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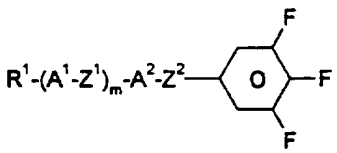
(54) Abstract Title

Liquid crystalline media having 4,4'-dialk-(1E or 3E)-enyl-1,1'-bicyclohexane & 3,4,5-trifluorophenyl-terminated components, and use in IPS displays

(57) A liquid-crystalline medium, of positive dielectric anisotropy, where the medium comprises at least one mesogenic compound of formula I and at least one bisalkenyl compound of formula I* is disclosed. There is also disclosed an electro-optical liquid-crystal display, having a realignment layer for realigning the liquid crystals whose field has a significant component parallel to the liquid-crystal layer, which comprises such a liquid-crystalline medium.

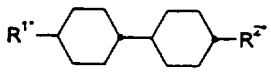
The threshold voltages and the response times of in-phase switching (IPS)displays can be improved with the aid of such a medium. These media are distinguished by their relatively high clearing points and low rotational viscosity values and their increased stability to crystallization at low temperatures.



I

[in which

R^1 (terminus), A^1/A^2 (ring) and Z^1/Z^2 (link) are as defined in claim 1 and m is 0, 1 or 2]



I*

[in which

R^{1*} and R^{2*} are each, independently of one another, 1E-alkenyl or 3E-alkenyl having C_{2-7} or C_{4-7} carbon atoms, respectively.]

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Electro-optical liquid-crystal display

The invention relates to an electro-optical liquid-crystal display having a realignment layer for realigning the liquid crystals whose field has a significant component parallel to the liquid-crystal layer and which comprises a liquid-crystalline medium of positive dielectric anisotropy, where the medium comprises at least one mesogenic compound containing a 3,4,5-trifluorophenyl group and at least one bisalkenyl compound of the formula I*.

In conventional liquid-crystal displays (TN, STN, OMI or AMD-TN), the electric fields for realignment are generated essentially perpendicular to the liquid-crystal layer.

International Patent Application WO 91/10936 discloses a liquid-crystal display in which the electric signals are generated in such a way that the electric fields have a significant component parallel to the liquid-crystal layer (IPS, in-plane switching). The principles of operating such a display are described, for example, by R.A. Soref in Journal of Applied Physics, vol. 45, No. 12, pp. 5466-5468 (1974).

EP 0 588 568 discloses various ways of addressing a display of this type.

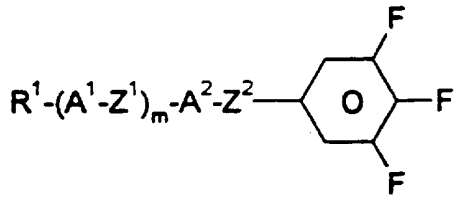
These IPS displays can be operated with liquid-crystalline materials either of positive or of negative dielectric anisotropy ($\Delta\varepsilon \neq 0$). However, using the materials known hitherto, relatively high threshold voltages and long response times are reached in IPS displays. In addition, the problem of crystallization of the liquid-crystal medium at low temperatures can occur in IPS displays containing materials known hitherto. The object was therefore to indicate liquid-crystalline materials which are suitable for achieving relatively low threshold voltages and short response times in IPS displays and which, in particular, have an improved low-temperature shelf life.

Surprisingly, this object has been achieved by the use of liquid-crystalline materials comprising at least one compound of formula I containing a 3,4,5-trifluorophenyl group and at least one compound of the formula I*.

Compounds of the formula I are disclosed, for example, in EP 0 387 032 and EP 0 441 932. Compounds of the formula I* are covered by the broad generic formula in EP 0 168 683.

However, there is no indication in the documents mentioned above that the threshold voltages and the response times of IPS displays can be improved with the aid of these substances. The novel IPS mixtures are distinguished by their relatively high clearing points and low rotational viscosity values and their increased stability to crystallization at low temperatures.

The invention therefore relates to an electro-optical liquid-crystal display having a realignment layer for realigning the liquid crystals whose field has a significant component parallel to the liquid-crystal layer and which contains a liquid-crystalline medium of positive dielectric anisotropy, where the medium comprises at least one compound of the formula I



I

in which

R^1 is H, an alkyl or alkenyl radical having 1 to 15 carbon atoms which is unsubstituted, monosubstituted by CN or CF_3 or at least monosubstituted by halogen, where one or more CH_2 groups in these radicals may also, in each case independently of one another, be replaced by -O-, -S-, -CO-, -CO-O-, -O-CO- or -O-CO-O- in such a way that O atoms are not linked directly to one another,

A^1 and A^2 are each, independently of one another, a

(a) trans-1,4-cyclohexylene radical or 1,4-cyclohexenylene radical, in which, in addition, one or more non-adjacent CH_2 groups may be replaced by -O- and/or -S-,

(b) 1,4-phenylene radical, in which, in addition, one or two CH groups may be replaced by N,

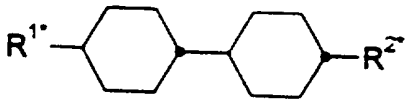
(c) radical from the group consisting of 1,4-dicyclo(2,2,2)octylene, piperidine-1,4-diyl, naphthalene-2,6-diyl, decahydronaphthalene-2,6-diyl and 1,2,3,4-tetrahydronaphthalene-2,6-diyl,

where the radicals (a) and (b) may be substituted by one or two fluorine atoms,

Z^1 and Z^2 are each, independently of one another, -CO-O-, -O-CO-, $-CH_2O-$, $-OCH_2-$, $-CH_2CH_2-$, -CH=CH-, -C≡C-, or a single bond, or one of the radicals Z^1 and Z^2 is $-(CH_2)_4-$ or $-CH=CH-CH_2CH_2-$, and

m is 0, 1 or 2,

and at least one compound of the formula I*



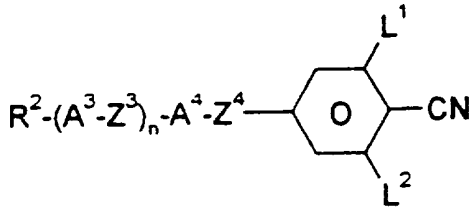
I*

in which

R^{1*} and R^{2*} are each, independently of one another, 1E-alkenyl or 3E-alkenyl having 2-7 carbon atoms.

