

LIQUID CRYSTAL PHASE

DESCRIPTION

The invention relates to liquid crystal phases (LC phases) which have particularly low threshold voltages, broad nematic phase ranges and do not crystallize at low temperatures.

Liquid crystal display elements (LC display elements) increasingly utilize the properties of nematic or nematic-cholesteric liquid crystal materials of significantly changing their optical properties such as light absorption, light scattering, birefringence, reflectance or colour under the influence of electric fields. The function of such display elements is based for example on the phenomena of dynamic scattering, the deformation of aligned phases, the guest-host effect, the Schadt-Helfrich effect in the twisted cell, or the cholesteric-nematic phase transition.

The industrial application of these effects in electronic components requires liquid crystal phases which must meet a large number of requirements. Of particular importance here are the chemical resistance to moisture, air and physical factors such as heat, radiation in infrared, visible and ultraviolet regions and continuous and alternating electric fields. Industrially utilizable liquid crystal phases are also required to have a liquid crystal mesophase within a suitable temperature range, a very low viscosity, a good deep temperature behaviour, i.e. very low transition temperatures smectic/nematic and no crystallization at low

temperatures, a high steepness of the electro-optical characteristic and adequate dissolving power for pleochroic dyes. Finally, they must not have any self-absorption in the region of visible light, i.e. they must be colourless.

None of the hitherto disclosed series of compounds with a liquid crystal mesophase contain an individual compound which meets all these requirements. For that reason, the rule is to prepare mixtures of two to twenty-five, preferably three to fifteen, compounds in order to obtain substances which are usable as liquid crystal phases. Usually at least one compound having a low melting and clear point is included. The result is normally a mixture whose melting point is below that of the lower-melting component, while the clear point is between the clear points of the components. However, optimal phases cannot be easily prepared in this way, since the components having the high melting and clear points and/or very high dielectric anisotropy also confer on the mixtures a high viscosity and crystallization problems at low temperatures. As a result the switching times of the electro-optical display elements prepared therewith are changed in an undesirable manner.

Liquid crystal (LC) phases of the state of the art containing similar components are described in WO 88/02018. There is, however, still a strong demand for LC phases which have much lower threshold voltages or higher clearing points and simultaneously good deep temperature behaviour.

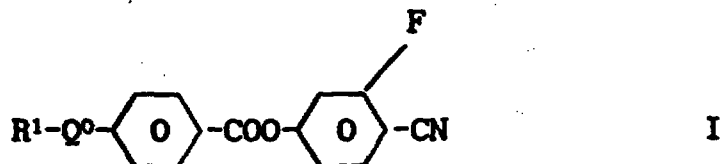
To reduce the threshold voltage, hitherto disclosed LC phases have added to them strongly polar nematic compounds having a terminal cyano group. The effective dipole moment of these compounds, however, is distinctly reduced by a more or less strong antiparallel association of these molecules, so that relatively large amounts of polar compounds need to be added. This in turn gives rise to various disadvantages, such as unfavorable elastic properties of the LC phases, and high viscosity. On addition of 4-cyano-3-fluorophenyl p-alkylbenzoates as strongly polar components to ZLI-1957/5 (commercially available mixture from E. Merck, Darmstadt, containing phenylcyclohexane, cyclohexylbiphenyl, bis-cyclohexylbiphenyl compounds and phenyl cyclohexylbenzoates), it has been possible to show (Hp. Schad and S.M. Kelly, J. Chem. Phys. 81 (3), 1514-15 (1984)) that the threshold voltage is reduced, which is explained in terms of a reduced degree of association of the added compounds. However, even these LC phases do not meet all the above mentioned requirements at the same time. In particular, for many applications their threshold voltages are still too high, and, in addition, the steepnesses of the electro-optic characteristic are not sufficient for highly informative displays owing to the relatively large ratio of the elastic constants for bending (K_2) and spreading (K_1) K_2/K_1 . The hitherto disclosed mixtures therefore have an excessively high threshold voltage and/or an unacceptably poor steepness of characteristic (characterized by an excessively high K_2/K_1) and/or high temperature dependence of the threshold voltage dV/dT and/or large angular dependence of contrast.

There is thus still a great need for liquid crystal phases having high clear points, low melting points, a low viscosity (and hence short switching times) and a low threshold voltage, which at the same time have favorable electro-optic steepness and excellent viewing angle characteristic combined with a good deep temperature behaviour and a birefringence suitable for use in standard display cells.

An object of the invention is to provide liquid crystal phases which have a nematic phase within the required temperature range and are completely or almost completely free from the abovementioned disadvantages.

