDCl_3$) δ 169.1, 158.3, 140.1, 139.6, 117.7, 111.8, 111.6, 63.2, 57.5, 55.5, 29.0, 23.7, 19.6, 19.0.

To a cold solution (0 °C) of amide (6.6 g, 20 mmol) in 50 mL of CH_2Cl_2 was added slowly a solution of $SOCl_2$ (7.15 g, 4.36 mL, 60 mmol) in 50 mL of the same solvent. This mixture was stirred for 2 h at 0 °C and then washed with an ice cold sodium hydroxide solution (1 M) and saturated sodium bicarbonate solution. After drying over sodium sulfate, the solvent was removed to yield 6.08 g (19.5 mmol, 98%) of the bromo oxazoline **4** as a yellow liquid: $[\alpha]_D$ −47.5 ($c = 2.0$, EtOH), ^{1}H NMR (200 MHz, $CDCl_3$): δ 6.96 (d, $J = 3.0$ Hz, 1H), 6.86 (d, $J = 3.0$ Hz, 1H), 4.44 (m, 1H), 4.17 (m, 2H), 3.78 (s, 3H), 2.40 (s, 3H), 1.91 (oct., $J = 6.7$ Hz, 1H) 1.06 (d, $J = 6.7$ Hz, 3H), 0.99 (d, $J = 6.7$ Hz, 3H); ^{13}C NMR (50 MHz, $CDCl_3$): δ 163.6, 158.1, 140.3, 131.8, 116.7, 114.6, 113.6, 72.9, 70.5, 55.5, 32.70, 23.9, 18.9, 18.4.

(+)-(*S*,*S*,*S*)- and (−)-(*R*,*S*,*S*)-4,4′-Dimethoxy-6,6′-dimethyl-2,2′-(4,5-dihydro-4-isopropyl-1,3-oxazol-2-yl)biphenyl, 5 and 6. A mixture of the bromo oxazoline **4** (5 g,16 mmol) and 5 g of freshly activated copper in 30 mL of freshly distilled DMF was heated at reflux for 3 h. After cooling, the mixture was diluted with CH_2Cl_2 and washed with aqueous ammonia until the copper has been completely removed. The organic layer was washed with water and dried ($MgSO_4$) and the solvent removed to give a yellow oil. Flash chromatography (ether/hexane: 20/80) over Et_3N-pretreated silica gel afforded 1.6 g (43%) of the atropisomer (−)-(*R*,*S*,*S*)-**6** (rf 0.22) and 1.1 g (31%) of (+)-(*S*,*S*,*S*)-**7** (rf 0.32).

^{1}H NMR of the (*R*,*S*,*S*) diastereomer (200 MHz, $CDCl_3$) δ 7.14 (d, $J = 2.7$ Hz, 2H), 6.86 (d, $J = 2.7$ Hz, 2H), 4.05−3.6 (m, 6H), 3.84 (s, 6H), 1.95 (s, 6H), 1.54 (oct, $J = 6.7$ Hz, 2H), 0.74 (d, $J = 6.7$ Hz, 6H), 0.70 (d, $J = 6.7$ Hz, 6H); ^{13}C NMR (50 MHz, $CDCl_3$) δ 164.2, 158.1, 139.4, 132.1, 129.3, 118.0, 110.9, 72.5, 70.0, 55.4, 32.6, 20.6, 18.7, 18.1; $[\alpha]_D$ −119.5 ($c = 1.4$, EtOH). Anal. Calcd for $C_{28}H_{36}O_4N_2$: C, 72.43; H, 7.7; N, 6.0. Found: C, 72.45; H, 7.66; N, 5.88.

(11) Edwards, J. D.; Cashan, J. L. *J. Am. Chem. Soc.* **1956**, *78*, 3821−3824.

^{1}H NMR of the (*S*,*S*,*S*) diastereomer (200 MHz, $CDCl_3$) δ 7.23 (d, J = 2.8 Hz, 2H), 6.86 (d, J = 2.8 Hz, 2H) 4.02−3.66 (m, 6H), 3.85 (s, 6H), 1.90 (s, 6H), 1.64−1.54 (oct, J = 6.7 Hz, 2H), 0.82 (d, J = 6.8 Hz, 6H) 0.75 (d, J = 6.8 Hz, 6H); ^{13}C NMR (50 MHz, $CDCl_3$) δ 164.1, 157.9, 138.9, 132.5, 129.2, 118.2, 111.1, 72.4, 70.0, 55.3, 32.8, 20.5, 18.8, 18.2; $[\alpha]_D$ +29.5 (c = 1.4, EtOH).