Preferred embodiments are IPS displays where

- the medium additionally comprises at least one compound of the formula II



II

in which

L^1 and L^2 are each, independently of one another, H or F,

R^2 is as defined for R^1,

A^3 and A^4 are each, independently, as defined for A^1 and A^2,

Z^3 and Z^4 are each, independently of one another, as defined for Z^1 and Z^2, and

n is 0, 1 or 2,

- the medium additionally comprises at least one compound of the formula III

$$R^3-(A^5-Z^5)_o-A^6-R^4 \qquad \text{III}$$

in which

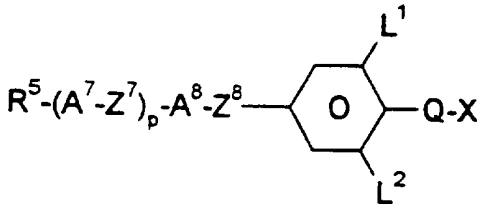
R^3 and R^4 are each, independently of one another, as defined for R^1,

A^5 and A^6 are each, independently, as defined for A^1 and A^2,

Z^5 is in each case, independently of the others, as defined for Z^1 and Z^2, and

o is 1, 2 or 3;

- the medium comprises at least one compound of the formula IV



IV

in which

R^5 is as defined for R^1,

A^7 and A^8 are each, independently of one another, as defined for A^1 and A^2,

Z^7 and Z^8 are each, independently of one another, as defined for Z^1 and Z^2,

L^1 and L^2 are each, independently of one another, H or F,

Q is a polyfluoroalkylene radical of the formula

$-(O)_q-(CH_2)_r-(CF_2)_s-$

in which

q is 0 or 1

r is 0 or an integer between 1 and 6 and

s is an integer between 1 and 6,

X is H, F or Cl, and

p is 0, 1 or 2.

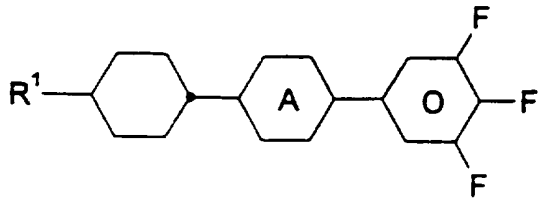
Preference is furthermore given to an IPS display in which the pixels are addressed by means of an active matrix.

The invention furthermore relates to a liquid-crystalline medium of positive dielectric anisotropy which comprises at least one compound of the formula I and at least one compound of the formula I*, in particular which comprises

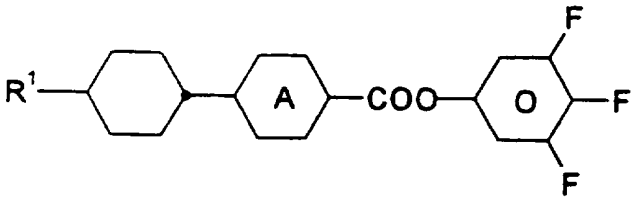
-	from 10 to 60 % by weight,	preferably from 30 to 60% by weight, of at least one compound of the formula I,
-	from 5 to 40% by weight,	preferably from 10 to 25% by weight, of at least one compound of the formula I*,
-	from 0 to 40% by weight,	preferably from 0 to 25% by weight, of at least one compound of the formula II,
-	from 0 to 30% by weight,	preferably from 0 to 15% by weight, of at least one compound of the formula III, and
-	from 5 to 50% by weight,	preferably from 10 to 30% by weight, of a compound of the formula IV.

The novel liquid-crystalline medium preferably comprises:

- at least one compound selected from the formulae Ia and/or Ib

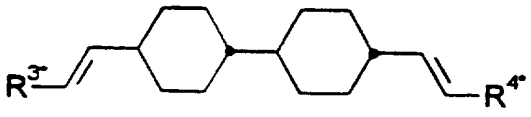


Ia

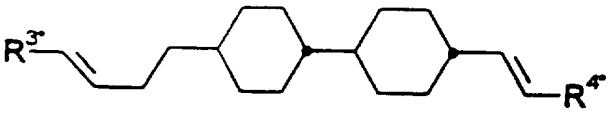


Ib

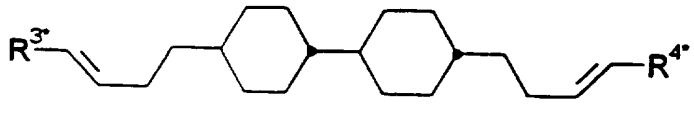
- at least one compound selected from the formulae I*a to I*c



I*a



I*b



I*c

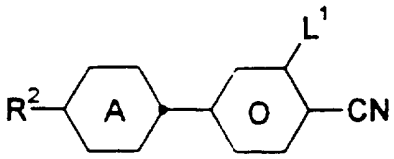
where

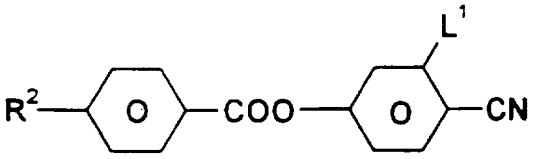
R^{3*} and R^{4*} are each, independently of one another, H, CH_3, C_2H_5 or n-C_3H_7.

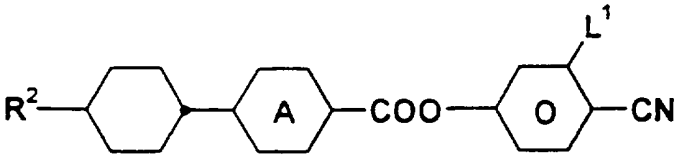
Preferred compounds are compounds of the formula I*a and compounds in which R^{3*} and R^{4*} are H, CH_3 or C_2H_5.

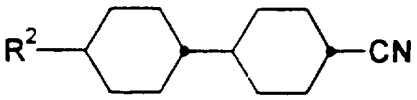
Preference is furthermore given to compounds of the formulae I*a and I*c in which R^{3*} and R^{4*} are identical.

