

Description

The present invention is concerned with novel chiral dopants for liquid crystals and their manufacture, and with liquid crystalline mixtures which contain said dopants and their use for optical and electro-optical purposes.

Liquid crystal materials for electro-optical indicators frequently contain one or more optically active additives for the induction of a chiral structure. For example, liquid crystal phases for indicators having a twisted nematic structure can be doped with optically active additives, e.g. in order to avoid a reversal of the direction of twisting (reverse twist) in TN cells (twisted-nematic) or in order to produce a sufficient twisting in cells having a highly twisted nematic structure, such as STN cells (super twisted-nematic), SBE cells (super birefringence effect) or OMI cells (optical mode interference). Further, cholesteric liquid crystals for phase-change cells can preferably consist of a nematic basic material and one or more optically active dopants and ferroelectric liquid crystals for indicators based on chiral tilted smectic phases can preferably consist of a material having a tilted smectic phase and one or more optically active dopants.

The electro-optical characteristics of liquid crystal indicators are temperature-dependent, which is disturbing especially in the case of multiplex operation. It is, however, known that this temperature dependence can be compensated for at least partly by the addition of a chiral dopant which induces a lower pitch with increasing temperature. Such an inverse temperature dependence has hitherto been found only for a few compounds. It can, however, also be achieved by the use of at least 2 chiral dopants which have a different relative temperature dependence and induce a different twisting direction (US 4 264 148). Of course, this usually requires a relatively high amount of chiral dopants.

Cholesteric liquid crystals reflect light essentially only in a wavelength range for which the wavelength is approximately equal to the helical pitch. The spectral width of this reflected light can be varied by a suitable choice of the liquid crystal. The reflected light is completely circularly polarized. The direction of rotation of the reflected light depends on the direction of rotation of the cholesteric helical structure. The light which is circularly polarized in the opposite direction is transmitted unimpaired. These properties can be utilized for the production

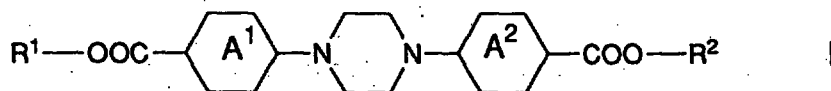
of optical filters, polarizers, analyzers etc. Further, cholesteric liquid crystals are also variously used for thermochromic applications.

Cholesteric liquid crystals for the above applications can preferably consist of a nematic or cholesteric basic material and one or more chiral dopants, which permits a simple adjustment of the desired helical pitch.

In order to produce cholesteric mixtures having a pitch in the range of the wavelength of visible light, the chiral dopant should have a twisting capacity which is as high as possible and should have a good solubility in usual liquid crystal materials. Furthermore, the chiral dopants should have a sufficient stability. They should have a good compatibility with the mesophase type of liquid crystal material and should not restrict the mesophase range too severely.

Dopants for the above purpose are now provided in accordance with the present invention.

The invention is concerned with chiral compounds of the general formula



wherein rings A¹ and A² each independently signify pyridine-2,5-diyl, pyrimidine-2,5-diyl or 1,4-phenylene, which is unsubstituted or substituted with at least one of halogen, cyano and/or methyl; R¹ and R² each independently represent alkyl with 1 to 18 carbon atoms in which optionally 1 -CH₂- group or 2 non-adjacent -CH₂- groups can be replaced by -O-, -COO- and/or -OOC- and/or one -CH₂-CH₂- group can be replaced by -CH=CH-; with the proviso that at least one of the groups R¹ and R² must be chiral.

The compounds of formula I can be manufactured readily in a manner known per se. They have a relatively low viscosity and are stable towards electric and magnetic fields.

They have a good solubility in usual liquid crystal materials and facilitate a high twisting of the liquid crystal structure. The clearing points of liquid crystals are not lowered or are lowered only insignificantly upon the addition of compounds of formula I.

The compounds of formula I can be used as dopants not only in nematic or cholesteric liquid crystals, but also in smectic liquid crystals.

The term "1,4-phenylene, which is unsubstituted or substituted with at least one of halogen, cyano and/or methyl" embraces in the scope of the present invention groups such as 1,4-phenylene, 2-fluoro-1,4-phenylene, 2,3-difluoro-1,4-phenylene, 2-chloro-1,4-phenylene, 2-bromo-1,4-phenylene, 2-cyano-1,4-phenylene, 2,3-dicyano-1,4-phenylene, 2-methyl-1,4-phenylene and the like. 1,4-Phenylene, 2-fluoro-1,4-phenylene and 2,3-difluoro-1,4-phenylene are preferred groups.