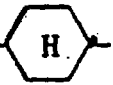
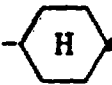
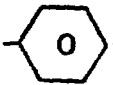
It has now been found that a liquid crystal phase having particularly favorable properties, in particular an acceptable combination of threshold steepness, viewing angle, temperature dependence at a low threshold voltage and favorable deep temperature behaviour is obtained when, in accordance with the present invention, it comprises:-

- 15 to 80 wt.% of a component A consisting of two or more compounds of the formula I



wherein

R^1 is an alkyl or alkenyl group with 1-12 carbon atoms, or an alkyl group with 2-12 carbon atoms wherein one CH_2 group is replaced by an oxygen atom, and

Q^0 is , , , , or a single bond;

- a component B consisting of two or more compounds selected from the following formulae II to IV:



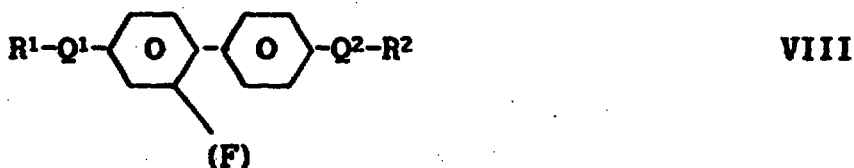
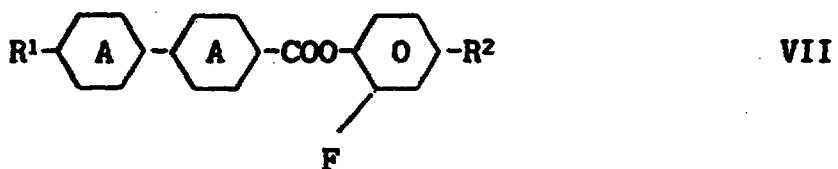
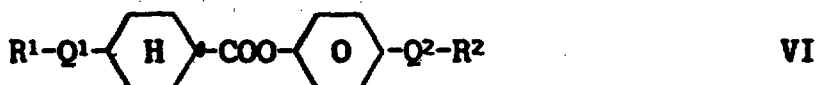
wherein ring A is 1,4-phenylene or trans-1,4-cyclohexylene, ring A^0 is trans-1,4-cyclohexylene or trans-1,3-dioxane-2,5-diyl, R^1 and Q^0 have the meanings indicated above and the total proportion of components A and B is more than 32 wt.%;

- 5 to 21 wt.% of a component C consisting of at least one compound of the formula V:



wherein R^1 and ring A have the meanings indicated above and R^2 is n-alkyl or n-alkoxy with in each case up to 7 carbon atoms, and;

- 3 to 30 wt.% of a component D consisting of one or more non polar additives selected from the following formulae VI to VIII:



wherein R^1 , R^2 and the rings A each independently have the meanings indicated above and Q^1 and Q^2 each are independently $-\text{H}-$, $-\text{H}-\text{CH}_2\text{CH}_2-$ or $-\text{CH}_2\text{CH}_2-\text{H}-$.

In an embodiment a liquid crystal phase in accordance with the invention can also contain one or more pleochroic dyes (guest-host systems).

The invention further provides electro-optical liquid crystal display elements which contain such phases.

The guest-host systems according to the invention generally contain 0.1 to 15, preferably 0.5 to 10, in particular 1 to 7, percent by weight of pleochroic dyes.

The pleochroic dyes of the guest-host system according to the invention are preferably chosen in such a way that they cover a suitable part of the visible spectrum and that the absorption in this range is more or less constant.

The preparation of the guest-host systems according to the invention is effected in conventional manner. In general, the desired amounts of the various pleochroic dyes are dissolved in the host material, preferably at elevated temperature.

However, it is also possible to mix solutions of the pleochroic dye and of the host material in a suitable organic solvent, for example acetone, chloroform or methanol, and to remove the solvent after thorough mixing, for example by distillation under reduced pressure. It is self-evident that with this method it is necessary to ensure that the solvent does not introduce any contaminants or undesirable dopants.

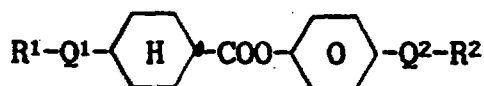
The individual compounds of the formula I to VIII of the liquid crystal phases according to the invention are either known or preparable by methods which are easily derivable by those skilled in the art from the prior art, since they are based on standard methods described in the literature.

Corresponding compounds of the formula I are described for example in German Patent Applications P 34 05 914 and P 35 15 633; in European Patent Specification 0,019,665; in S.M. Kelly and Hp. Schad, Helvetica Chimica Acta, 67, 1580-1587 (1984); in S.M. Kelly, *ibid.*, 67, 1572-1579 (1984); in Japanese Offenlegungsschrift 59-191,789 and European Offenlegungsschriften 0,099,099 and 0,119,756. Compounds of the formula II are described for example in German Offenlegungsschriften 29 44 905, 31 12 185, 31 46 249, 31 50 761, 31 50 763, 32 07 114, 32 27 916, 33 02 218, 33 34 054, in European Offenlegungsschrift 0,122,389, in U.S. Patent 4,322,354 and in Japanese Offenlegungsschrift 56-164,179.

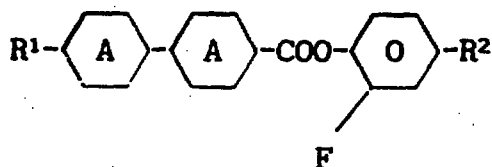
It was found, surprisingly, that the combination according to the invention of components A, B, C and D gives LC phases which on the one hand have wide mesophase ranges with low melting points and low smectic-nematic transition temperatures and on the other are capable of multiplexed drive at very low supply voltage by virtue of their good electro-optic steepness, viewing angle characteristic and high dielectric anisotropy.