- at least one compound selected from the formulae IIa to IId

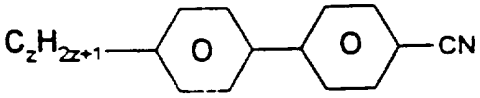

IIa


IIb


IIc

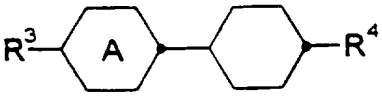

IId

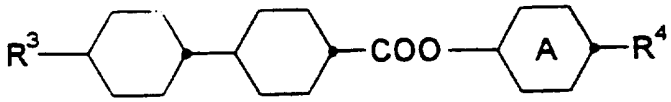
- in a particularly preferred form, at least one compound of the formula IIa1

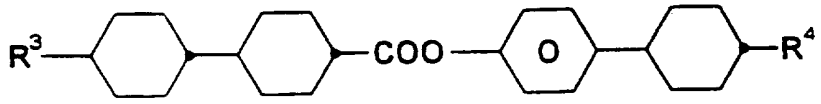

IIa1

in which z is 1-12;

- at least one compound selected from the formulae IIIa, IIIb and IIIc,

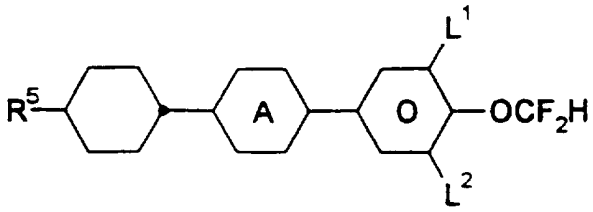

IIIa


IIIb

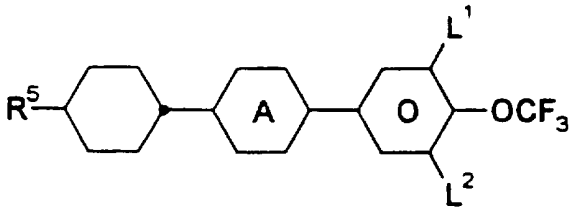

IIIc

and

- if desired, at least one compound selected from the formulae IVa and IVb,



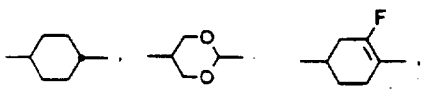
IVa



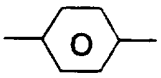
IVb

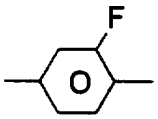
in which

is in each case



or

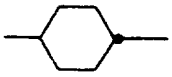




R^1, R^2, R^3, R^4, R^5, L^1 and L^2 are each as defined above.

In a particularly preferred embodiment, the novel media comprise at least one compound of the formula Ia in which

is



and at least one compound of the formula I*a and/or I*c.

In a further preferred embodiment, the novel media comprise at least one compound of the formula Ia and at least one compound of the formula Ib and a compound of the formula I*, preferably I*a, I*b or I*c.

The novel liquid-crystalline media generally have a birefringence (Δn) < 0.12, preferably between 0.05 and 0.11, in particular between 0.07 and 0.10.

The viscosity (at 20°C) of the novel mixtures is generally less than 30 $mm^2 \cdot s^{-1}$, in particular between 15 and 25 $mm^2 \cdot s^{-1}$. The specific resistivity of the novel materials at 20°C is generally between 5×10^{10} and

5×10^{13} Ω · cm, particularly preferably between 5×10^{11} and 5×10^{12} Ω · cm. The rotational viscosity of the novel mixtures at 20°C is generally less than 150 mPa·s, in particular between 50 and 100 mPa·s.

It has been found that even a relatively small proportion of compounds of the formulae I* and I in a mixture with conventional liquid-crystal materials, but in particular with one or more compounds of the formula II, III and/or IV, results in a significant lowering of the threshold voltage, in favourable levels of rotational viscosity γ, and in fast response times, with at the same time broad nematic phases having low smectic-nematic transition temperatures being observed. The compounds of the formulae I*, I to IV are colourless, stable and readily miscible with one another and with other liquid-crystal materials.

The term "alkyl" covers straight-chain and branched alkyl groups having 1-7 carbon atoms, in particular the straight-chain groups methyl, ethyl, propyl, butyl, pentyl, hexyl and heptyl. Group [sic] having 2-5 carbon atoms are generally preferred.

The term "alkenyl" covers straight-chain and branched alkenyl groups having 2-7 carbon atoms, in particular the straight-chain groups. In particular, alkenyl groups are C_2-C_7-1E-alkenyl, C_4-C_7-3E-alkenyl, C_5-C_7-4-alkenyl, C_6-C_7-5-alkenyl and C_7-6-alkenyl, in particular C_2-C_7-1E-alkenyl, C_4-C_7-3E-alkenyl and C_5-C_7-4-alkenyl. Examples of preferred alkenyl groups are vinyl, 1E-propenyl, 1E-butenyl, 1E-pentenyl, 1E-hexenyl, 1E-heptenyl, 3E-butenyl, 3E-pentenyl, 3E-hexenyl, 3E-heptenyl, 4-pentenyl, 4Z-hexenyl, 4E-hexenyl, 4Z-heptenyl, 5-hexenyl, 6-heptenyl and the like. Groups having up to 5 carbon atoms are generally preferred.

The term "fluoroalkyl" preferably covers straight-chain groups having a terminal fluorine atom, i.e. fluoromethyl, 2-fluoroethyl, 3-fluoropropyl, 4-fluorobutyl, 5-fluoropentyl, 6-fluorohexyl and 7-fluoroheptyl. However, other positions of the fluorine are not excluded.

The term "oxaalkyl" preferably covers straight-chain radicals of the formula C_nH_{2n+1}-O-$(CH_2)_m$, in which n and m are each, independently of one another, from 1 to 6. Preferably, n = 1 and m is from 1 to 6.

