

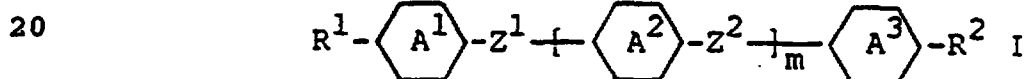
Description

The invention relates to a matrix liquid-crystal display containing

- two plane parallel support plates which together with a frame form a cell,
- integrated non-linear elements for switching individual picture elements on the support plates and
- a nematic liquid-crystal mixture which is present in the cell and has a positive dielectric anisotropy and high resistivity,

the liquid-crystal mixture being based on the following components:

- a) at least 10% by weight of a liquid-crystalline component B comprising one or more compounds having a dielectric anisotropy of more than +1.5,
- b) up to 90% by weight of a liquid-crystalline component A comprising one or more compounds having a dielectric anisotropy of -1.5 to +1.5 of the general formula I



in which

R^1 and R^2 are each, independently of one another, n-alkyl, ω -fluoroalkyl or n-alkenyl having up to 9 carbon atoms,

the rings A^1 , A^2 and A^3 are each, independently of one another, 1,4-phenylene, 2- or 3-fluoro-1,4-phenylene, trans-1,4-cyclohexylene or 1,4-cyclohexenylene,

Z^1 and Z^2 are each, independently of one another, $-\text{CH}_2\text{CH}_2-$ or a single bond,

and

m is 0, 1 or 2, and

- c) 0 to 20% by weight of a liquid-crystalline component C comprising one or more compounds having a dielectric anisotropy of less than -1.5,

and the nematic liquid-crystal mixture having a nematic phase range of at least 60°C, a maximum viscosity at 20°C of 30 mPa.s and a mean dielectricity constant $\bar{\epsilon} \leq 8$.

- Matrix liquid-crystal displays (MLC displays) according to the preamble are known. For example, active elements (i.e. transistors) can be used as non-linear elements for the individual switching of the individual picture elements. This is referred to as an "active matrix", in which two types can be distinguished:
1. MOS (metal oxide semiconductor) transistors on a silicon wafer as the substrate.
 2. Thin film transistors (TFT) on a glass plate as the substrate.

In the case of type 1, dynamic scattering or the guest/host effect is usually used as the electrooptical effect. The use of single-crystal silicon as the substrate material limits the size of the display, since, even if different partial displays are put together in the form of modules, difficulties arise at the joints.

In the case of the more promising type 2, which is preferred, the TN effect is usually used as the electro-optical effect. Two technologies are distinguished: TFTs consisting of compound semiconductors, such as, for example, CdSe, or TFTs based on polycrystalline or amorphous silicon. The latter technology is the subject of intense development work worldwide.

The TFT matrix is disposed on the inside surface of one of the glass plates of the display, while the other glass plate carries the transparent counter electrode on its inside surface. Compared with the size of the picture element electrode, the TFT is very small and essentially does not interfere with the picture. This technology can also be extended to picture displays in fully satisfactory colours by arranging a mosaic of red, green and blue filters in such a manner that each filter element is opposite to a switchable picture element.

The TFT displays usually operate as TN cells which contain crossed polarizers in transmission and are illuminated from behind.

The term MLC displays in this context comprises each matrix display which has integrated non-linear elements, i.e. apart from the active matrix also displays which contain passive elements such as varistors or diodes (MIM = metal/insulator/metal).

MLC displays of this type are in particular suitable for TV applications (e.g. portable TVs) or for highly informative displays in automobile and aircraft construction. In addition to problems regarding the angle dependency of the contrast and the switching times, difficulties in MLC displays arise from the insufficient resistivity of the liquid-crystal mixtures [TOGASHI, S., SEKIGUCHI, K., TANABE, H., YAMAMOTO, E., SORIMACHI, K., TAJIMA, E., WATANABE, H., SHIMIZU, H., Proc. Eurodisplay 84, Sept. 1984: A 210-288 Matrix LCD Controlled by Double Stage Diode Rings, p. 141 ff, Paris; STROMER, M., Proc. Eurodisplay 84, Sept. 1984: Design of Thin Film Transistors for Matrix Addressing of Television Liquid-crystal Displays, p. 145 ff, Paris]. With decreasing resistivity, the contrast of an MLC display deteriorates. Since the resistivity of the liquid-crystal mixture usually decreases by interaction with the inside surfaces of the displays over the lifetime of an MLC display, a high (initial) resistance is very important for achieving acceptable service lives.

Therefore, there is still a high demand for MLC displays which have very high resistivity in combination with a large range of operating temperatures, short switching times and low threshold voltage.

The object of the invention is to provide MLC displays which do not or only to a small extent have the above disadvantages and, at the same time, have very high resistivities.

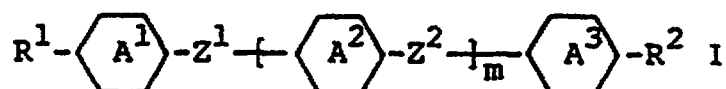
It has now been found that this object can be achieved by using nematic liquid-crystal mixtures in these display elements, which mixtures are based on the abovementioned components A, B and C, B and C, or B.

Accordingly, the invention relates to an MLC display containing

- two plane parallel support plates which together with a frame form a cell,
- integrated non-linear elements for switching individual picture elements on the support plates and
- 5 - a nematic liquid-crystal mixture which is present in the cell and has a positive dielectric anisotropy and high resistivity,

the liquid-crystal mixture being based on the following components:

- 10 a) at least 10% by weight of a liquid-crystalline component B comprising one or more compounds having a dielectric anisotropy of more than +1.5,
- b) up to 90% by weight of a liquid-crystalline component A comprising one or more compounds having a
- 15 dielectric anisotropy of -1.5 to +1.5 of the general formula I



in which

- 20 R¹ and R² are each, independently of one another, n-alkyl, ω-fluoroalkyl or n-alkenyl having up to 9 carbon atoms,

the rings A¹, A² and A³

- are each, independently of one another, 1,4-phenylene, 2- or 3-fluoro-1,4-phenylene,
- 25 trans-1,4-cyclohexylene or 1,4-cyclohexenylene,

Z¹ and Z² are each, independently of one another, -CH₂CH₂- or a single bond,

and

- 30 m is 0, 1 or 2, and

- c) 0 to 20% by weight of a liquid-crystalline component C comprising one or more compounds having a dielectric anisotropy of less than -1.5,

- and the nematic liquid-crystal mixture having a nematic phase range of at least 60°C, a maximum viscosity at 20°C
- 35 of 30 mPa.s and a mean dielectricity constant ε ≤ 8.