The term "halogen" signifies in the scope of the present invention fluorine, chlorine, bromine or iodine, especially fluorine and chlorine.

The term "alkyl with 1 to 18 carbon atoms in which optionally 1 -CH₂- group or 2 non-adjacent -CH₂- groups can be replaced by -O-, -COO- and/or -OOC- and/or one -CH₂-CH₂- group can be replaced by -CH=CH-" embraces in the scope of the present invention not only straight-chain, but also branched residues with 1 to 18, preferably 1 to 12 or 4 to 12, carbon atoms such as C₁-C₁₂ alkyl, C₄-C₁₂ 2-methylalkyl, C₄-C₁₂ 2-(3-alkenyl), C₄-C₁₂ 1-(alkoxycarbonyl)ethyl, C₅-C₁₂ 1-[(alkenyloxy)carbonyl]ethyl and the like. Such residues are, for example, 2-butyl, 2-pentyl, 2-hexyl, 2-heptyl, 2-octyl, 2-nonyl, 2-decyl, 2-undecyl, 2-dodecyl, 2-methylbutyl, 2-methylpentyl, 2-methylhexyl, 2-methylheptyl, 2-methyloctyl, 2-methylnonyl, 2-methyldecyl, 2-methylundecyl, 2-methyldodecyl, 2-(3-butenyl), 2-(3E-pentenyl), 2-(3E-hexenyl), 2-(3E-heptenyl), 2-(3E-octenyl), 2-(3E-nonenyl), 2-(3E-decenyl), 2-(3E-undecenyl), 2-(3E-dodecenyl), 1-(methoxycarbonyl)ethyl, 1-(ethoxycarbonyl)ethyl, 1-(propyloxy-carbonyl)ethyl, 1-(butoxycarbonyl)ethyl, 1-(pentyloxycarbonyl)-ethyl, 1-(hexyloxycarbonyl)ethyl, 1-(heptyloxycarbonyl)ethyl, 1-(octyloxycarbonyl)ethyl, 1-(nonyloxycarbonyl)-ethyl, 1-(decyloxy-carbonyl)ethyl, 1-(undecyloxycarbonyl)ethyl, 1-(dodecyloxy-carbonyl)ethyl, 1-([trans-2-propenyloxy]carbonyl)ethyl, 1-([trans-2-butenyloxy]carbonyl)ethyl, 1-([trans-2-pentenyl]oxy]carbonyl)-ethyl, 1-([trans-2-hexenyloxy]carbonyl)ethyl, 1-([trans-2-heptenyloxy]carbonyl)ethyl, 1-([trans-2-octenyloxy]carbonyl)-ethyl, 1-([trans-2-nonenyl]oxy]carbonyl)ethyl, 1-([trans-2-decenyl]oxy]carbonyl)ethyl, 1-([trans-2-undecenyl]oxy]carbonyl)-ethyl, 1-([trans-2-dodecenyl]oxy]carbonyl)ethyl and the like.

Compounds of formula I in which rings A¹ and A² both have the same significance and residues R¹ and R² both have the same significance are preferred. Compounds of formula I in which rings A¹ and A² signify pyridine-2,5-diyl or 1,4-phenylene, which is unsubstituted or substituted with at least one of halogen, cyano and/or methyl, are especially preferred.

Further especially preferred compounds of formula I are compounds in which the chiral alkyl groups have 4 to 12, especially 4 to 8, carbon atoms and in which both chiral alkyl groups have the R-configuration or both chiral alkyl groups have the S-configuration. Preferably, the centre of chirality is situated as close as possible to the central part of the ring, whereby an especially high twisting capacity is achieved.

Compounds of formula I in which rings A¹ and A² signify pyridine-2,5-diyl are particularly preferred. These compounds are characterized by good solubility and high polarizability, whereby the compounds - in addition to their use as dopants in nematic mixtures - are also excellently suited for use in ferroelectric liquid crystals.

Other preferred compounds of formula I are compounds in which rings A¹ and A² signify a 1,4-phenylene group, which is unsubstituted or substituted with at least one of halogen, cyano and/or methyl.

As mentioned above, the compounds of general formula I are very readily accessible synthetically. The compounds of formula I in which rings A¹ and A² signify 1,4-phenylene can be manufactured e.g. by converting the commercially available 1,4-piperazinediyl-diphenyl in a manner known per se via bis-4,4'-(1,4-piperazinediyl)dibenzaldehyde into a derivative suitable for esterification with ROH (J. Med. Chem. 10, 111 [1967]). The compounds of formula I in which rings A¹ and A² signify pyridine-2,5-diyl can be manufactured by coupling the corresponding 6-chloro-nicotinic acid ester with piperazine in a suitable solvent. The manufacturing methods are illustrated in more detail by the Examples.