Through a suitable choice of the meanings of R^1 and R^5, the response times, the threshold voltage, the steepness of the transmission characteristic lines, etc., can be modified as desired. For example, 1E-alkenyl radicals, 3E-alkenyl radicals, 2E-alkenyloxy radicals and the like generally result in shorter response times, improved nematic tendencies and a higher ratio between the elastic constants k_{33} (bend) and k_{11} (splay) compared with alkyl and alkoxy radicals. 4-Alkenyl radicals, 3-alkenyl radicals and the like generally result in lower threshold voltages and smaller values of k_{33}/k_{11} compared with alkyl and alkoxy radicals.

A $-CH_2CH_2-$ group in Z^1, Z^2, Z^3, Z^4, Z^5, Z^7 and/or Z^8 generally results in higher values of k_{33}/k_{11} compared with a single covalent bond. Higher values of k_{33}/k_{11} facilitate, for example, flatter transmission characteristic lines in TN cells having a 90° twist (for achieving grey shades) and steeper transmission characteristic lines in STN, SBE and OMI cells (greater multiplexibility), and vice versa.

The optimum mixing ratio between the compounds of the formulae I*, I and II + III + IV depends substantially on the desired properties, on the choice of the components of the formulae I*, I, II, III and/or IV and on the choice of any other components present. Suitable mixing ratios within the abovementioned range can easily be determined from case to case.

The total amount of compounds of the formulae I*, I to IV in the novel mixtures is not crucial. The mixtures preferably comprise 50-90 % by weight of compounds of the formulae I, I* and IV. The mixtures may also contain one or more further components in order to optimize various properties. However, the observed effect on the response times and the threshold

voltage is generally higher the greater the total concentration of compounds of the formulae I*, I and IV.

In a particularly preferred embodiment, the novel media comprise compounds of the formula IV in which Q-X is OCF_3 or $OCHF_2$. A favourable synergistic effect with the compounds of the formula I*, I and II results in particularly advantageous properties.

The novel liquid-crystalline media preferably comprise 2 to 40, in particular 4 to 30, components as further constituents besides one or more compounds of the formulae I*, I, II, III and IV. These media very particularly preferably comprise 7 to 25 components besides one or more compounds according to the invention. These further constituents are preferably selected from nematic or nematogenic (monotropic or isotropic) substances, in particular substances from the classes of the azoxybenzenes, benzylideneanilines, biphenyls, terphenyls, phenyl or cyclohexyl benzoates, phenyl or cyclohexyl esters of cyclohexanecarboxylic acid, phenyl or cyclohexyl esters of cyclohexylbenzoic acid, phenyl or cyclohexyl esters of cyclohexylcyclohexanecarboxylic acid, cyclohexylphenyl esters of benzoic acid, of cyclohexanecarboxylic acid and of cyclohexylcyclohexanecarboxylic acid, phenylcyclohexanes, cyclohexylbiphenyls, phenylcyclohexylcyclohexanes, cyclohexylcyclohexanes, cyclohexylcyclohexylcyclohexenes, 1,4-bis-cyclohexylbenzenes, 4,4'-bis-cyclohexylbiphenyls, phenyl- or cyclohexylpyrimidines, phenyl- or cyclo-hexylpyridines, phenyl- or cyclohexyldioxanes, phenyl- or cyclohexyl-1,3-dithianes, 1,2-diphenylethanes, 1,2-di-cyclohexylethanes, 1-phenyl-2-cyclohexylethanes, 1-cyclohexyl-2-(4-phenylcyclohexyl)ethanes, 1-cyclohexyl-2-biphenylylethanes, 1-phenyl-2-cyclohexylphenylethanes optionally halogenated stilbenes, benzyl phenyl ethers, tolans and substituted cinnamic acids. The 1,4-phenylene groups in these compounds may also be fluorinated.

The most important compounds suitable as further constituents of novel media can be characterized by the formulae 1, 2, 3, 4 and 5:

R'-L-E-R"	1
R'-L-COO-E-R"	2
R'-L-OOC-E-R"	3
R'-L-CH_2CH_2-E-R"	4
R'-L-C≡C-E-R"	5

In the formulae 1, 2, 3, 4 and 5, L and E, which may be identical or different, are in each case, independently of one another, a bivalent radical from the group formed by -Phe-, -Cyc-, -Phe-Phe-, -Phe-Cyc-, -Cyc-Cyc-, -Pyr-, -Dio-, -G-Phe- and -G-Cyc- and their mirror images, where Phe is unsubstituted or fluorine-substituted 1,4-phenylene, Cyc is trans-1,4-cyclohexylene or 1,4-cyclohexylene [sic], Pyr is pyrimidine-2,5-diyl or pyridine-2,5-diyl, Dio is 1,3-dioxane-2,5-diyl and G is 2-(trans-1,4-cyclohexyl)ethyl, pyrimidine-2,5-diyl, pyridine-2,5-diyl or 1,3-dioxane-2,5-diyl.

One of the radicals L and E is preferably Cyc, Phe or Pyr. E is preferably Cyc, Phe or Phe-Cyc. The novel media preferably comprise one or more components selected from the compounds of the formulae 1, 2, 3, 4 and 5 in which L and E are selected from the group consisting of Cyc, Phe and Pyr and simultaneously one or more components selected from the compounds of the formulae 1, 2, 3, 4 and 5 in which one of the radicals L and E is selected from the group consisting of Cyc, Phe and Pyr and the other radical is selected from the group consisting of -Phe-Phe-, -Phe-Cyc-, -Cyc-Cyc-, -G-Phe- and -G-Cyc-, and optionally one or more components selected from the compounds of the formulae 1, 2, 3, 4 and 5 in which the radicals L and E are selected from the group consisting of -Phe-Cyc-, -Cyc-Cyc-, -G-Phe- and -G-Cyc-.

In a smaller sub-group of the compounds of the formulae 1, 2, 3, 4 and 5, R' and R" are in each case,

independently of one another, alkyl, alkenyl, alkoxy, alkoxyalkyl, alkenyloxy or alkanoyloxy having up to 8 carbon atoms. This smaller sub-group is called group A below, and the compounds are labeled with the sub-formulae 1a, 2a, 3a, 4a and 5a. In most of these compounds, R' and R" are different from one another, one of these radicals usually being alkyl, alkenyl, alkoxy or alkoxyalkyl.