EP-A 261 614 discloses liquid-crystal cells

containing a highly twisted liquid-crystal layer (for example STN-LCDs) based on similar mixtures, where the mixtures described therein are based exclusively on nitrile-containing, dielectrically positive components.

5 The invention also relates to the corresponding liquid-crystal mixtures whose component B contains nitrile-free compounds, in particular for use in MLC displays. However, the mixtures are also suitable for many other applications, such as, for example, TN, STN or
10 OMI.

 Nematic liquid-crystal mixtures which instead of the compounds of the formula I contain analogous compounds in which one of the radicals R^1 and R^2 is n-alkyl and the other is n-alkoxy are known and commercially
15 utilized in various designs. However, these liquid-crystal mixtures are distinguished by values for the resistivity which are too low and are often between 5×10^9 and $1.1 \times 10^{11} \Omega \text{cm}$ or less at 20° . The corresponding MLC displays have values for the resistivity which are too
20 low for some commercial applications.

 The resistivity of liquid-crystal mixtures is in general high, if the dielectric anisotropy is small, since the polar components which are present in mixtures which have a high $\Delta\epsilon$ have a stabilizing effect on ions
25 and thus lead to high conductivity or low resistance. Surprisingly, it has now been found that the resistivity is particularly high, if the mean dielectricity constant $\bar{\epsilon} [= \frac{1}{2} (2 \epsilon_1 + \epsilon_{11})]$ is small and, at the same time, the dielectrically neutral ($\Delta\epsilon$ from -1.5 to +1.5) components
30 of the liquid-crystal mixture do not contain any functional groups such as, for example, aromatically bound alkoxy or ester functions. The dielectrically positive ($\Delta\epsilon \geq 1.5$) components usually carry terminal cyano groups. However, in the mixtures according to the inven-
35 tion, it is preferred to use, in addition to compounds which have a terminal cyano, also those which have a terminal -NCS, F, Cl, -CF₃, -CHF₂, -OCF₃, -OCHF₂, -OCF₂CF₂H or -OC₂F₅.

 However, component B can also substantially

consist only of nitrile-containing compounds, of which those compounds of the formulae IIa to IIf where X is CN are preferred. In this case, the liquid-crystal mixture essentially consists of components A, B and C, or A and B.

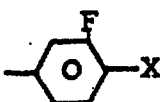
Particular preference is given to liquid-crystal mixtures which contain nitrile-containing and nitrile-free, fluorinated compounds, the latter preferably conforming to the formulae IIa to IIf in which X is F, Cl, $-CF_3$, $-CHF_2$, $-OCF_3$, $-OCHF_2$, $-OCF_2CF_3$ or $-OC_2F_5$.

The ratio of nitrile-free to nitrile-containing compounds in component B is preferably $> 1 : 1$, in particular $> 2 : 1$. Particularly preferred ranges are $2.5 : 1$ to $6 : 1$.

However, very particular preference is given to liquid-crystal mixtures whose component B essentially consists of nitrile-free, fluorinated compounds. Preferably, the abovementioned preferred compounds of the formulae IIa to IIf are used.

'Essentially' is understood to mean that the amount of further compounds in the corresponding component is $\leq 20\%$, in particular $\leq 10\%$.

Preference is also given to liquid-crystal mixtures whose component B contains compounds whose end groups are chlorinated. Compounds of this type are known to one skilled in the art and preferably conform to the formulae IIa to IIf where X is Cl. In a particularly preferred embodiment, the mixtures contain one or more compounds of the formula IIa to IIf in which A^2-X or A^3-X

is  where X is CF_3 , $-OCF_3$, $-OCHF_2$ or Cl.

Furthermore, component B can also contain tetranuclear compounds, for example in accordance with formulae IIc to IIf in which one of the rings A^1 to A^3 is present twice.

In a particularly preferred embodiment, the mixtures contain compounds which have a terminal nitrile and are present in component B in an amount from 0 to 50% by weight. Particular preference is given to mixtures

which do not contain any compounds which have a terminal nitrile. Surprisingly, it has been found that groups such as $-\text{OCF}_3$, $-\text{OCHF}_2$, $-\text{OCF}_2\text{CF}_2\text{H}$ or $-\text{OC}_2\text{F}_5$ have a considerably less stabilizing effect on ions in the displays than $-\text{OCH}_3$ or $-\text{OC}_2\text{H}_5$. The same is true for aliphatically bound alkoxy (compounds of the formulae III and IV).

The mixtures according to the invention preferably have a resistivity of $\geq 10^{12} \Omega \times \text{cm}$, particularly preferably $> 10^{13} \Omega \times \text{cm}$, at 20° . The mean ϵ is preferably ≤ 7 , in particular ≤ 5 .

The values of dielectric anisotropy of the individual compounds of components A to C are determined at 20° by extrapolation from a polar mixture (containing 24% of p-trans-4-propylcyclohexylbenzonitrile, 36% of p-trans-4-pentylcyclohexylbenzonitrile, 25% of p-trans-4-heptylcyclohexylbenzonitrile and 15% of 4-cyano-4'-(trans-4-pentylcyclohexyl)biphenyl), if the compound to be determined contains a dipole along the longitudinal axis of the molecule, or from a neutral mixture (containing 22% of trans-1-p-ethylphenyl-4-propylcyclohexane, 20% of trans-1-p-methoxyphenyl-1-propylcyclohexane, 15% of trans-1-p-ethoxyphenyl-4-propylcyclohexane, 19% of 4-ethyl-4-(trans-4-propylcyclohexyl)biphenyl, 14% of 4-ethyl-4'-(trans-4-pentylcyclohexyl)biphenyl, 5% of 4,4'-bis(trans-4-propylcyclohexyl)biphenyl and 5% of 4-(trans-4-pentylcyclohexyl)-4'-(trans-4-propylcyclohexyl)biphenyl) in the case of neutral compounds.