(+)-(*R*)-4,4′-Dimethoxy-6,6′-dimethylbiphenyl-2,2′-dimethanol, 8. To a THF solution (100 mL) of (−)-(*R*,*S*,*S*)-**6** (2.4 g, 5.2 mmol) were added H_2O (4 mL), trifluoroacetic acid (6 mL), and 32 g of Na_2SO_4, and this suspension was stirred overnight at room temperature. After filtration, the solvent was removed in vacuo and the orange oil dissolved in 80 mL of CH_2Cl_2. To this solution were added pyridine (8 mL) and acetic anhydride (8 mL), and the mixture was stirred at room temperature overnight. After washing with 1 N HCl (3 × 50 mL) and then water (100 mL) and drying of $MgSO_4$, the solvent was removed giving 1.9 g (68%) of diester **7** as a white solid: mp 165 °C; $[\alpha]_D$ −60 (c = 2, EtOH); ^{1}H NMR (200 MHz, $CDCl_3$) δ 7.35 (d, J = 2.7 Hz, 2H), 7.02 (d, J = 2.7 Hz, 2H), 5.45 (d, J = 9.0, 2H), 4.35−4.27 (dd, J = 4.5 and J = 11.6 Hz, 2H); 3.95−3.73 (m, 4H), 3.88 (s, 6H), 1.95 (s, 6H), 1.89 (s, 6H), 1.44−1.33 (m, 2H) 0.84 (d, J = 6.7 Hz, 12H); ^{13}C NMR (50 MHz, $CDCl_3$) δ 168.0, 166.5, 158.3, 139.0, 132.4, 131.4, 120.0, 112.4, 65.4, 55.4, 53.5, 28.6, 23.2, 20.5, 19.4, 18.9.

Diester (−)-**7** (650 mg, 1.11 mmol) was dissolved in 30 mL of THF and cooled at 0 °C. $LiAlH_4$ (338 mg, 8.90 mmol) was added. After stirring for 2 h, the mixture was hydrolyzed with saturated NH_4Cl solution and acidified to pH 1 with 3 N HCl solution. The product was extracted with ether and dried over $MgSO_4$ and the solvent evaporated. Purification by flash chromatography with ethyl acetate as eluent afforded 320 mg (1.05 mmol, 95%) of diol **8**: mp 83 °C; $[\alpha]_D$ +12 (c = 1.8, EtOH); ^{1}H NMR (200 MHz, $CDCl_3$) δ 6.86 (d, J = 2.5 Hz, 2H), 6.75 (d, J = 2.5 Hz, 2H), 4.13 (d, J = 11.6 Hz, 2H), 3.98 (d, J = 11.6 Hz, 2H), 3.80 (s, 6H), 1.8 (s, 6H); ^{13}C NMR (50 MHz, $CDCl_3$) δ 158.8, 140.3, 138.0, 130.0, 115.3, 111.7, 62.9, 55.2, 20.3. Anal. Calcd for $C_{18}H_{22}O_4$: C, 71.50; H, 7.27. Found: C, 71.35; H, 7.13.

(+)-(*R*)-4,4′-Dimethoxy-6,6′-dimethylbiphenyl-2,2′-dialdehyde, 9. To a solution of oxalyl chloride (0.28 mL; 3.17 mmol) in CH_2Cl_2 (10 mL) at −78 °C were added 0.45 mL (6.35 mmol) of DMSO. The reaction mixture was stirred for 30 min, and then diol **8** (240 mg, 0.79 mmol) in CH_2Cl_2 (6 mL) was added dropwise. After stirring for 30 min, the mixture was allowed to warm to room temperature and then cooled once more to −78 °C and Et_3N (1.1 mL, 7.7 mmol) added dropwise. After stirring for 1 h, the mixture was hydrolyzed at 0 °C with 4 mL of H_2O, and the product was extracted with CH_2Cl_2, washed with a saturated solution of NaCl, dried ($MgSO_4$), and purified by flash chromatography (ethyl acetate/hexane: 2/8), giving 220 mg (93%) of the white solid **19**: mp 30 °C, $[\alpha]_D$ +30 (c = 1.7, EtOH); ^{1}H NMR (200 MHz, $CDCl_3$) δ 9.54 (s, 2H), 7.39 (d, J = 2.8 Hz, 2H), 7.13 (d, J = 2.8 Hz, 2H), 3.90 (s, 6H), 1.94 (s, 6H); ^{13}C NMR (50 MHz, $CDCl_3$) δ 181.0, 159.6, 139.8, 136.2, 132.8, 123.2, 108.5, 55.6, 19.7. Anal. Calcd for $C_{18}H_{18}O_4$: C, 72.47; H, 6.03. Found: C, 72.28; H, 6.05.