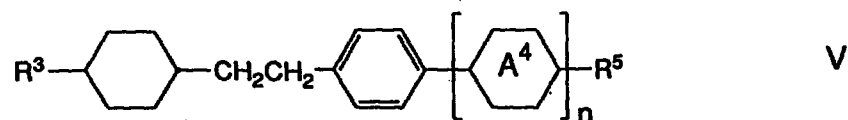
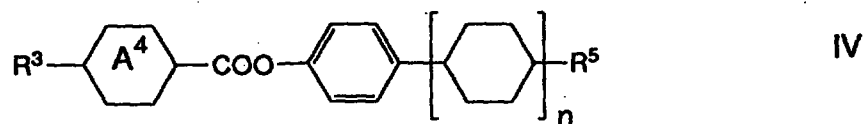
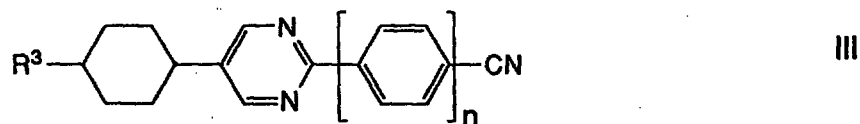
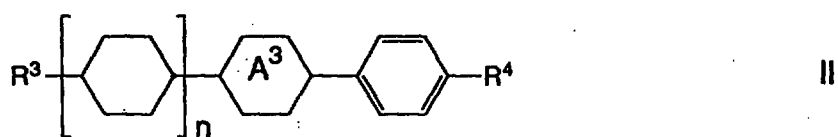
The invention is also concerned with liquid crystalline mixtures containing a liquid crystalline carrier material and one or more optically active compounds of formula I. Suitable carrier materials are basically all liquid crystal materials which have a twistable liquid crystal phase with an adequate mesophase range.

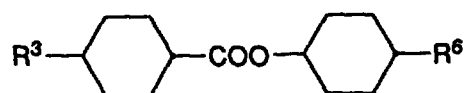
The compounds of formula I are especially suitable as chiral dopants for nematic or cholesteric carrier materials. The liquid crystalline carrier material can be a single compound or a mixture and preferably has a clearing point of at least about 60°C, particularly at least about 80°C.

The content of chiral dopant of formula I is determined essentially by its twisting capacity and the desired pitch. The content of chiral dopant can therefore vary in a wide range according to application and can be, for example, about 0.1-30 wt.%. Depending on cell type and thickness, a pitch of about 30-40 μm is mainly required for indicators based on liquid crystals having a twisted nematic structure and therefore a correspondingly lower content is sufficient. On the other hand, for applications which are based on the reflection of visible light by cholesteric layers, pitches of about 0.4-0.6 μm are required, which necessitates a correspondingly higher content of chiral dopant.

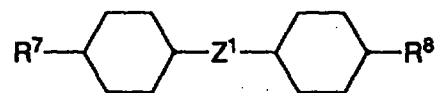
Suitable liquid crystalline carrier materials are known and are commercially available in large numbers. As a rule, liquid crystalline mixtures containing 2 or more components as carrier materials are preferred. Basically, however, a single liquid crystalline compound can also be used as the carrier material when it has a sufficiently broad mesophase.

Compounds of the following general formulae are especially suitable as components for liquid crystalline carrier materials