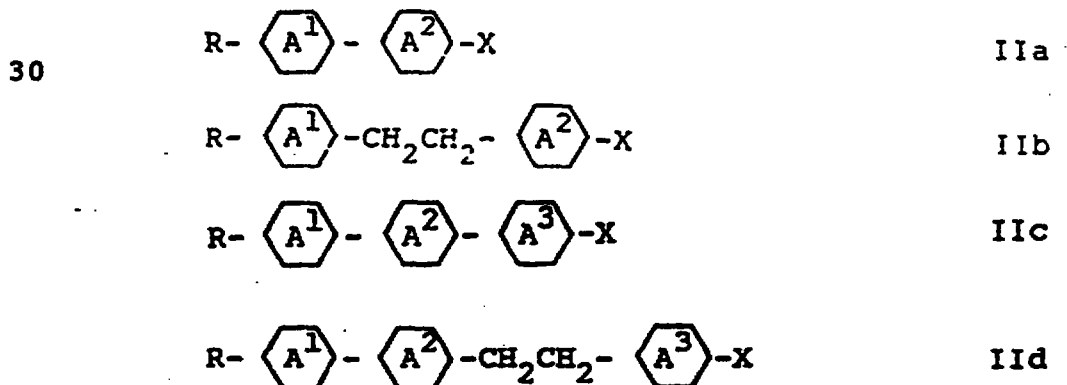
The liquid-crystal mixtures according to the invention make it possible to achieve a high value for the resistivity in combination with low viscosities, which allows to produce excellent MLC displays. The MLC displays according to the invention preferably operate in the first transmission minimum according to Gooch and Tarry [C.H. Gooch and H.A. Tarry, Electron. Lett. 10, 2-4, 1974; C.H. Gooch and H.A. Tarry, Appl. Phys., Vol. 8, 1575-1584, 1975], in which case in addition to particularly favourable electrooptical properties such as, for example, high steepness of the characteristic curve and low angle dependence of the contrast (German Patent

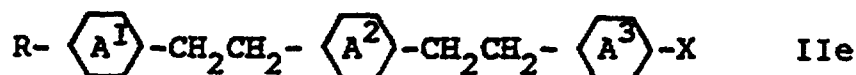
Specification 3,022,818) in combination with the same threshold voltage as in an analogous display, a smaller dielectric anisotropy is sufficient in the second minimum. This makes it possible to achieve significantly higher resistivities in the first minimum, when the mixtures according to the invention are used.

The viscosity at 20°C is preferably ≤ 25 mPa.s. The nematic phase range is preferably at least 70°, in particular at least 80°. Preferably, this range extends at least from -20° to +70°.

The individual compounds of the formulae I to IV and their subformulae which can be used in the MLC displays according to the invention are either known or can be prepared analogously to known compounds.

Preferred liquid-crystal mixtures to be used according to the invention contain a total of, preferably, 10% to 90%, in particular 20% to 90%, of compounds of the formula I. If component B is not composed predominantly of strongly dielectrically positive nitrile components but predominantly only of weakly dielectrically positive compounds such as, for example, the fluorinated compounds mentioned below, component A can under certain circumstances be omitted entirely, and the mixtures according to the invention can in this special embodiment be solely based on component B and, if desired, component C. Particular preference is given to liquid-crystal mixtures whose component B contains one or more compounds selected from the group consisting of compounds of the formulae IIa to IIf





in which

R is n-alkyl or n-alkenyl of up to 9 carbon atoms,

X is cyano, -NCS, F, Cl, -CF₃, -CHF₂, -OCF₃, -OCHF₂, -OCF₂CF₃H or -OC₂F₅, and

the rings A¹, A² and A³

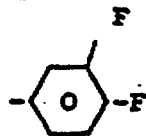
are each, independently of one another, 1,4-phenylene, 2- or 3-fluoro-1,4-phenylene, 2,3-difluoro-1,4-phenylene, trans-1,4-cyclohexylene or 1,4-cyclohexenylene.

Preferably, component B contains compounds of the formulae IIa to IIIf in which X is cyano and compounds of the formulae IIa to IIIf in which X is -NCS, F, Cl, -CF₃, -CHF₂, -OCF₃, -OCHF₂, -OCF₂CF₃H or -OC₂F₅, and the amount of cyano compounds in component B is 0 to 50% by weight.

In a particularly preferred embodiment, component B does not contain any compounds of the formulae IIa to IIIf in which X is cyano.

In the compounds of the partial formulae IIa to IIIf, X is preferably F, Cl, CF₃, -OCF₃, -OCHF₂ or -CHF₂.

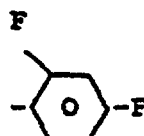
The rings A¹, A² and A³ are each preferably, independently of one another, trans-1,4-cyclohexylene or 1,4-phenylene. In a preferred embodiment, one of the rings A¹, A² and A³ is 2- or 3-fluoro-1,4-phenylene or 2,3-difluoro-1,4-phenylene. The ring bound to X (i.e. A² in IIa and IIb and A³ in IIc to IIIf) is preferably 1,4-phenylene which is unsubstituted or even mono- or di-substituted by fluorine. A²-X and A³-X are preferably a group selected from the formulae (a) to (h):



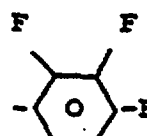
(a)



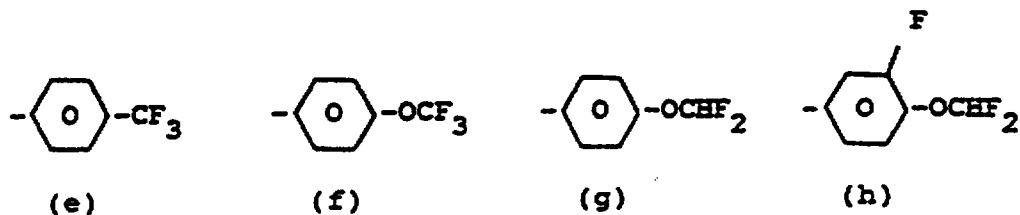
(b)