In another smaller sub-group of the compounds of the formulae 1, 2, 3, 4 and 5 which is known as group B, R" is -F, -Cl, -NCS or $-(O)_iCH_{3-(k+1)}F_kCl_l$, where i is 0 or 1, and k+l is 1, 2 or 3; the compounds in which R" has this meaning are labeled with the sub-formulae 1b, 2b, 3b, 4b and 5b. Particular preference is given to those compounds of the sub-formulae 1b, 2b, 3b, 4b and 5b in which R" is -F, -Cl, -NCS, $-CF_3$, $-OCHF_2$ or $-OCF_3$.

In the compounds of the sub-formulae 1b, 2b, 3b, 4b and 5b, R' is as defined for the compounds of the sub-formulae 1a-5a and is preferably alkyl, alkenyl, alkoxy or alkoxyalkyl.

In a further smaller sub-group of the compounds of the formulae 1, 2, 3, 4 and 5, R" is -CN; this sub-group is known as group C below, and the compounds of this sub-group are correspondingly described by sub-formulae 1c, 2c, 3c, 4c and 5c. In the compounds of the sub-formulae 1c, 2c, 3c, 4c and 5c, R' is as defined for the compounds of the sub-formulae 1a-5a and is preferably alkyl, alkoxy or alkenyl.

In addition to the preferred compounds of groups A, B and C, other compounds of the formulae 1, 2, 3, 4 and 5 having other variants of the proposed substituents are also customary. All these substances can be obtained by methods which are known from the literature or analogously thereto.

Besides compounds of the formula I and I*, the novel media preferably comprise one or more compounds selected from group A and/or group B and/or group C. The proportions by weight of the compounds from these groups in the novel media are preferably

Group A: 0 to 90%, preferably 20 to 90%, in particular 30 to 90%

Group B: 0 to 80%, preferably 10 to 80%, in particular 10 to 65%

Group C: 0 to 80%, preferably 5 to 80%, in particular 5 to 50%,

the sum of the proportions by weight of the group A and/or B and/or C compounds present in the particular novel media preferably being 5%-90% and in particular 10% to 90%.

The novel media preferably comprise 1 to 40%, particularly preferably 5 to 30%, of compounds of the formulae I and I*. Further preferred media are those which comprise more than 40%, in particular 45 to 90%, of compounds of the formulae I and I*. The media preferably comprise three, four or five compounds of the formulae I and I*.

The structure of the IPS display according to the invention corresponds to the usual construction for such displays, as described, for example, in WO 91/10936 or EP 0 588 568. The term conventional construction is broadly drawn here and also covers all derivatives and modifications of the IPS display, in particular, for example, including matrix display elements based on poly-Si TFT or MIM.

However, an essential difference between the displays according to the invention and those conventional hitherto is in the choice of the liquid-crystal parameters of the liquid-crystal layer.

The liquid-crystal mixtures which can be used in accordance with the invention are prepared in a manner conventional per se. In general, the desired amount of the components used in lesser amount is dissolved in the components making up the principal constituent, expediently at elevated temperature. It is also possible to mix solutions of the components in an organic solvent, for example in acetone, chloroform or methanol, and,

after mixing, to remove the solvent again, for example by distillation.

The dielectrics may also comprise further additives known to the person skilled in the art and described in the literature. For example, 0-15% of pleochroic dyes or chiral dopants can be added.

C denotes a crystalline phase, S a smectic phase, S_B a smectic B phase, N a nematic phase and I the isotropic phase.

V_o denotes the capacitive threshold voltage. Δn denotes the optical anisotropy and n_o the ordinary refractive index (in each case at 589 nm). $\Delta\varepsilon$ denotes the dielectric anisotropy ($\Delta\varepsilon = \varepsilon_\parallel - \varepsilon_\perp$, where $\varepsilon_\parallel$ denotes the dielectric constant parallel to the longitudinal axes of the molecules and $\varepsilon_\perp$ denotes the dielectric constant perpendicular thereto). The electro-optical data were measured in a planar cell at 20°C, unless expressly stated otherwise. The optical data were measured at 20°C, unless expressly stated otherwise.

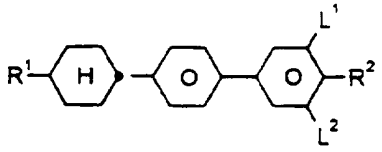
The cells are dark in the "off" state.

In the present application and in the examples below, the structures of the liquid-crystal compounds are indicated by acronyms, the transformation into chemical formulae taking place as in Tables A and B below. All the radicals C_nH_{2n+1} are straight-chain alkyl radicals containing n or m carbon atoms, respectively. The coding in Table B is self-evident. In Table A, only the acronym for the parent structure is given. In individual cases, the acronym for the parent structure is followed, separated by a hyphen, by a code for the substituents R^1, R^2, L^1 and L^2:

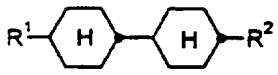
Code for R^1, R^2, L^1, L^2	R^1	R^2	L^1	L^2
nm	C_nH_{2n+1}	C_mH_{2m+1}	H	H
nOm	C_nH_{2n+1}	OC_mH_{2m+1}	H	H
nO.m	OC_nH_{2n+1}	C_mH_{2m+1}	H	H
n	C_nH_{2n+1}	CN	H	H
nN.F	C_nH_{2n+1}	CN	F	H
nN.F.F	C_nH_{2n+1}	CN	F	F
nF	C_nH_{2n+1}	F	H	H
nOF	OC_nH_{2n+1}	F	H	H
nCl	C_nH_{2n+1}	Cl	H	H
nF.F	C_nH_{2n+1}	F	F	H
nCF_3	C_nH_{2n+1}	CF_3	H	H
$nOCF_3$	C_nH_{2n+1}	OCF_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_2H_{2s}-	CN	H	H
nAm	C_nH_{2n+1}	$COOC_mH_{2m+1}$	H	H
nF.F.F	C_nH_{2n+1}	F	F	F
nCl.F.F	C_nH_{2n+1}	Cl	F	F
nCF_3.F.F	C_nH_{2n+1}	CF_3	F	F
$nOCF_3$.F.F	C_nH_{2n+1}	OCF_3	F	F
$nOCF_2$.F.F	C_nH_{2n+1}	$OCHF_2$	F	F
$nOCF_3$.F	C_nH_{2n+1}	OCF_3	F	H

Preferred media comprise, in particular, one or more compounds from Tables A and B in addition to the compounds of the formulae I and I*.