The LC phases according to the invention preferably contain at least two components, in particular at least three components, of the formula I and at least two components, in particular at least three components, of the formula II and/or III.

Preferred LC phases contain at least one component of the formula VI and/or VII



VI



VII

wherein R^1 , R^2 and the rings A each independently have the meanings indicated above and Q^1 and Q^2 each are independently $-\text{H}-$, $-\text{H}-\text{CH}_2\text{CH}_2-$ or $-\text{CH}_2\text{CH}_2-\text{H}-$.

The LC phases according to the invention preferably contain compounds wherein A is trans-1,4-cyclohexylene. R^2 is preferably n-alkyl.

The total proportion of the components A and B is preferably 55 to 85 wt.%, in particular 70 to 85 %.

R^1 is preferably alkyl, alkenyl, alkoxy or alkoxymethyl in each case with 1 to 7 C atoms, in particular alkyl or alkoxymethyl.

R^1 is preferably straight-chain alkyl of 2 to 7 C atoms.

When the alkyl groups in the compounds of formulae I to VIII contain 3 or more carbon atoms, these can be arranged in a straight or branched chain. However, the phases according to the invention did not use any components which contain more than one branched alkyl group. Such branched alkyl groups

for the purposes of the present invention contain not more than one chain branching; preferably this is a methyl or ethyl group in the 1- or 2-position of carbon skeleton, so that suitable branched alkyl groups are in particular: 2-methylpropyl, 2-methylbutyl, 1-methylpentyl, 2-methylpentyl, 1-methylhexyl. Generally the liquid crystal dielectrics according to the invention contain only one component having a branched-chain alkyl radical in order to induce, if desired, optical activity. For this purpose, normally not more than 10 percent by weight, preferably 0.5 to 3 percent by weight, of a component having a branched alkyl radical are added.

Preferred phases according to the invention contain compounds of the formula III in which R^1 is n-alkyl of 2 to 7 C-atoms.

The total proportion of the compounds of the formula V in the LC phases according to the invention is 5 % to 21 %, in particular 6 to 15 %.

The preparation of the phases according to the invention is effected in the conventional manner. In general, the desired amount of the components which is used in the smaller amount is dissolved in the components which constitutes the main constituent, preferably at elevated temperature. If this temperature is chosen to be above the clear point of the main constituent, the completeness of the process of dissolving can be observed particularly easily.

However, it is also possible to mix solutions of the components in a suitable organic solvent, for example acetone, chloroform or methanol, and to remove the solvent after thorough mixing, for example by distillation under reduced pressure. It is self-evident that with this method it must be ensured that the solvent does not introduce any contaminants or undesirable dopants.

By means of suitable additives the liquid crystal phases according to the invention can be modified in such a way that they can be used in any hitherto disclosed kind of liquid crystal display element.

Such additives are known to those skilled in the art and are exhaustively described in the literature. It is possible to add for example conducting salts, preferably ethyldimethyldodecylammonium 4-hexyloxybenzoate, tetrabutylammonium tetraphenylboranate or complex salts of crown ethers (cf. for example I. Haller et al., Mol. Cryst. Liq. Cryst. volume 24, pages 249-258, (1973)) for improving the conductivity of substances for modifying the dielectric anisotropy, the viscosity and/or the orientation of the nematic phases. Such substances are described for example in German Offenlegungsschriften 22 09 127, 22 40 864, 23 21 632, 23 38 281, 24 50 088, 26 37 430, 28 53 728 and 29 02 177.

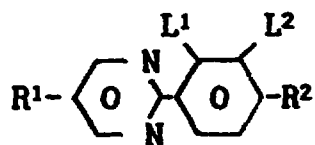
The examples below serve to illustrate the invention without limiting it. In the examples, the melting point and clear

point of a liquid crystal substance are given in degrees Celsius. The percentages are by weight. The values of the threshold voltages relate to an angle of observation of 0° , 10 % contrast and 20 °C.

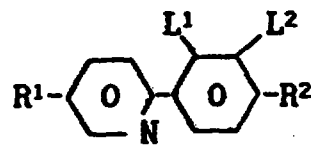
In the present patent application and in the following examples all chemical structures of LC compounds are given by acronyms the transformation of which into chemical formulae is done as shown in the following. All residues C_nH_{2n+1} and C_mH_{2m+1} are straight-chained alkyl groups with n resp. m carbon atoms. The codes of Table B are self-explanatory. In Table A only the acronym for the core structure is given. In an actual compound this acronym is followed by a dash and a code for the substituents R^1 , R^2 , L^1 and L^2 as follows:

Code for R^1 , R^2 , L^1 , L^2	R^1	R^2	L^1	L^2
nm	C_nH_{2n+1}	C_mH_{2m+1}	H	H
nOm	C_nH_{2n+1}	OC_mH_{2m+1}	H	H
nO.m	OC_nH_{2n+1}	C_mH_{2m+1}	H	H
n	C_nH_{2n+1}	CN	H	H
nN.F	C_nH_{2n+1}	CN	H	F
nF	C_nH_{2n+1}	F	H	H
nOF	OC_nH_{2n+1}	F	H	H
nCl	C_nH_{2n+1}	Cl	H	H
nF.F	C_nH_{2n+1}	F	H	F
nOmFF	C_nH_{2n+1}	OC_mH_{2m+1}	F	F
nmF	C_nH_{2n+1}	C_mH_{2m+1}	F	H
nCF ₃	C_nH_{2n+1}	CF ₃	H	H
nOCF ₃	C_nH_{2n+1}	OCF ₃	H	H
nOCF ₂	C_nH_{2n+1}	OCHF ₂	H	H
nS	C_nH_{2n+1}	NCS	H	H
rVsN	$C_rH_{2r+1}-CH=CH-C_sH_{2s}-$	CN	H	H
rEsN	$C_rH_{2r+1}-O-C_sH_{2s}-$	CN	H	H
nNF	C_nH_{2n+1}	CN	F	H
nAm	C_nH_{2n+1}	$COOC_mH_{2m+1}$	H	H

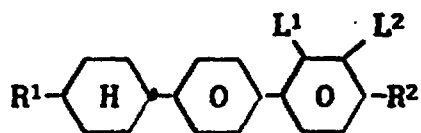
Table A:



PYP



PYRP



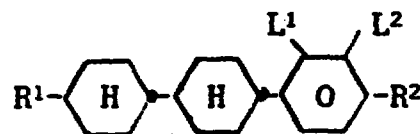
BCH



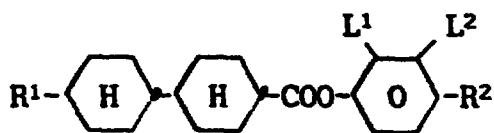
CBC



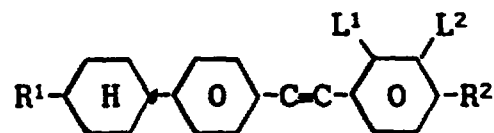
CCH



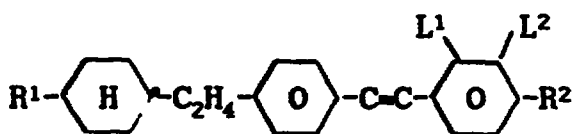
CCP



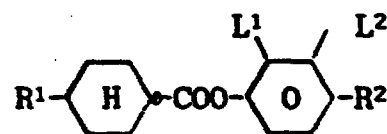
CP



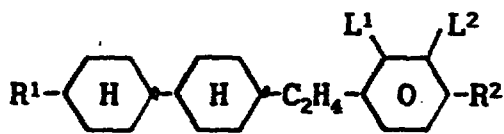
CPTP



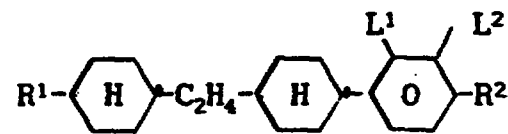
CEPTP



D



ECCP



CECP

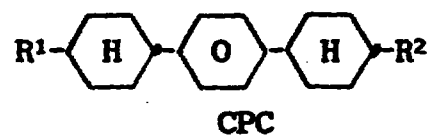
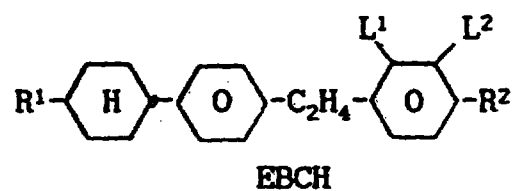
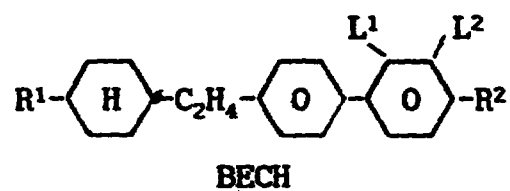
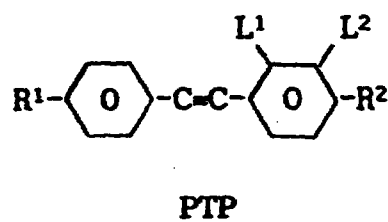
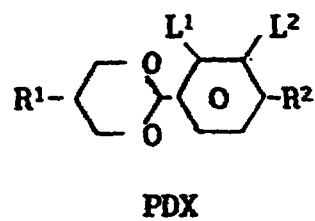
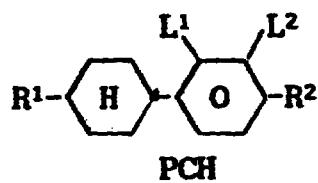
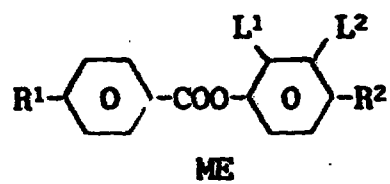
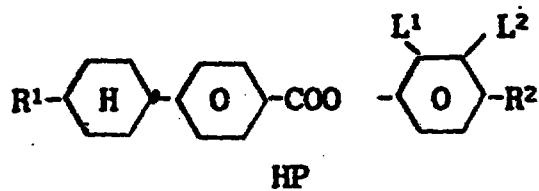
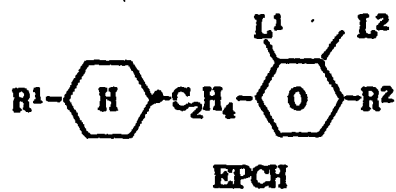
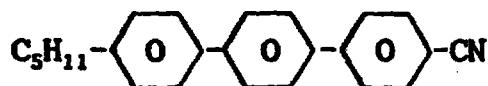
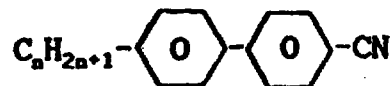