(+)-(*R*)-4,4′-Dihydroxy-6,6′-dimethylbiphenyl-2,2′-dicarboxaldehyde, 10. To a solution of dialdehyde **9** (400 mg,1,41 mmol) in 30 mL of anhydrous CH_2Cl_2 was added 5.6 mmol of BBr_3 (5.6 mL of a 1 M solution in CH_2Cl_2) at −78 °C. The mixture was warmed slowly to room temperature and stirred for 24 h. After pouring into water, the product was extracted with ether and washed with aqueous 2 N NaOH. The aqueous layer was acidified with 3 N HCl, and the diphenol **10** extracted with ether and dried ($MgSO_4$), and the solvent removed to give 284 mg of a white solid (yield 90%): mp 136 °C, $[\alpha]_D$ +49 (c = 1, acetone); ^{1}H NMR (200 MHz, $CDCl_3$) δ 9.54 (s, 2H), 8.90 (s, 2H), 7.78 (d, J = 2.5, 2H), 7.16 (d, J = 2.5, 2H), 1.94 (s, 6H); ^{13}C NMR (50 MHz, $CDCl_3$) δ 192.0, 137.5, 132.7, 123.8, 123.0, 113.2, 112.8, 19.8.

(+)-(*R*)-4,4′-Bis(4-(dodecyloxy)benzoyloxy)-6,6′-dimethylbiphenyl-2,2′-carboxaldehyde, 11. To a solution of **10** (85 mg, 0.317 mmol) in 15 mL of CH_2Cl_2 were added successively DMAP (0.160 g, 1.3 mmol) and 4-(dodecyloxy)benzoyl chloride (250 mg, 0.760 mmol). The reaction mixture was stirred overnight and then worked up as usual, affording 190 mg of a white solid (yield: 71%): mp 114 °C; $[\alpha]_D$ +18.5 (c = 2, acetone); ^{1}H NMR (200 MHz, $CDCl_3$) δ 9.65 (s, 2H), 8.16 (d, J = 8.29, 4H), 7.78 (d, J = 2.1, 2H), 7.50 (d, J = 2.1, 2H), 7.00 (d, J = 8.9, 4H), 4.06 (t, J = 6.5, 4H), 2.06 (s, 6H), 1.84 (m, 4H), 1.56−1.27 (m, 36H), 0.89 (t, 6H); ^{13}C NMR (50 MHz, $CDCl_3$) δ 164.6, 164.0, 151.4, 139.7, 136.5, 136.0, 132.5, 129.3, 121.0, 119.5, 114.6, 68.5, 32.0, 29.7, 29.5, 29.2, 26.1, 22.8, 19.9, 14.2. Anal. Calcd for $C_{54}H_{70}O_8$: C, 76.6; H, 8.27. Found: C, 76.70; H, 8.41.

(+)-(*R*)-4,4′-Bis(4-(dodecyloxy)benzoyloxy)-6,6′-dimethylbiphenyl-2,2′-dimethanol, 12. To a solution of dialdehyde **11** (160 mg, 0.19 mmol) in a mixture of 15 mL of EtOH and 8 mL of CH_2Cl_2 was added 17.2 mg of $NaBH_4$ (0.45 mmol). The reaction mixture was stirred for 20 min and then quenched with saturated NH_4Cl. After addition of 15 mL of CH_2Cl_2, the organic layer was decanted, washed twice with H_2O, dried (Na_2SO_4), and then evaporated. The crude product was purified by flash chromatogaphy on silica gel (eluent: AcOEt) to afford 130 mg (81%) of the diol **12**: mp 121 °C; $[\alpha]_D$ +7 (c = 2, acetone); ^{1}H NMR (200 MHz, $CDCl_3$) δ 8.15 (d, J = 9.0, 4H), 7.27 (d, J = 2.0, 2H), 7.13 (d,J = 2.0, 2H), 6.96 (d, J = 9.0, 4H), 4.27 (d, J = 12.2, 2H), 4.15 (d, J = 12.2, 2H), 4.04 (t, J = 6.5, 4H), 3.2 (sbroad, 2H), 1.93 (s, 6H), 1.83 (m, 4H), 1.6−1.2 (m, 36H), 0.88 (t, 6H); ^{13}C NMR (50 MHz, $CDCl_3$) δ 165.3, 163.7, 150.5, 140.7, 137.7, 134.6, 132.4, 122.6, 121.6, 120.0, 114.4, 66.4, 62.5, 32.0, 29.74, 29.70, 29.67, 29.48, 29.45, 29.22, 26.10, 22.79, 20.15, 14.2. Anal. Calcd for $C_{54}H_{74}O_8$: C, 76.23; H, 8.70. Found: C, 76.24; H, 8.63.