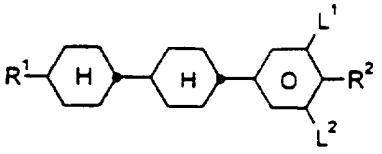
Table A:



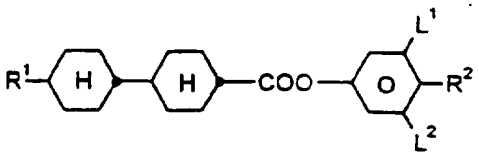
BCH



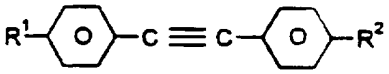
CCH



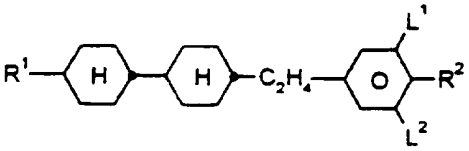
CCP



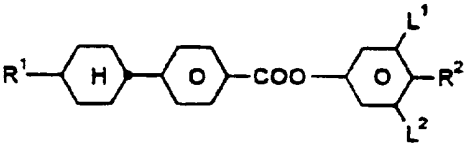
CP



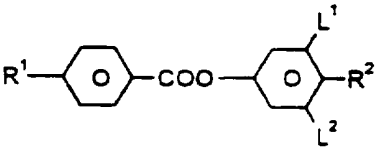
PTP



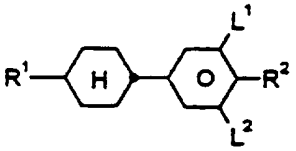
ECCP



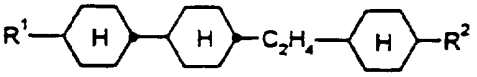
HP



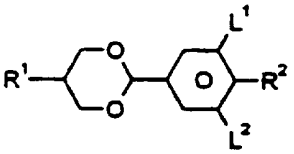
ME



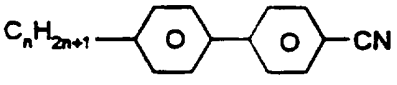
PCH



CH

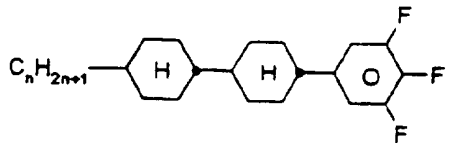


PDX

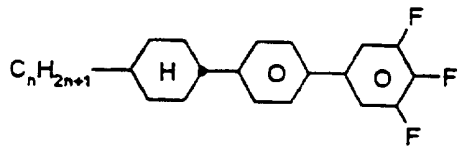


K3 · n

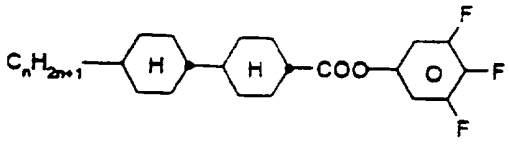
Table B:



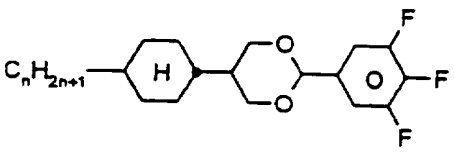
CCP-nF.F.F



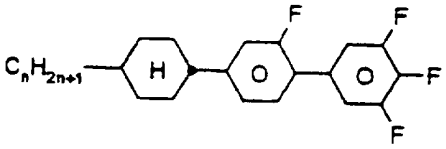
BCH-nF.F.F



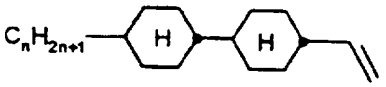
CCZU-n-F



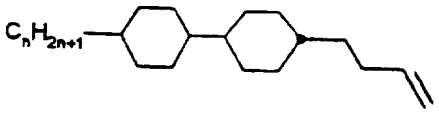
CDU-n-F



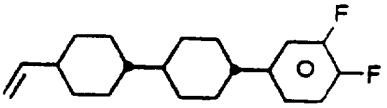
CGU-n-F



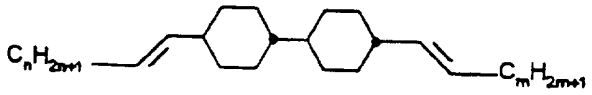
CC-n-V



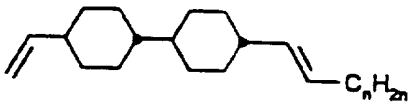
CC-n-2V



CCG-V-F



CC-nV-Vm



CC-V-Vn

Example 1

An IPS display comprises a nematic mixture having

clearing point	+73°C
Δn[589 nm, 20°C]	0.0768
n_o	1.4732
rotational viscosity (20°C)	80 mPa·s

and comprising

CCP-20CF_3	8.0 %
CCP-30CF_3	6.0 %
CCP-40CF_3	5.0 %
CCP-50CF_3	5.0 %

CCP-2F.F.F	9.0 %
CCP-3F.F.F	8.0 %
CCP-5F.F.F	6.0 %
CCZU-2-F	6.0 %
CCZU-3-F	9.0 %
CCZU-5-F	6.0 %
PCH-2N.F.F	5.0 %
PCH-3N.F.F	5.0 %
PCH-5N.F.F	4.0 %
CC-V-V1	18.0 %

and has high contrast and short response times.

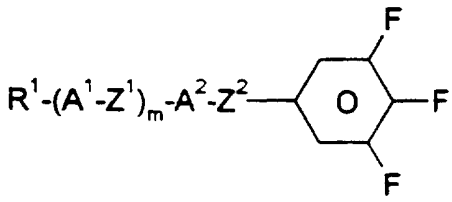
The shelf life at -30°C up to which no crystallization of the mixture occurs is 890 hours.