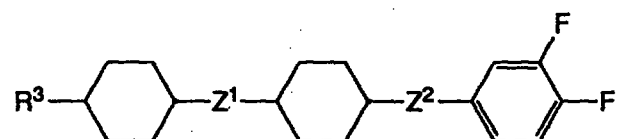




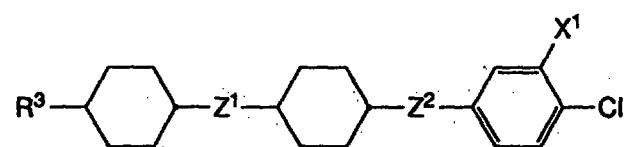
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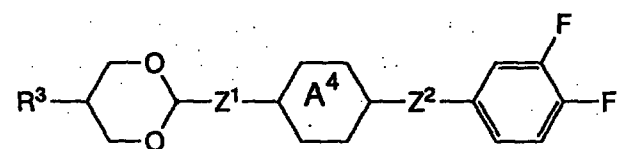
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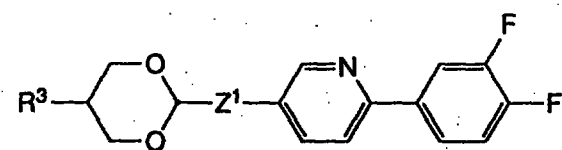
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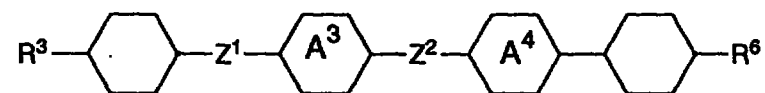
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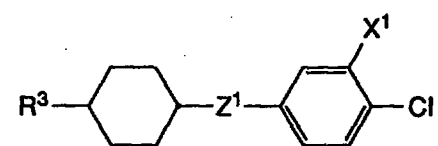
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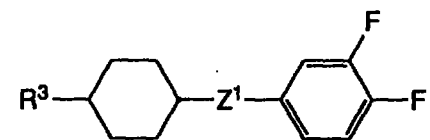
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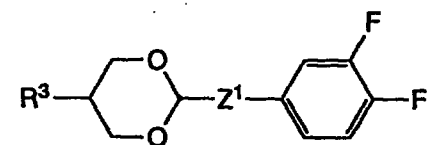
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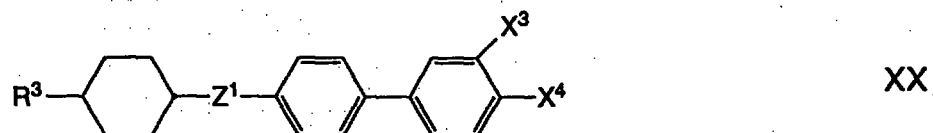
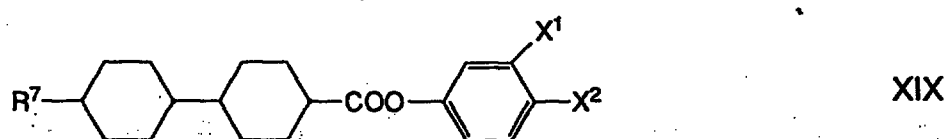
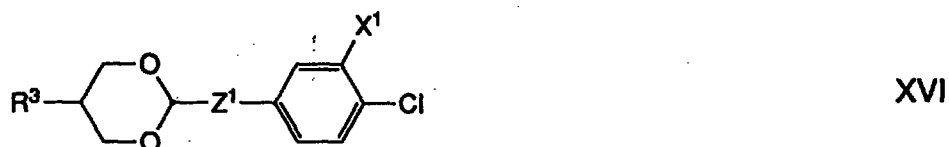
XIII



XIV



XV



wherein ring A³ signifies 1,4-phenylene, pyridine-2,5-diyl, pyrimidine-2,5-diyl, trans-1,4-cyclohexylene or trans-1,3-dioxane-2,5-diyl; ring A⁴ represents 1,4-phenylene or trans-1,4-cyclohexylene; n signifies the number 0 or 1; Z¹ and Z² each independently denote a single bond or -CH₂CH₂-, with two aromatic rings always being linked by a single bond; R³ and R⁶ each independently denote alkyl, alkoxy-alkyl, 3E-alkenyl and on saturated rings also 1E-alkenyl; R⁴ signifies alkyl, 3E-alkenyl, 4-alkenyl, alkoxy, 2E-alkenyl-oxy, 3-alkenyloxy, 1-alkynyl, cyano, isothiocyanato or fluoro; R⁵ denotes alkyl, 3E-alkenyl, 4-alkenyl or on trans-1,4-cyclohexylene also 1E-alkenyl or on 1,4-phenylene also cyano, isothiocyanato, alkoxy, 2E-alkenyl or 3-alkenyloxy; R⁷ signifies alkyl, 1E-alkenyl, 3E-alkenyl or 4-alkenyl; R⁸ represents cyano, alkyl, 1E-alkenyl, 3E-alkenyl, 4-alkenyl, alkoxy, 2E-alkenyloxy, 3-alkenyloxy, alkoxymethyl or (2E-alkenyl)oxymethyl; X¹ signifies hydrogen, fluorine or chlorine; X² denotes cyano, fluorine or chlorine; X³ signifies hydrogen or fluorine; and X⁴ stands for chlorine or fluorine.

R³, R⁴, R⁵, R⁶, R⁷ and R⁸ preferably have 1 to 12 carbon atoms, particularly 1 to 7 carbon atoms.