(−)-(*R*)-3,9-Bis(4-(dodecyloxy)benzoyloxy)-5,7-dihydro-1,11-dimethyldibenzo[*c*,*e*]thiepine, 13. To a solution of diol **12** (90 mg, 0.1 mmol) and NaI (33.3 mg, 0.22 mmol) in acetonitrile (10 mL) was slowly added freshly distilled $ClSiMe_3$ (25 mg, 0.22 mmol). After stirring overnight, a sodium hydrogen sulfite solution was added and the diiodo compound extracted with ether, affording 112 mg of a yellow liquid (yield: 98.9%); $[\alpha]_D$ +7.7 (c = 2, acetone); ^{1}H NMR (200 MHz, $CDCl_3$) δ 8.16 (d, J = 8.9, 4H), 7.35 (d, J = 2.2, 2H), 7.15 (d, J = 2.2, 2H), 6.99 (d, J = 8.9, 4H), 4.23 (d, J = 9.7, 2H), 4.11 (d, J = 9.7, 2H), 4.05 (t, J = 6.5, 4H), 2.8 (s, 6H), 1.83 (m, 4H), 1.5−1.2 (m, 36H), 0.89 (t, 6H); ^{13}C NMR (50 MHz, $CDCl_3$) δ 164.8, 163.8, 150.9, 138.7, 138.1, 133.8, 132.4, 123.6, 121.9, 114.5, 68.4, 62.5, 32.0, 29.7, 29.5, 29.1, 26.1, 20.4, 20.1, 14.2.

The diiodo compound (100 mg, 0.09 mmol) was dissolved in a mixture of CH_3CN (10 mL) and THF (10 mL) and stirred at room temperature for 3 days with lithium sulfide (12.8 mg, 0.28 mmol). The solvent was removed and the residue poured into water, extracted with ether, dried, and chromatographed on silica gel (eluent AcOEt/hexane 20/80) to give pure **13** (65% yield): $[\alpha]_D$ −74 (c = 2, acetone); ^{1}H NMR (200 MHz, $CDCl_3$) δ 8.15(d, J = 8.8, 4H), 7.12 (d, J = 2.3, 2H), 7.05 (d, J = 2.3, 2H), 6.98 (d, J = 8.8, 4H), 4.05 (t, 4H), 3.32 (s, 4H), 2.15 (s, 6H), 1.83 (m, 4H), 1.5−1.2 (m, 36H), 0.89 (t, 6H); ^{13}C NMR (50 MHz, $CDCl_3$) δ 165.0, 163.7, 150.8, 137.9, 137.0, 134.5, 132.4, 122.3, 121.6, 118.7, 114.4, 66.4, 32.2, 32.0, 29.8, 29.7, 29.5, 29.2, 26.1, 22.8, 20.0, 14.2. Anal. Calcd for $C_{54}H_{74}O_6S$: C, 76.19; H, 8.70. Found: C, 76.13; H, 8.76.

(−)-(*R*)-3,9-Bis(4-(dodecyloxy)benzoyloxy)-5,7-dihydro-1,11′-dimethyldibenzo[*c*,*e*]thiepin Dioxide, 14. To a solution of 21 mg of thiepin **13** in 5 mL of CH_2Cl_2 was added *N*-methyl-1,2-epoxy-1,2,3,4-tetrahydroisoquinolinium tetrafluoborate (25.2 mg, 0.05 mmol). After stirring for 10 min, the solvent was removed and the product flash chromatographed on SiO_2 (ether/hexane 40/60), affording 21 mg of thiepin 6,6′-dioxide **14** (yield 96%): $[\alpha]_D$ −45 (c = 0.5, acetone); ^{1}H NMR (200 MHz, $CDCl_3$) δ 8.15 (d, J = 8.9, 4H), 7.28 (d, J = 2.0, 2H), 7.25 (d, J = 2.0, 2H), 6.99 (d, J = 8.9, 4H), 4.06 (t, 4H), 4.02 (d, J = 13.4, 4H), 3.90 (d, J = 13.4, 2H), 2.22 (s, 6H), 1.84 (q, 4H), 1.6−1.2 (m, 36H), 0.89 (t, 6H); ^{13}C NMR (50 MHz, $CDCl_3$) δ 164.7, 163.8, 161.1, 139.1, 134.5, 132.5, 130.1, 124.5, 121.7, 121.1, 114.5, 88.5, 57.8, 32.0, 29.7, 29.5, 29.2, 26.0, 22.8, 20.1, 14.2. Anal. Calcd for $C_{54}H_{72}O_8S$: C, 73.6; H, 8.2. Found: C, 73.42; H, 8.2.

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