(c)

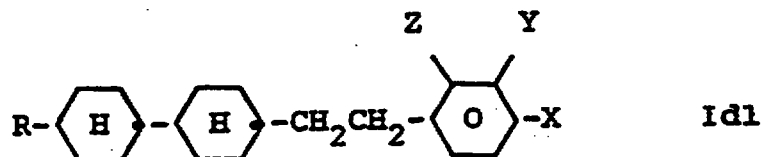
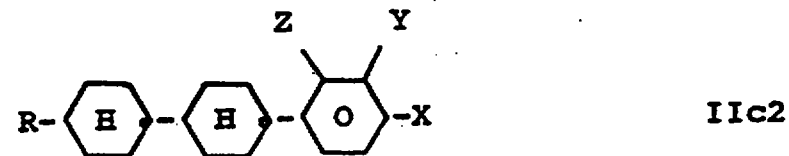
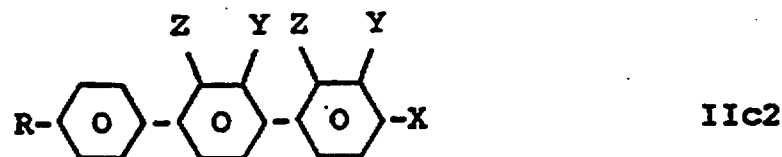
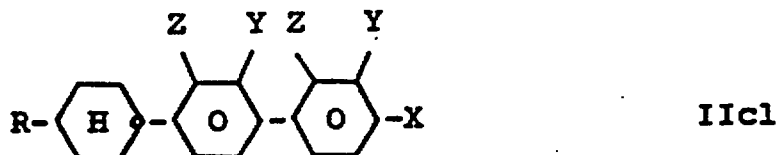
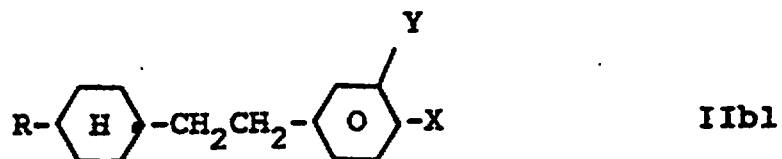


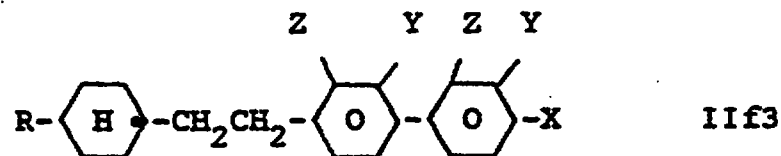
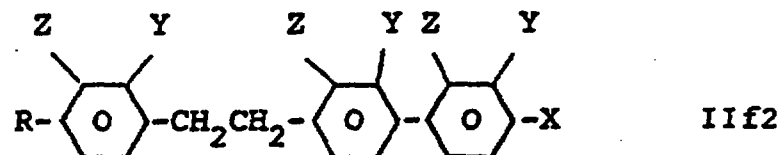
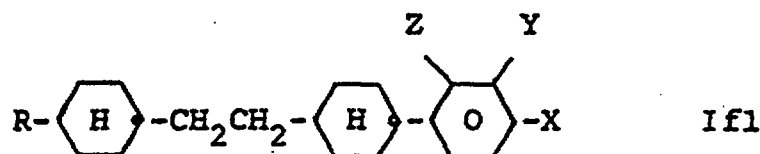
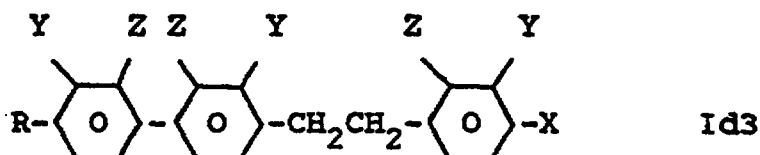
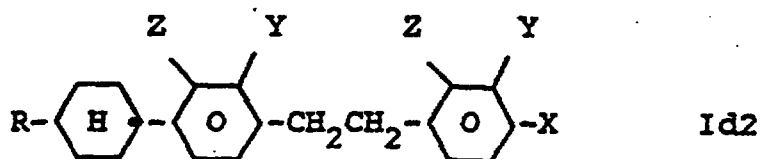
(d)



of which (a), (b), (d), (f), (g) and (h) are particularly preferred.

Particularly preferred smaller groups of compounds are listed below:



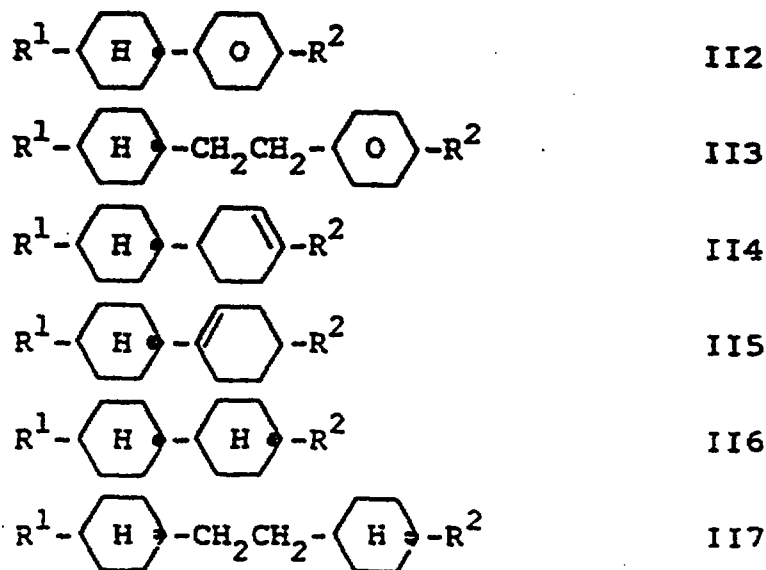


In the partial formulae IIa1 to IIf3, R is in each case n-alkyl or n-alkenyl of up to 9 carbon atoms. Y and Z are each, independently of one another, H or F although one or two of the radicals Y and Z is preferably fluorine. However, X is preferably F, Cl, -CF₃-, -OCF₃, or -OCHF₂.