The aforementioned term "aromatic ring" signifies 1,4-phenylene, pyridine-2,5-diyl or pyrimidine-2,5-diyl. The afore-

mentioned term "saturated ring" signifies trans-1,4-cyclohexylene or trans-1,4-dioxane-2,5-diyl.

The invention is illustrated in more detail by the following Examples. In connection with liquid crystal phases and phase transitions C signifies a crystalline phase, N signifies a nematic phase, N* signifies a cholesteric phase, S signifies a smectic phase and I signifies the isotropic phase. The helical pitch is denoted by p. Optical antipodes have in each case "mirror image properties", i.e. the same melting point etc., but lead to opposite helical rotation and opposite circular polarization of reflected light.

Example 1

A mixture of 1.4 g of (S)-1-(ethoxycarbonyl)ethyl 6-chloronicotinate, 0.2 g of piperazine and 25 ml of ethanol was heated at 80°C for 2 days. The reaction mixture was treated with 500 ml of water and then extracted three times with 100 ml of diethyl ether each time. The combined organic phases were washed twice with 500 ml of concentrated sodium chloride solution each time, dried over magnesium sulphate, filtered and subsequently concentrated. The residue was chromatographed on silica gel with toluene/ethyl acetate (vol. 4:1). Recrystallization from ethanol gave pure bis-[(S)-1-(ethoxycarbonyl)ethyl] 6,6'-(1,4-piperazinediyl)dinicotinate with m.p. (C-I) 143°C, $[\alpha]_{589}^{20} = +68.3^\circ$.

The (S)-1-(ethoxycarbonyl)ethyl 6-chloronicotinate used as the starting material was prepared as follows:

- a) 1.5 g of 6-chloronicotinic acid were heated to 80°C for 24 hours with 25 ml of thionyl chloride in toluene. The solution obtained was evaporated under reduced pressure, the residue was treated with 20 ml of absolute toluene and the solution was again evaporated under reduced pressure. The solid residue was sublimed in a bulb tube. This gave 14.84 g of 6-chloronicotinoyl chloride with m.p. 48°C.
- b) 2.5 g of 6-chloronicotinoyl chloride were taken up in 50 ml of absolute toluene and treated with a solution of 1.7 g of ethyl L(-)-lactate in 5 ml of absolute pyridine. The reaction mixture was heated to reflux for 1 hour, then cooled, treated with dilute hydrochloric acid and extracted three times with 50 ml of dichloromethane each time. The combined organic phases were washed twice with 100 ml of water each time, dried over mag-

nesium sulphate and concentrated. The crude product obtained was purified by column chromatography on silica gel with toluene/ethyl acetate (vol. 4:1). This gave 2.6 g of pure (97%) (S)-1-(ethoxycarbonyl)ethyl 6-chloronicotinate with $[\alpha]_{589}^{20} = +14.4^\circ$.

The following compounds can be manufactured in an analogous manner:

Bis-[(S)-1-(methoxycarbonyl)ethyl] 6,6'-(1,4-piperazine-diyl)dinicotinate, m.p. 169° , $[\alpha]_{589}^{20} = +70.9^\circ$;

bis-[(S)-1-(propyloxycarbonyl)ethyl] 6,6'-(1,4-piperazine-diyl)dinicotinate, m.p. 160° ;

bis-[(S)-1-(butoxycarbonyl)ethyl] 6,6'-(1,4-piperazinediyl)-dinicotinate, m.p. 125° , $[\alpha]_{589}^{20} = +61.6^\circ$;

bis-[(S)-1-([trans-2-butenyloxy]carbonyl)ethyl] 6,6'-(1,4-piperazinediyl)dinicotinate;

bis-[(S)-1-([trans-2-pentenlyoxy]carbonyl)ethyl] 6,6'-(1,4-piperazinediyl)dinicotinate;

bis-[(S)-1-([trans-2-hexenyloxy]carbonyl)ethyl] 6,6'-(1,4-piperazinediyl)dinicotinate, m.p. 130° ;

bis-[(S)-2-pentyl] 6,6'-(1,4-piperazinediyl)dinicotinate, m.p. 119° , $[\alpha]_{589}^{20} = +49.8^\circ$;

bis-[(S)-2-hexyl] 6,6'-(1,4-piperazinediyl)dinicotinate;

bis-[(S)-2-heptyl] 6,6'-(1,4-piperazinediyl)dinicotinate;

bis-[(S)-2-octyl] 6,6'-(1,4-piperazinediyl)dinicotinate, m.p. 94° , $[\alpha]_{589}^{20} = +65^\circ$;

bis-[(S)-2-nonyl] 6,6'-(1,4-piperazinediyl)dinicotinate;