Patent claims

1. Electro-optical liquid-crystal display

- having a realignment layer for realigning the liquid crystals whose field has a significant component parallel to the liquid-crystal layer

- and containing a liquid crystalline medium of positive dielectric anisotropy, characterized in that the medium comprises at least one compound of the formula I



I

in which

R^1 is H, an alkyl or alkenyl radical having 1 to 15 carbon atoms which is unsubstituted, monosubstituted by CN or CF_3 or at least monosubstituted by halogen, where one or more CH_2 groups in these radicals may also, in each case independently of one another, be replaced by -O-, -S-, -CO-, -CO-O-, -O-CO- or -O-CO-O- in such a way that O atoms are not linked directly to one another,

A^1 and A^2 are each, independently of one another, a

(a) 1,4-cyclohexenylene radical or trans-1,4-cyclohexylene radical, in which, in addition, one or more non-adjacent CH_2 groups may be replaced by -O- and/or -S-,

(b) 1,4-phenylene radical, in which, in addition, one or two CH groups may be replaced by N,

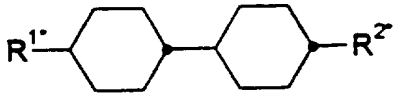
(c) radical from the group consisting of 1,4-dicyclo[2.2.2]octylene, piperidine-1,4-diyl, naphthaline-2,6-diyl, decahydronaphthaline-2,6-diyl and 1,2,3,4-tetrahydronaphthaline-2,6-diyl,

where the radicals (a) and (b) may be substituted by one or two fluorine atoms,

Z^1 and Z^2 are each, independently of one another, -CO-O-, -O-CO-, $-CH_2O-$, $-OCH_2-$, $-CH_2CH_2-$, -CH=CH-, -C≡C-, or a single bond, or one of the radicals Z^1 and Z^2 is $-(CH_2)_4-$ or $-CH=CH-CH_2CH_2-$, and

m is 0, 1 or 2,

and at least one compound of the formula I*

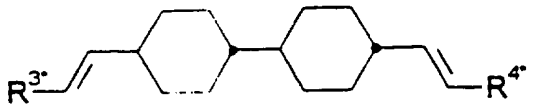


I*

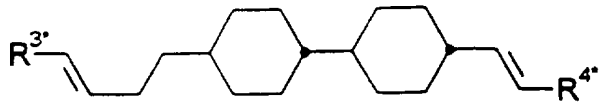
in which

R^{1*} and R^{2*} are each, independently of one another, 1E-alkenyl or 3E-alkenyl having 2-7 carbon atoms.

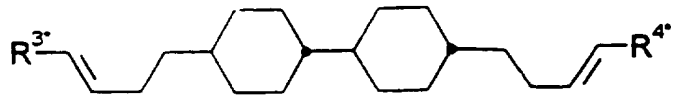
2. Liquid-crystal display according to one of Claims 1 and 2, characterized in that the medium comprises at least one compound of the formula I*a, I*b or I*c:



I*a



I*b

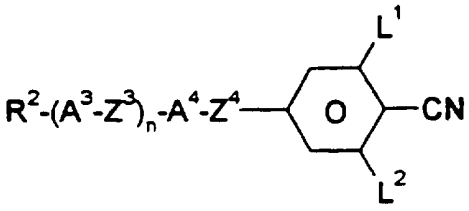


I*c

in which

R^{3*} and R^{3*} are each, independently of one another, H, CH_3, C_2H_5 or n-C_3H_7.

3. Liquid-crystal display according to one of Claims 1 and 2, characterized in that the medium comprises at least one compound of the formula II



II

in which

L^1 and L^2 are each, independently of one another, H or F,

R^2 is as defined for R^1,

A^3 and A^4 are each, independently, as defined for A^1 and A^2,

Z^3 and Z^4 are each, independently of one another, as defined for Z^1 and Z^2, and

n is 0, 1 or 2.

4. Liquid-crystal display according to one of Claims 1 to 3, characterized in that the medium comprises at least one compound of the formula III

$$R^3-(A^5-Z^5)_o-A^6-R^4 \qquad III$$

in which

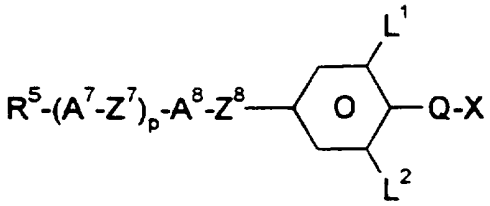
R^3 and R^4 are each, independently of one another, as defined for R^1,

A^5 and A^6 are each, independently, as defined for A^1 and A^2,

Z^5 is in each case, independently of the others, as defined for Z^1 and Z^2, and

o is 1, 2 or 3.

5. Liquid-crystal display according to one of Claims 1 to 4, characterized in that the medium comprises at least one compound of the formula IV



IV

in which

R^5 is as defined for R^1,

A^7 and A^8 are each, independently of one another, as defined for A^1 and A^2,

Z^7 and Z^8 are each, independently of one another, as defined for Z^1 and Z^2,

L^1 and L^2 are each, independently of one another, H or F,

Q is a polyfluoroalkylene radical of the formula

$-(O)_q-(CH_2)_r-(CF_2)_s-$

in which

q is 0 or 1

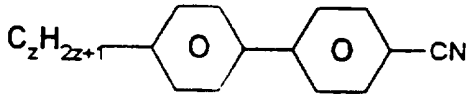
r is 0 or an integer between 1 and 6 and

s is an integer between 1 and 6,

X is H, F or Cl, and

p is 0, 1 or 2.

6. Liquid-crystal display according to one of Claims 1 to 5, characterized in that the medium comprises at least one compound of the formula IIa1



IIa1

in which z is 1-12.

7. Display according to one of Claims 1 to 6, characterized in that the pixels are addressed by means of an active matrix.