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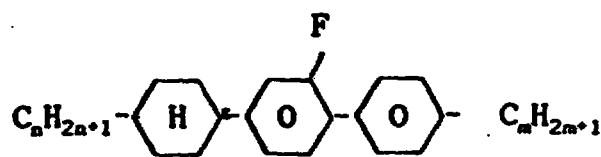
T15



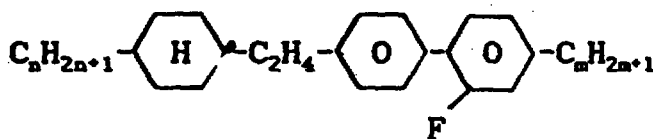
K3n



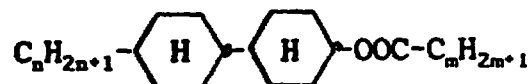
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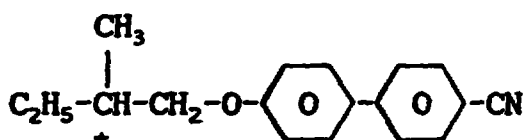
BCH-n.Fm



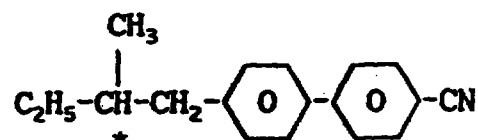
Inm



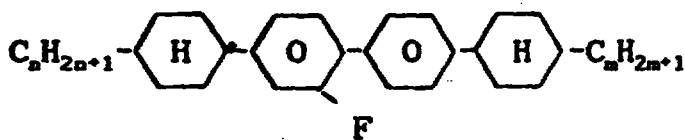
C-nm



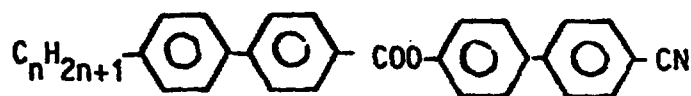
C15



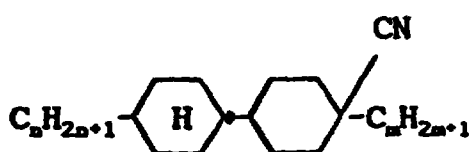
CB15



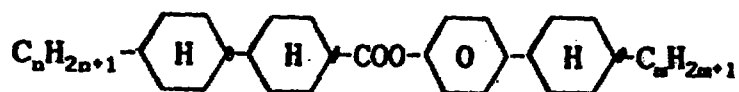
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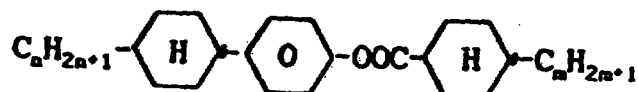
BB 3n



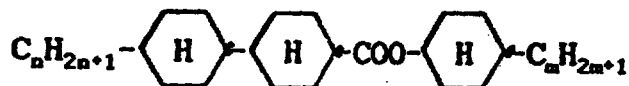
CCN-nm



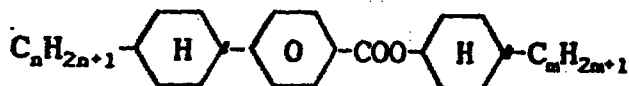
CCPC-nm



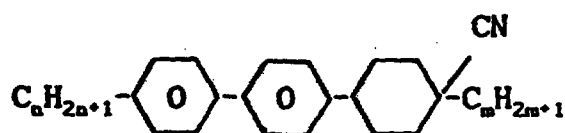
HD-nm



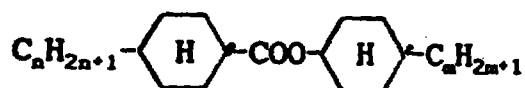
CH-nm



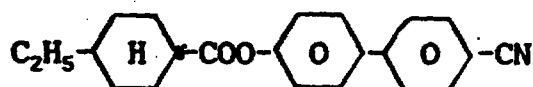
HH-nm



NCB-nm



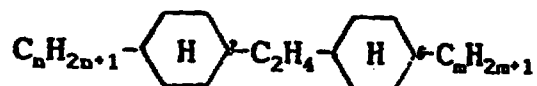
OS-nm



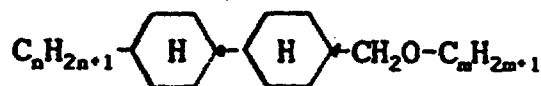
CHE



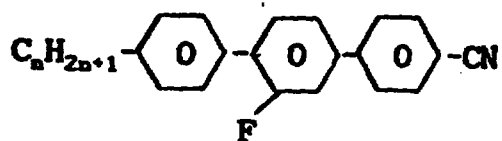
ECBC-nm



ECCH-nm



CCH-n1Em



T-nFn

Example 1:

Composition:

D-33	4.09 %
D-35	5.0 %
D-37	3.9 %
ME2N.F	6.0 %
ME3N.F	8.16 %
ME5N.F	14.18 %
ME7N.F	13.88 %
K6	8.94 %
K15	13.9 %
HP-4N.F	10.95 %
CBC-33	2.96 %
CBC-53	3.94 %
CHE	4.1 %

Clearing point	62.1-67.6 °C
Optical anisotropy Δn	0.165
(20 °C, 589 nm) n_o	1.510
n_e	1.675
Viscosity η +20 °C	64.3 cSt

Multiplex properties

measured at 90° twist

V(90,0,20) (Threshold)	0.76 V
V(10,0,20) (Saturation)	1.10 V

Example 2:

Composition:

D-33	4.04 %
D-35	4.94 %
D-37	3.85 %
ME2N.F	3.92 %
ME3N.F	4.93 %
ME5N.F	8.89 %
K6	10.0 %
K15	26.67 %
CP-55F	8.96 %
CBC-53	4.94 %
CHE	7.98 %
K12	10.88 %

Properties:

Clearing point	62.1-66.5 °C
Optical anisotropy Δn	0.171
(20 °C, 589 nm) n_o	1.514
n_e	1.685
Viscosity η +20 °C	41.4 cSt

Multiplex properties

measured at 90° twist

V(90,0,20) (Threshold)	1.07 V
V(10,0,20) (Saturation)	1.50 V

Example 3:

Composition:

CBC-53	4.0 %
CBC-53F	3.0 %
CBC-33F	3.0 %
CP-35F	9.0 %
CP-55F	10.0 %
D-35	13.0 %
K6	10.0 %
ME2N.F	4.0 %
ME3N.F	6.0 %
ME5N.F	12.0 %
PDX-3	8.0 %
PDX-4	10.0 %
PDX-5	8.0 %

Properties:

Clearing point [°C]	73°
Δn	0.128
V(90,0,20) (threshold)	1.10 V
Viscosity (cSt) 20 °C	47

Example 4:

Clearing point [°C]	62.6-67.3
Viscosity (cSt) 20 °C	40.3
Δn (589 nm, 20 °C)	0.17
n_o (589 nm, 20 °C)	1.684
n_e (589 nm, 20 °C)	1.514
$V_{(90,0,20)}$	1.11
$V_{(10,0,20)}$	1.53
$V_{(90,45,20)}$	0.85
$V_{(50,10,20)}$	1.27
M_{20}	1.80

Composition [%]:

CBC-53	4.99
CP-55F	8.99
CHE	8.04
D-33	12.98
K6	9.97
K12	10.01
K15	26.98
ME2N.F	4.0
ME3N.F	5.02
ME5N.F	9.02

Example 5:

Clearing point [°C]	63.2-67.5
Viscosity (cSt) 20 °C	69.3
Δn (589 nm, 20 °C)	0.132
n_e (589 nm, 20 °C)	1.629
n_o (589 nm, 20 °C)	1.497
$V_{(90,0,20)}$	0.72
$V_{(10,0,20)}$	1.00
$V_{(90,45,20)}$	0.49
$V_{(50,10,20)}$	0.80
M_{20}	2.00

Composition [%]:

CBC-33F	2.99
CBC-53	2.98
CP-55F	6.97
D-35	14.98
HP-4N.F	11.00
ME2N.F	6.00
ME3N.F	8.06
ME4N.F	14.03
ME5N.F	13.98
PDX-3	9.00
PDX-4	10.01

120 hrs at -20 °C: no crystals

Example 6:

Clearing point [°C]	63.3-68.6
Viscosity (cSt) 20 °C	67.3
Δn (589 nm, 20 °C)	0.168
n_e (589 nm, 20 °C)	1.682
n_o (589 nm, 20 °C)	1.514
$V_{(90.0,20)}$	0.69
$V_{(10.0,20)}$	1.00
$V_{(90.45,20)}$	0.59
$V_{(50.10,20)}$	0.80
M_{20}	1.70

Composition [%]:

CBC-33	2.95
CBC-53	3.97
CHE	7.49
D-35	10.95
HP-4N.F	7.42
K6	9.13
K9	6.94
K15	7.05
ME2N.F	6.94
ME3N.F	9.4
ME4N.F	13.86
ME5N.F	13.90

Example 7:

Clearing point [°C]	71.3-79.3
Viscosity (cSt) 20 °C	46.2
Δn (589 nm, 20 °C)	0.130
n_e (589 nm, 20 °C)	1.627
n_o (589 nm, 20 °C)	1.496
$V_{(90,0,20)}$	1.09
$V_{(10,0,20)}$	1.48
$V_{(90,45,20)}$	0.86
$V_{(50,10,20)}$	1.23
M_{20}	1.71

Composition [%]:

CBC-33	3.04
CBC-53	3.99
CBC-33F	2.99
CP-35F	6.98
CP-55F	9.98
D-33	4.71
D-35	5.76
D-37	4.48
K6	9.98
ME2N.F	3.99
ME3N.F	6.12
ME5N.F	12.05
PDX-3	7.52
PDX-4	9.85
PDX-5	8.56