bis-[(R)-1-(methoxycarbonyl)ethyl] 6,6'-(1,4-piperazine-diyl)dinicotinate, m.p. 169° , $[\alpha]_{589}^{20} = +70.9^\circ$;

bis-[(R)-1-(propyloxycarbonyl)ethyl] 6,6'-(1,4-piperazine-diyl)dinicotinate, m.p. 160° ;

bis-[(R)-1-(butoxycarbonyl)ethyl] 6,6'-(1,4-piperazinediyl)-dinicotinate, m.p. 125° , $[\alpha]_{589}^{20} = -61.6^\circ$;

bis-[(R)-1-(trans-2-butenyloxy)carbonyl)ethyl] 6,6'-(1,4-piperazinediyl)dinicotinate;

bis-[(R)-1-(trans-2-pentenlyoxy)carbonyl)ethyl] 6,6'-(1,4-piperazinediyl)dinicotinate;

bis-[(R)-1-(trans-2-hexenyloxy)carbonyloxy)ethyl] 6,6'-(1,4-piperazinediyl)dinicotinate, m.p. 130° ;

bis-[(R)-2-pentyl] 6,6'-(1,4-piperazinediyl)dinicotinate, m.p. 119° , $[\alpha]_{589}^{20} = -49.8^\circ$;

bis-[(R)-2-hexyl] 6,6'-(1,4-piperazinediyl)dinicotinate;

bis-[(R)-2-heptyl] 6,6'-(1,4-piperazinediyl)dinicotinate;

bis-[(R)-2-octyl] 6,6'-(1,4-piperazinediyl)dinicotinate, m.p.
94°C, $[\alpha]_{589}^{20} = -65^{\circ}$;
bis-[(R)-2-nonyl] 6,6'-(1,4-piperazinediyl)dinicotinate.

Example 2

1.1 g of bis-4,4'-(1,4-piperazinediyl)benzoyl chloride, 0.5 g of ethyl L(-)-lactate and 25 ml of toluene were reacted in an analogous manner to Example 1b). This gave 0.8 g of bis-[(S)-1-ethoxycarbonyl]ethyl] 4,4'-(1,4-piperazinediyl)dibenzoate.

The bis-4,4'-(1,4-piperazinediyl)benzoyl chloride used as the starting material was prepared as follows:

- a) A solution of 2 g of bis-4,4'-(1,4-piperazinediyl)dibenzaldehyde in 100 ml of acetone was treated dropwise with 100 ml of Jones' reagent. The mixture was stirred at room temperature for 1 hour and then poured into 100 ml of water. The precipitate which thereby resulted was filtered off, washed portionwise with water and dried in a vacuum. The crude product was recrystallized from ethanol and gave 1.2 g of pure bis-4,4'-(1,4-piperazinediyl)dibenzoic acid.
- b) 1.2 g of bis-4,4'-(1,4-piperazinediyl)dibenzoic acid, 10 ml of thionyl chloride and 100 ml of toluene were reacted in an analogous manner to Example 1a). This gave 1.1 g of bis-4,4'-(1,4-piperazinediyl)benzoyl chloride.

The following compounds can be manufactured in an analogous manner:

Bis-[(S)-1-(methoxycarbonyl)ethyl] 4,4'-(1,4-piperazinediyl)dibenzoate;
bis[(S)-1-(propyloxycarbonyl)ethyl] 4,4'-(1,4-piperazinediyl)dibenzoate;
bis[(S)-1-(butoxycarbonyl)ethyl] 4,4'-(1,4-piperazinediyl)-dibenzoate;
bis[(S)-2-pentyl] 4,4'-(1,4-piperazinediyl)dibenzoate;
bis[(S)-2-hexyl] 4,4'-(1,4-piperazinediyl)dibenzoate;
bis[(S)-2-heptyl] 4,4'-(1,4-piperazinediyl)dibenzoate;
bis[(S)-2-octyl] 4,4'-(1,4-piperazinediyl)dibenzoate;
bis[(S)-2-nonyl] 4,4'-(1,4-piperazinediyl)dibenzoate.

Example 3

The following nematic liquid crystal basic mixture BM-1 was used to measure the induced pitch and its temperature dependence in liquid crystal materials.