8. Liquid-crystalline medium of positive dielectric anisotropy which has a composition according to Claims 1 to 7.

9. Liquid-crystalline medium according to Claim 8, characterized in that it comprises

- from 10 to 60 % by weight, preferably from 30 to 60% by weight, of at least one compound of the formula I,

- from 5 to 40% by weight, preferably from 10 to 25% by weight, of at least one compound of the formula I*,

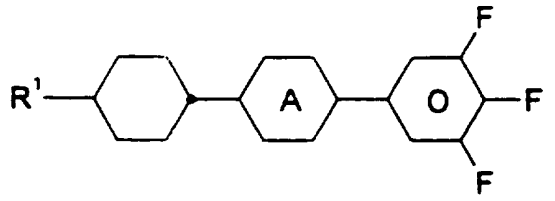
- from 0 to 40% by weight, preferably from 0 to 25% by weight, of at least one compound of the formula II,

- from 0 to 30% by weight, preferably from 0 to 15% by weight, of at least one compound of the formula III, and

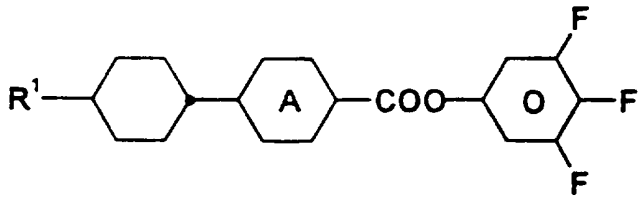
- from 5 to 50% by weight, preferably from 10 to 30% by weight, of a compound of the formula IV.

10. Liquid-crystalline medium according to Claim 8 or 9, characterized in that it comprises:

- at least one compound selected from the formulae Ia and/or Ib

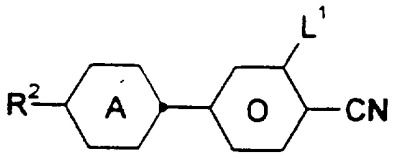


Ia

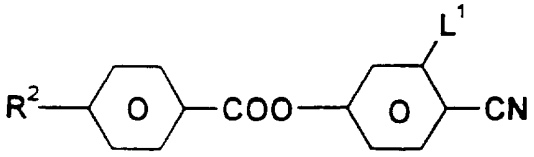


Ib

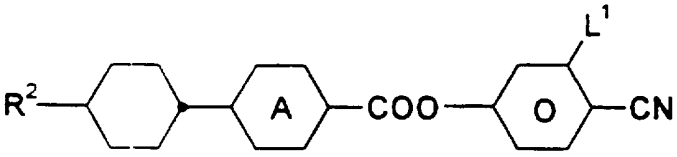
- if desired, at least one compound selected from the formulae IIa, IIb and IIc,



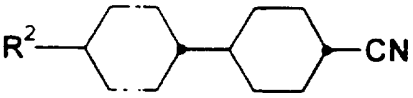
IIa



IIb

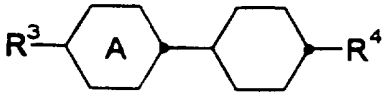


IIc

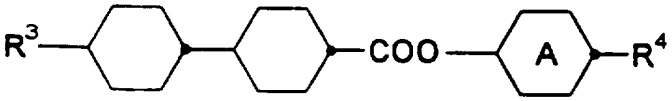


IId

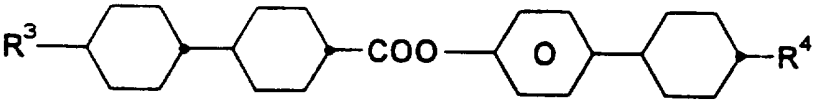
- if desired, at least one compound selected from the formulae IIIa, IIIb and IIIc,



IIIa

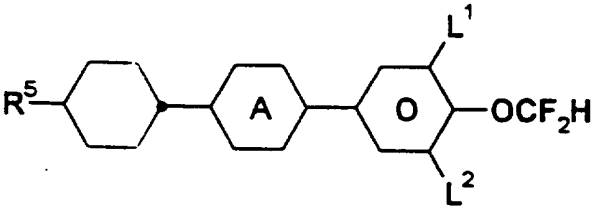


IIIb

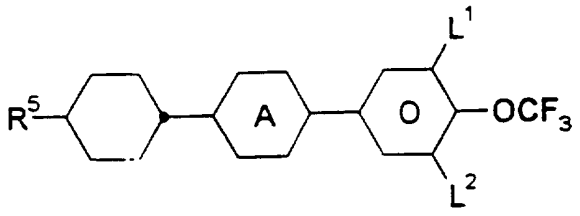


IIIc

- at least one compound selected from the formulae IVa and IVb,



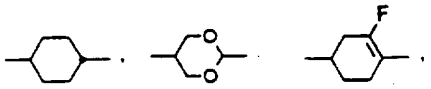
IVa



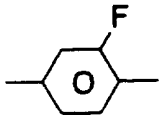
IVb

in which

is in each case



or



and R^1, R^2, R^3, R^4, R^5, L^1 and L^2 are each as defined above.

The Patent Office

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Application No: GB 9804140.3 **Examiner:** Stephen Quick
Claims searched: 1-10 **Date of search:** 15 May 1998

Patents Act 1977
Search Report under Section 17

Databases searched:

UK Patent Office collections, including GB, EP, WO & US patent specifications, in:

UK Cl (Ed.P): (not searched)

Int Cl (Ed.6): (not searched)

Other: Online: CAS ONLINE

Documents considered to be relevant:

Category	Identity of document and relevant passage		Relevant to claims
X,P	JP 100046150 A	(DAINIPPON INK AND CHEMICALS), see pages 11 (top right hand section, composition "3-2", noting 1st-4th & 6th components), 13 (top left hand section, composition "3-5", noting 1st, 2nd & 4th-7th components), 14 (composition "3-7", noting 1st, 2nd & 10th components), 15 (composition "3-8", noting 1st, 3rd-5th, 7th & 8th components) & 16 (composition "3-9", noting 1st, 2nd, 4th-7th, 10th & 11th components); and Chemical Abstracts, abstr no 128:186563, see abstract	1 & 8 at least

X	Document indicating lack of novelty or inventive step	A	Document indicating technological background and/or state of the art.
Y	Document indicating lack of inventive step if combined with one or more other documents of same category.	P	Document published on or after the declared priority date but before the filing date of this invention.
&	Member of the same patent family	E	Patent document published on or after, but with priority date earlier than, the filing date of this application.