Example 8:

Clearing point [°C]	71.1-78.3
Viscosity (cSt) 20 °C	46.7
Δn (589 nm, 20 °C)	0.183
n_e (589 nm, 20 °C)	1.700
n_o (589 nm, 20 °C)	1.516
M_{20}	1.71

Composition [%]:

CBC-33	3.0
CBC-53	4.98
CHE	8.96
CP-55F	8.84
D-33	6.25
K6	9.89
K12	10.54
K15	26.70
ME2N.F	5.93
ME3N.F	5.98
ME5N.F	8.93

Example 9:

Clearing point [°C]	73.5-80.4
Viscosity (cSt) 20 °C	47.2
Δn (589 nm, 20 °C)	0.128
n_e (589 nm, 20 °C)	1.623
n_o (589 nm, 20 °C)	1.495
$V_{(90,0,20)}$	1.105
$V_{(10,0,20)}$	1.513

Composition [%]:

CBC-53	4.0
CBC-53F	3.0
CBC-33F	3.0
CP-35F	9.0
CP-55F	10.0
D-35	13.0
K6	10.0
ME2N.F	4.0
ME3N.F	6.0
ME5N.F	12.0
PDX-3	8.0
PDX-4	10.0
PDX-5	8.0

Example 10:

Clearing point [°C]	71.1-78.3
Viscosity (cSt) 20 °C	46.71
An (589 nm, 20 °C)	0.184
n _e (589 nm, 20 °C)	1.700
n _o (589 nm, 20 °C)	1.516
V _(90,0,20)	1.12
V _(50,0,20)	1.35
V _(10,0,20)	1.63

Composition [%]:

CBC-33	3.0
CBC-53	4.98
CHE	8.96
CP-55F	8.84
D-33	6.25
K6	9.89
K12	10.54
K15	26.70
ME2N.F	5.93
ME3N.F	5.98
ME5N.F	8.93

Example 11:

Clearing point [°C]	69.4-75.0
Viscosity (cSt) 20 °C	46.71
Δn (589 nm, 20 °C)	0.16431
n_o (589 nm, 20 °C)	-
n_e (589 nm, 20 °C)	-
$V_{(10,0,20)}$	1.033
$V_{(40,0,20)}$	1.994
$V_{(50,0,20)}$	1.042
V (90,45,20)	0.752
M_{20}	1.8537

Composition (%):

PCH-3	7
K6	9
K9	9
K15	14
ME2N.F	9
ME3N.F	8
ME5N.F	9
CP-58F	8
CP-38F	7
CBC-83F	3
CBC-53	3
CBC-33F	3
BB21	2
PDX-4	4
D-35	5

Example 12:

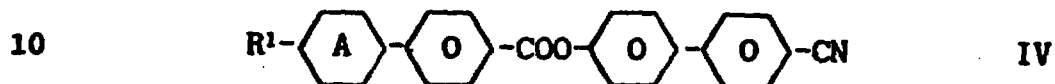
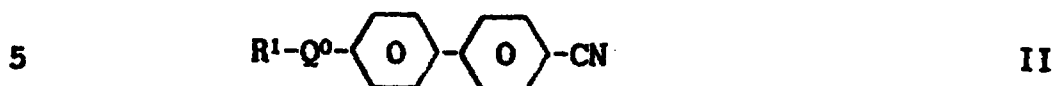
Clearing point [°C]	62.5-64.1
Viscosity (cSt) 20 °C	73.16
Δn (589 nm, 20 °C)	0.13145
n_o (589 nm, 20 °C)	1.62891
n_e (589 nm, 20 °C)	1.49746
$V_{(90,0,20)}$	0.661
$V_{(40,0,20)}$	0.929
$V_{(50,0,20)}$	0.694
$V_{(90,45,20)}$	0.496
M_{20}	1.845

Composition (%):

CBC-53	3
CBC-55	7
D-402	9
D-302	9
HP-4N.F	11
ME2N.F	6
ME3N.F	8
ME4N.F	14
ME5N.F	14
PDX-3	9
PDX-4	10

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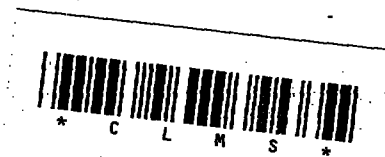
- a component B, which comprises two or more compounds selected from those having the following formulae II to IV:



wherein ring A is a 1,4-phenylene or a trans-1,4-cyclohexylene group, ring A[°] is a trans-1,4-cyclohexylene
15 or a trans-1,3-dioxane-2,5-diyl group, R¹ and Q⁰ have the meanings indicated above and the total proportion of components A and B is more than 32 wt.%;

- 5 to 21 wt.% of a component C, which comprises at
20 least one compound of the formula V:





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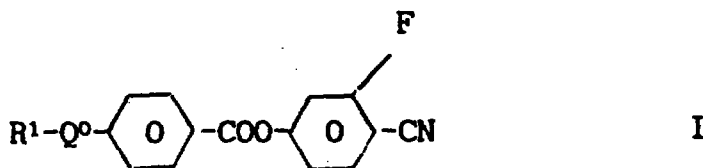
CLAIMS