5.36 wt.% of	4'-ethyl-4-cyanobiphenyl,
3.18 "	4'-propyl-4-cyanobiphenyl,
6.08 "	4'-butyl-4-cyanobiphenyl,
6.53 "	4-(trans-4-propylcyclohexyl)benzonitrile,
14.67 "	4-(trans-4-pentylcyclohexyl)benzonitrile,
5.21 "	4-ethyl-1-(trans-4-propylcyclohexyl)benzene,
16.54 "	4-ethoxy-1-[2-(trans-4-propylcyclohexyl)-ethyl]benzene,
5.60 "	4"-pentyl-4-cyano-p-terphenyl,
5.71 "	4'-(trans-4-pentylcyclohexyl)-4-cyanobiphenyl,
15.95 "	1-[2-(trans-4-butylcyclohexyl)ethyl]-4-(trans-4-pentylcyclohexyl)benzene,
4.74 "	4-[2-(trans-4-butylcyclohexyl)ethyl]-4'-(trans-4-pentylcyclohexyl)biphenyl,
7.59 "	4-[2-(trans-4-butylcyclohexyl)ethyl]-4'-(trans-4-pentylcyclohexyl)-1,1'-ethylenedibenzene,
2.84 "	trans-4-[2-trans-4-propylcyclohexyl)ethyl]-cyclohexanecarboxylic acid 4-cyanophenyl ester;
m.p. < -30°C, cl.p. (N-I) 90°C; $\Delta\epsilon = 8.5$; $\Delta n = 0.139$ and $\eta = 22 \text{ mPa}\cdot\text{s}$ measured at 22°C.	

Liquid crystal basic mixture BM-1 was treated with each of the following optically active dopants:

- D-1 = bis-[(R)-2-octyl] 6,6'-(1,4-piperazinediyl)dinicotinate.
- D-2 = bis-[(S)-1-(ethoxycarbonyl)ethyl] 6,6'-(1,4-piperazinediyl)dinicotinate.

The results obtained for the chiral doped mixtures have been compiled in Table 1 in which A, B and C denote the parameters of the equation

$$\frac{1}{pc} = A + BT_1 + CT_1^2$$

and p, c and T_1 have the following significances:

$$T_1 = T - 22^\circ\text{C};$$

- T = temperature in °C;
P = pitch in μm (a positive value signifies dextrorotatory helical structure and a negative value signifies a levorotatory helical structure);
c = concentration of the optically active dopant in wt.%.

Table 1

Mixture	Dopant	A [10 ⁻² •μm ⁻¹ •wt. % ⁻¹]	B [10 ⁻⁴ •μm ⁻¹ •wt. % ⁻¹ •°C ⁻¹]	C [10 ⁻⁶ •μm ⁻¹ •wt. % ⁻¹ •°C ⁻²]	p•c (at 22°C) [μm•wt. %]
M-1	7 wt.% of D-1	18.43	-3.94	-5.55	+5.4
M-2	7 wt.% of D-2	-21.20	5.52	-2.44	-4.7

Example 5

The following liquid crystal basic mixture BM-2 was used to measure the spontaneous polarizability (P_s) of ferroelectric smectic liquid crystal materials.

4.6 wt.% of	2-(4-octyloxyphenyl)-5-heptylpyrimidine
15.7 "	2-(4-nonyloxyphenyl)-5-nonylpyrimidine
15.7 "	2-(4-hexyloxyphenyl)-5-nonylpyrimidine
13.6 "	2-(4-decyloxyphenyl)-5-decylpyrimidine
25.1 "	4-decyloxybenzoic acid 4-[2-(trans-4-pentyl-cyclohexyl)ethyl]phenyl ester
12.6 "	4-undecyloxybenzoic acid 4-[2-(trans-4-pentyl-cyclohexyl)ethyl]phenyl ester
12.6 "	4-dodecyloxybenzoic acid 4-[2-(trans-4-pentyl-cyclohexyl)ethyl]phenyl ester.

The liquid crystal basic mixture BM-2 was treated with an optically active dopant:

D-3 = bis-[(S)-2-octyl] 6,6'-(1,4-piperazinediyl)-dinicotinate

93 wt.% of BM-2

7 wt.% of D-3

$\Delta T (S_c^*)$ -4°C , $P_s (T_{sc}^* -15^\circ) = 88 \text{ nC/cm}^2$, τ 550 μsec .

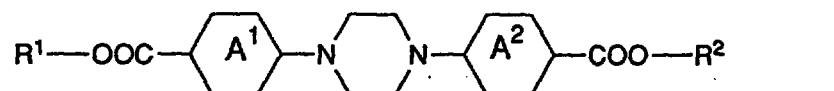
$\Delta T (S_c^*)$ = lowering of the phase transition temperature S_c^* to S_A , N or I.

$P_s (T_{sc}^* -15^\circ)$ = spontaneous polarizability measured below the phase transition temperature.

τ = switching velocity.