Component B preferably represents 10% to 100%, in particular 20% to 80%, of the mixtures according to the invention.

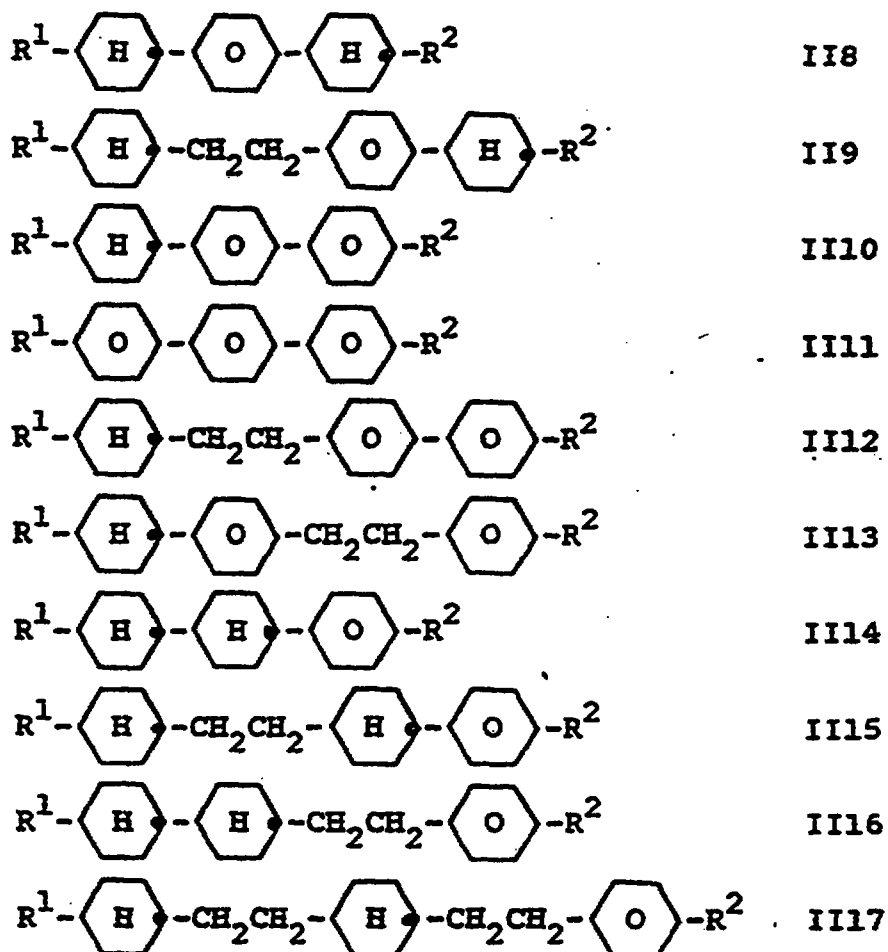
10 Component A preferably contains one or more compounds selected from the group consisting of III1 to III7:

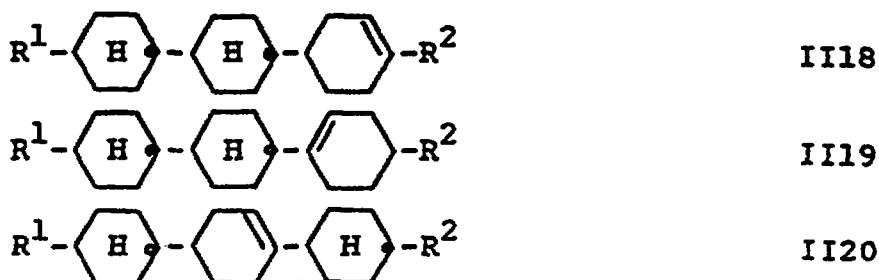




in which R¹ and R² have the meaning given in Claim 1.

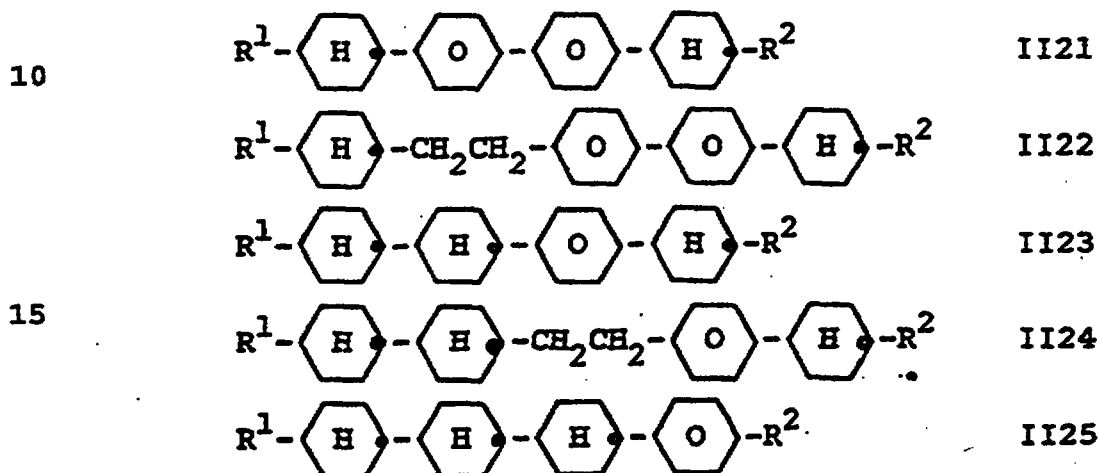
Preferably, component A additionally contains one or more compounds selected from the group consisting of II8 to II20:





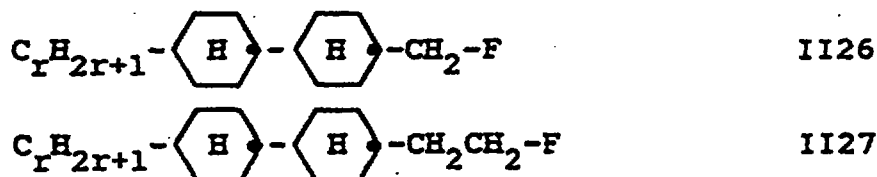
in which R^1 and R^2 have the meaning given in Claim 1 and the 1,4-phenylene groups in II18 to II17 can each, independently of one another, also be mono- or polysubstituted by fluorine.