1. A liquid crystal phase comprising:-

5

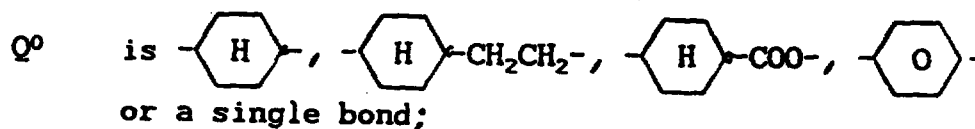
- 15 to 80 wt.% of a component A, which comprises two or more compounds of the formula I

10



15

wherein R¹ is an alkyl or alkenyl group with 1-12 carbon atoms, or an alkyl group with 2-12 carbon atoms wherein one CH₂ group is replaced by an oxygen atom, and

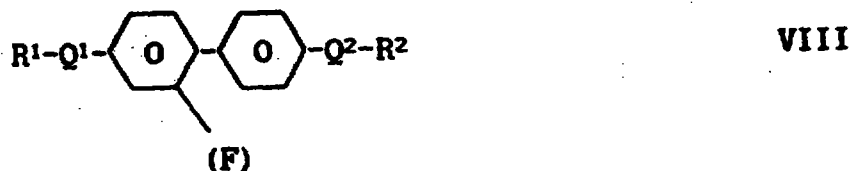
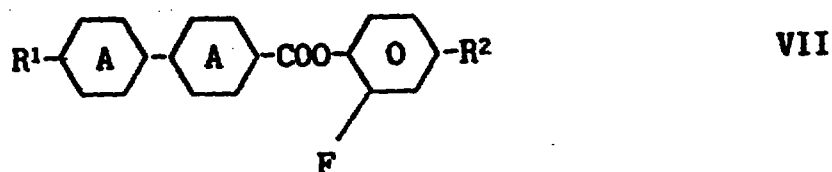
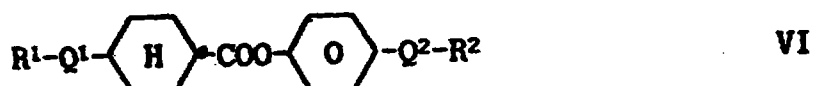




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wherein R^1 and ring A have the meanings indicated above and R^2 is an n-alkyl or n-alkoxy group with in each case up to 7 carbon atoms, and;

- 5 - 3 to 30 wt.% of a component D, which comprises one or more non polar additive selected from those having the following formulae VI to VIII:



wherein R^1 , R^2 and the rings A each independently have the meanings indicated above and Q^1 and Q^2 each are independently $-\text{C}_6\text{H}_4-$, $-\text{C}_6\text{H}_4-\text{CH}_2\text{CH}_2-$ or $-\text{CH}_2\text{CH}_2-\text{C}_6\text{H}_4-$.

20

2. A liquid crystal phase as claimed in claim 1 comprising at least three compounds of formula I.



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3. A liquid crystal phase as claimed in claim 1 or claim 2 comprising at least three compounds of formula II or III.
- 5 4. A liquid crystal phase as claimed in any of claims 1-3, comprising at least one compound of formula VI or VII.
- 10 5. A liquid crystal phase as claimed in any of claims 1-4, wherein A is trans-1,4-cyclohexylene and R^2 is an n-alkyl group.
- 15 6. A liquid crystal phase as claimed in any of claims 1-5, wherein the total proportion of components A and B is 55 to 85 wt.% and preferably 70-85 wt.%.
7. A liquid crystal phase as claimed in any of claims 1-6, wherein R^1 is an alkyl, alkenyl or alkoxymethyl group with 1-7 carbon atoms.
- 20 8. A liquid crystal phase as claimed in any of claims 1-7 wherein R^1 and R^2 includes an alkyl chain



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having a single branch.

5 9. A liquid crystal phase as claimed in claim 8,
wherein the branch is a methyl or ethyl group in the 1-
or 2- positions in the carbon skeleton.

10 10. A liquid crystal phase as claimed in claim 9
wherein the alkyl chain is a 2-methylpropyl, 2-methyl-
butyl, 1-methylpentyl, 2-methylpentyl or 1-methylhexyl
group.

15 11. A liquid crystal phase as claimed in any of
claims 8-10 wherein only one component includes a
branched chain alkyl radical and said component
comprises up to 10% by weight of the liquid crystal
phase.

20 12. A liquid crystal phase as claimed in claim 11,
wherein said component comprises between 0.5 and 3% by
weight of the liquid crystal phase.



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13. A liquid crystal phase as claimed in any of claims 7-12, wherein R^1 is a straight chain alkyl group with 2-7 carbon atoms.

5 14. A liquid crystal phase as claimed in any of claims 1-13, comprising 6-15% of component C.

10 15. A liquid crystal phase as claimed in any of claims 1-14 further comprising one or more pleochroic dye.

15 16. A liquid crystal phase as claimed in claim 15, comprising 0.5 to 15% and preferably 1 to 7% by weight of pleochroic dye.

17. A liquid crystal phase substantially as hereinbefore described in the examples.

20 18. An electro-optical liquid crystal display element including a liquid crystal phase as claimed in any of claims 1-17.