Claims

1. Optically active compounds of the general formula



wherein rings A^1 and A^2 each independently signify pyridine-2,5-diyl, pyrimidine-2,5-diyl or 1,4-phenylene, which is unsubstituted or substituted with at least one of halogen, cyano and/or methyl; R^1 and R^2 each independently represent alkyl with 1 to 18 carbon atoms in which

Example 5

The following liquid crystal basic mixture BM-2 was used to measure the spontaneous polarizability (P_s) of ferroelectric smectic liquid crystal materials.

4.6 wt.% of	2-(4-octyloxyphenyl)-5-heptylpyrimidine
15.7 "	2-(4-nonyloxyphenyl)-5-nonylpyrimidine
15.7 "	2-(4-hexyloxyphenyl)-5-nonylpyrimidine
13.6 "	2-(4-decyloxyphenyl)-5-decylpyrimidine
25.1 "	4-decyloxybenzoic acid 4-[2-(trans-4-pentyl-cyclohexyl)ethyl]phenyl ester
12.6 "	4-undecyloxybenzoic acid 4-[2-(trans-4-pentyl-cyclohexyl)ethyl]phenyl ester
12.6 "	4-dodecyloxybenzoic acid 4-[2-(trans-4-pentyl-cyclohexyl)ethyl]phenyl ester.

The liquid crystal basic mixture BM-2 was treated with an optically active dopant:

D-3 = bis-[(S)-2-octyl] 6,6'-(1,4-piperazinediyl)-dinicotinate

93 wt.% of BM-2

7 wt.% of D-3

$\Delta T (S_c^*) -4^\circ\text{C}$, $P_s (T_{sc}^* -15^\circ) = 88 \text{ nC/cm}^2$, τ 550 μsec .

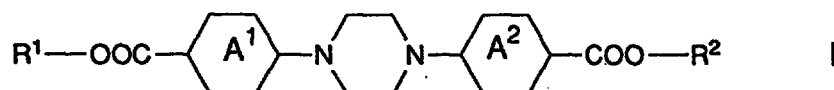
$\Delta T (S_c^*)$ = lowering of the phase transition temperature S_c^* to S_A , N or I.

$P_s (T_{sc}^* -15^\circ)$ = spontaneous polarizability measured below the phase transition temperature.

τ = switching velocity.

Claims

1. Optically active compounds of the general formula



wherein rings A^1 and A^2 each independently signify pyridine-2,5-diyl, pyrimidine-2,5-diyl or 1,4-phenylene, which is unsubstituted or substituted with at least one of halogen, cyano and/or methyl; R^1 and R^2 each independently represent alkyl with 1 to 18 carbon atoms in which



optionally 1 -CH₂- group or 2 non-adjacent -CH₂- groups can be replaced by -O-, -COO- and/or -OOC- and/or one -CH₂-CH₂- group can be replaced by -CH=CH-; with the proviso that at least one of the groups R¹ and R² must be chiral.

2. Optically active compounds according to claim 1, characterized in that rings A¹ and A² as well as residues R¹ and R² each have the same significance.

3. Optically active compounds according to claim 1 or 2, characterized in that rings A¹ and A² represent pyridine-2,5-diyl or 1,4-phenylene, which is unsubstituted or substituted with at least one of halogen, cyano and/or methyl.

4. Optically active compounds according to any one of claims 1 to 3, characterized in that R¹ and R² represent branched alkyl with 4 to 12 carbon atoms in which one -CH₂- group or two non-adjacent -CH₂- groups can be replaced by -O-, -COO- and/or -OOC- and/or one -CH₂-CH₂- can be replaced by -CH=CH-.

5. Optically active compounds in accordance with any one of claims 1 to 4, characterized in that R¹ and R² represent C₁-C₁₂ alkyl, C₄-C₁₂ 2-methylalkyl, C₄-C₁₂ 2-(3-alkenyl), C₄-C₁₂ 1-(alkoxycarbonyl)ethyl or C₅-C₁₂ 1-[(alkenyloxy)-carbonyl]ethyl.

6. Optically active compounds according to any one of claims 1 to 5, characterized in that rings A¹ and A² represent pyridine-2,5-diyl; and R¹ and R² signify 2-alkyl, 1-(alkoxycarbonyl)ethyl or 1-[(2-alkenyloxy)carbonyl]ethyl with 4 to 8 carbon atoms.

7. A liquid crystalline mixture containing a liquid crystalline carrier material and one or more optically active compounds of formula I defined in claim 1.

8. The use of a liquid crystalline mixture in accordance with claim 7 for optical and electro-optical purposes.



* C L M S *