5 Furthermore, component A preferably additionally contains one or more compounds selected from the group consisting of II21 to II25 contains [sic]:



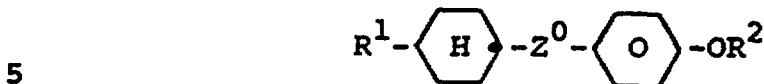
20 in which R^1 and R^2 have the meaning given in Claim 1 and the 1,4-phenylene groups in II21 to II25 can each, independently of one another, also be mono- or polysubstituted by fluorine.

Finally, those mixtures are preferred whose component A contains one or more compounds selected from the group consisting of II26 and II27:



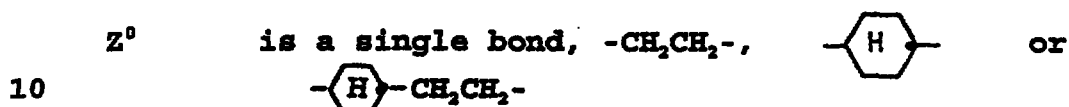
in which C_{1-7} is a straight-chain alkyl group of up to 7 carbon atoms.

In some cases, the addition of bonds [sic] of the formula



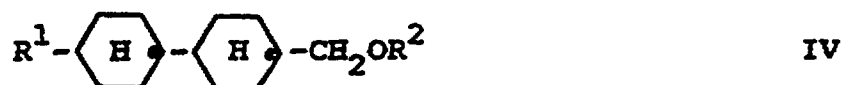
in which

R^1 and R^2 have the meaning given in Claim 1 and

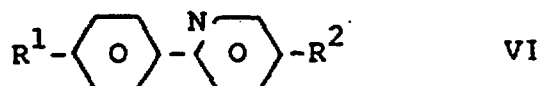
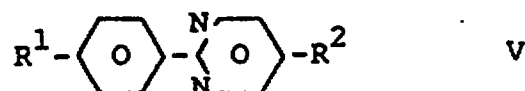


proves to be advantageous for suppressing smectic phases, although the resistivity is thereby lowered. Whether and in which amount these compounds should be added for achieving optimum parameter combinations for practical application can easily be determined by one skilled in the art. Usually, less than 15%, in particular 5-10%, are used.

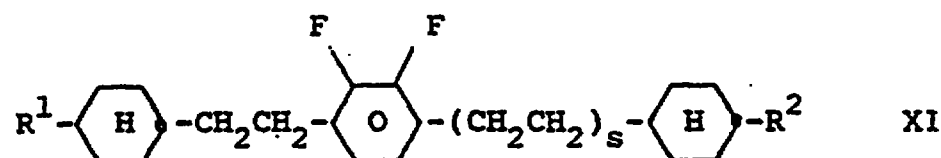
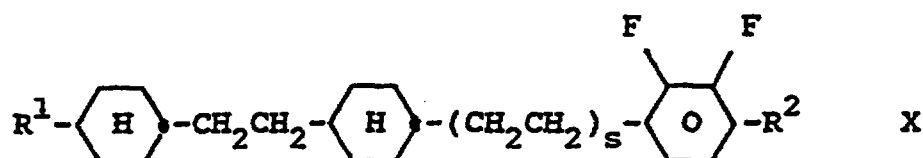
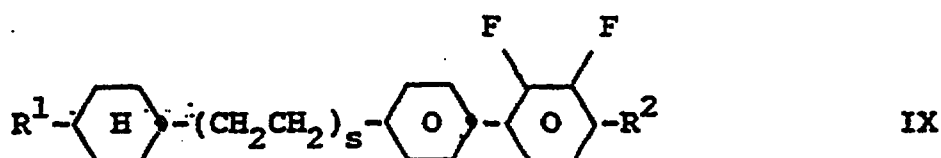
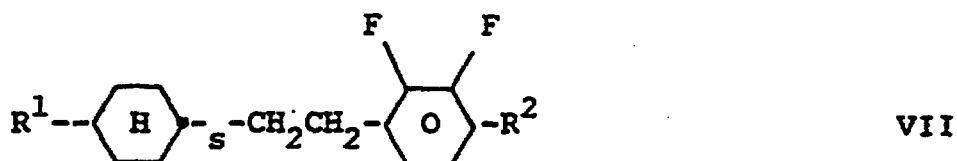
Further preference is given to liquid-crystal mixtures which, in addition to components A, B and C, additionally contain one or more compounds selected from the group consisting of III and IV:



25 in which R^1 and R^2 have the abovementioned meaning and/or one or more compounds selected from the group consisting of V and VI



in which R^1 and R^2 have the abovementioned meaning and/or one or more compounds selected from the group consisting of VII to XI



in which R^1 and R^2 have the abovementioned meaning and s is 0 or 1.

The amounts of the compounds of the formulae III to XI in the mixtures according to the invention (preferred ranges) can be seen from the table below:

Sum of compounds III and IV:	0% to 40%, preferably 10% to 30%
Sum of compounds V and VI:	0% to 40%, preferably 5% to 20%
Sum of compounds VII to XI:	0% to 20%, preferably 5% to 15%

It goes without saying that the mixtures according to the invention, which preferably consist essentially of the compounds mentioned as preferred for components A to C, may additionally also contain further

compounds not mentioned here explicitly. However, this leads in many cases to more unfavourable properties. One skilled in the art can easily determine whether and in which amounts further compounds can be used.

5 The design of the MLC display according to the invention which consists of polarizers, electrode base plates and electrodes which have been subjected to surface treatment is that which is customary for this type of display. The definition of customary design is in
10 this case very broad and also comprises all modifications and alterations of the MLC display, in particular also matrix display elements based on poly-Si TFT or MIM.

 However, a significant difference between the displays according to the invention and those which have
15 been customary so far and are based on the twisted nematic cell is the selection of the liquid-crystal parameters of the liquid-crystal layer.

 The preparation of the liquid-crystal mixtures to be used according to the invention is carried out in the
20 usual manner. As a rule, the desired amount of the components used in a minor amount is dissolved in the components which constitute the major component, advantageously at elevated temperature. It is also possible to mix solutions of the components in an organic
25 solvent, for example in acetone, chloroform or methanol, and remove the solvent again after the mixing, for example by distillation.

 The dielectrics can also contain further additives known to one skilled in the art and described in
30 the literature. For example, 0-15% pleochroic colorants or chiral doping substances can be added.

 The examples which follow are intended to illustrate the invention without limiting it. Hereinbefore and hereinafter all temperatures are given in °C.
35 The percentages are by weight.

Example 1

 A matrix liquid-crystal display of the TFT type containing a nematic liquid-crystal mixture consisting of 17% of p-trans-4-propylcyclohexylbenzonitrile,

- 13% of p-trans-4-butylcyclohexylbenzonitrile,
 22% of trans-1-p-propylphenyl-4-pentylcyclohexane,
 4% of 1-[trans-4-(trans-4-propylcyclohexyl)-cyclo-
 hexyl]-2-(p-methylphenyl)-ethane,
 5 4% of 1-[trans-4-(trans-4-propylcyclohexyl)-cyclo-
 hexyl]-2-(p-ethylphenyl)-ethane,
 4% of 1-[trans-4-(trans-4-propylcyclohexyl)-cyclo-
 hexyl]-2-(p-propylphenyl)-ethane,
 4% of 1-[trans-4-(trans-4-propylcyclohexyl)-cyclo-
 10 hexyl]-2-(p-pentylphenyl)-ethane,
 9% of 4-ethyl-4'-(trans-4-propylcyclohexyl)-biphenyl,
 9% of E-ethyl-4'-(trans-4-pentylcyclohexyl)-biphenyl,
 4% of 4,4'-bis-(trans-4-propylcyclohexyl)-2-fluoro-
 biphenyl,
 15 4% of 4,4'-bis-(trans-4-pentylcyclohexyl)-2-fluorobi-
 phenyl, and
 6% of 4-(trans-4-pentylcyclohexyl)-4'-(trans-4-propyl-
 cyclohexyl)-2-fluorobiphenyl

has a resistivity of 3×10^{12} Ω cm. The nematic mixture has
 20 a clear point of 91°, a viscosity of 18 mPa.s at 20°, a
 mean DC of 5.0 and an optical anisotropy of 0.118.

Example 2

- A nematic mixture consisting of
 17% of p-trans-4-propylcyclohexylbenzonitrile,
 25 13% of p-trans-4-butylcyclohexylbenzonitrile,
 13% of trans,trans-4-pentyl-4'-fluoromethyl-cyclohexyl-
 cyclohexane,
 13% of trans,trans-4-propyl-4'-fluoromethyl-cyclohexyl-
 cyclohexane,
 30 4% of 1-[trans-4-(trans-4-propylcyclohexyl)-cyclo-
 hexyl]-2-(p-methylphenyl)-ethane,
 4% of 1-[trans-4-(trans-4-propylcyclohexyl)-cyclo-
 hexyl]-2-(p-ethylphenyl)-ethane,
 4% of 1-[trans-4-(trans-4-propylcyclohexyl)-cyclo-
 35 hexyl]-2-(p-propylphenyl)-ethane,
 4% of 1-[trans-4-(trans-4-propylcyclohexyl)-cyclo-
 hexyl]-2-(p-pentylphenyl)-ethane,
 7% of 4-ethyl-4'-(trans-4-propylcyclohexyl)-biphenyl,
 7% of 4-ethyl-4'-(trans-4-pentylcyclohexyl)-biphenyl,

4% of 4,4'-bis-(trans-4-propylcyclohexyl)-2-fluorobiphenyl,

4% of 4,4'-bis-(trans-4-pentylcyclohexyl)-2-fluorobiphenyl, and

5 6% of 4-(trans-4-pentylcyclohexyl)-4'-(trans-4-propylcyclohexyl)-2-fluorobiphenyl

has a clear point of 93°, a viscosity of 19 mPa.s, a mean DC of 5.4, a Δn of 0.107 and a resistivity of 2.5×10^{12} Ω cm.

10 Example 3

A nematic mixture consisting of

10% of p-trans-4-pentylcyclohexyl-fluorobenzene,

17% of trans-1-p-propylphenyl-4-pentylcyclohexane,

10% of 1-[trans-4-(trans-4-propylcyclohexyl)-cyclohexyl]-2-(p-trifluoromethylphenyl)-ethane,

15 10% of 1-[trans-4-(trans-4-pentylcyclohexyl)-cyclohexyl]-2-(3,4-difluorophenyl)-ethane,

10% of 1-[trans-4-(trans-4-propylcyclohexyl)-cyclohexyl]-2-(3,4-difluorophenyl)-ethane,

20 20% of 1-[trans-4-(trans-4-propylcyclohexyl)-cyclohexyl]-2-(p-trifluoromethoxyphenyl)-ethane,

20% of 1-[trans-4-(trans-4-pentylcyclohexyl)-cyclohexyl]-2-(p-trifluoromethoxyphenyl)-ethane, and

25 3% of 4-(trans-4-pentylcyclohexyl)-4'-(trans-4-propylcyclohexyl)-2-fluorobiphenyl

has a clear point of 88°, a viscosity of 15.2 mPa.s, a mean DC of 4.3, a Δn of 0.078 and a resistivity of 8.6×10^{13} Ω cm. This mixture is particularly suitable for operation in the first minimum according to Gooch and

30 Tarry at a threshold voltage of 2.7 V.

Example 4

A nematic mixture consisting of

4% of 4,4'-bis-(trans-4-propylcyclohexyl)-2-fluorobiphenyl,

35 10% of p-trans-4-pentylcyclohexyl-fluorobenzene,

12% of trans-1-p-propylphenyl-4-pentylcyclohexane,

10% of 1-[trans-4-(trans-4-propylcyclohexyl)-cyclohexyl]-2-(p-trifluoromethylphenyl)-ethane,

10% of 1-[trans-4-(trans-4-pentylcyclohexyl)-cyclo-

- hexyl]-2-(3,4-difluorophenyl)-ethane,
 10% of 1-[trans-4-(trans-4-propylcyclohexyl)-cyclo-
 hexyl]-2-(3,4-difluorophenyl)-ethane,
 20% of 1-[trans-4-(trans-4-propylcyclohexyl)-cyclo-
 5 hexyl]-2-(p-trifluoromethoxyphenyl)-ethane,
 20% of 1-[trans-4-(trans-4-pentylcyclohexyl)-cyclo-
 hexyl]-2-(p-trifluoromethoxyphenyl)-ethane, and
 4% of 4-(trans-4-pentylcyclohexyl)-4'-(trans-4-propyl-
 cyclohexyl)-2-fluorobiphenyl
 10 has a clear point of 91°, a Δn of 0.076, a mean DC of 4.2
 and a resistivity of $7.3 \times 10^{13} \Omega \text{ cm}$.

Example 5

- A nematic mixture consisting of
 13% of p-trans-4-propylcyclohexylbenzonitrile,
 15 8% of p-trans-4-butylcyclohexylbenzonitrile,
 15% of trans,trans-4-pentyl-4'-fluoromethyl-cyclohexyl-
 cyclohexane,
 17% of trans,trans-4-propyl-4'-fluoromethyl-cyclohexyl-
 cyclohexane,
 20 4% of 1-[trans-4-(trans-4-propylcyclohexyl)-cyclo-
 hexyl]-2-(p-methylphenyl)-ethane,
 4% of 1-[trans-4-(trans-4-propylcyclohexyl)-cyclo-
 hexyl]-2-(p-ethylphenyl)-ethane,
 4% of 1-[trans-4-(trans-4-propylcyclohexyl)-cyclo-
 25 hexyl]-2-(p-propylphenyl)-ethane,
 4% of 1-[trans-4-(trans-4-propylcyclohexyl)-cyclo-
 hexyl]-2-(p-pentylphenyl)-ethane,
 9% of 4-ethyl-4'-(trans-4-propylcyclohexyl)-biphenyl,
 8% of 4-ethyl-4'-(trans-4-pentylcyclohexyl)-biphenyl,
 30 4% of 4,4'-bis-(trans-4-propylcyclohexyl)-2-fluorobi-
 phenyl,
 4% of 4,4'-bis-(trans-4-pentylcyclohexyl)-2-fluorobi-
 phenyl, and
 6% of 4-(trans-4-pentylcyclohexyl)-4'-(trans-4-propyl-
 35 cyclohexyl)-2-fluorobiphenyl

has a clear point of 96°, a Δn of 0.103, a mean DC of 4.9
 and a resistivity of $1.0 \times 10^{13} \Omega \text{ cm}$. This mixture is
 particularly suitable for operation in the first minimum
 according to Gooch and Tarry at a threshold voltage of

2.3 V.

Example 6

A nematic mixture consisting of

	13% of	p-trans-4-propylcyclohexylbenzonitrile,
5	13% of	trans,trans-4-pentyl-4'-fluoromethyl-cyclohexyl-cyclohexane,
	15% of	trans,trans-4-propyl-4'-fluoromethyl-cyclohexyl-cyclohexane,
10	12% of	trans,trans-4-pentyl-4'-(2-fluoroethyl)-cyclohexylcyclohexane,
	4% of	1-[trans-4-(trans-4-propylcyclohexyl)-cyclohexyl]-2-(p-methylphenyl)-ethane,
	4% of	1-[trans-4-(trans-4-propylcyclohexyl)-cyclohexyl]-2-(p-ethylphenyl)-ethane,
15	4% of	1-[trans-4-(trans-4-propylcyclohexyl)-cyclohexyl]-2-(p-propylphenyl)-ethane,
	4% of	1-[trans-4-(trans-4-propylcyclohexyl)-cyclohexyl]-2-(p-pentylphenyl)-ethane,
	9% of	4-ethyl-4'-(trans-4-propylcyclohexyl)-biphenyl,
20	8% of	4-ethyl-4'-(trans-4-pentylcyclohexyl)-biphenyl,
	4% of	4,4'-bis-(trans-4-propylcyclohexyl)-2-fluorobiphenyl,
	4% of	4,4'-bis-(trans-4-pentylcyclohexyl)-2-fluorobiphenyl, and
25	6% of	4-(trans-4-pentylcyclohexyl)-4'-(trans-4-propylcyclohexyl)-2-fluorobiphenyl

has a clear point of 99°, a Δn of 0.097, a mean DC of 4.1 and a resistivity of $7.8 \times 10^{13} \Omega \text{ cm}$. This mixture is particularly suitable for operation in the first minimum according to Gooch and Tarry at a threshold voltage of 2.9 V.

Example 7

A nematic mixture consisting of

	16% of	p-trans-4-propylcyclohexylbenzonitrile,
35	13% of	trans,trans-4-pentyl-4'-fluoromethyl-cyclohexyl-cyclohexane,
	13% of	trans,trans-4-propyl-4'-fluoromethyl-cyclohexyl-cyclohexane,
	11% of	trans,trans-4-pentyl-4'-(2-fluoroethyl)-cyclo-

- hexylcyclohexane,
- 4% of 1-[trans-4-(trans-4-propylcyclohexyl)-cyclohexyl]-2-(p-methylphenyl)-ethane,
- 4% of 1-[trans-4-(trans-4-propylcyclohexyl)-cyclohexyl]-2-(p-ethylphenyl)-ethane,
- 5 4% of 1-[trans-4-(trans-4-propylcyclohexyl)-cyclohexyl]-2-(p-propylphenyl)-ethane,
- 4% of 1-[trans-4-(trans-4-propylcyclohexyl)-cyclohexyl]-2-(p-pentylphenyl)-ethane,
- 10 9% of 4-ethyl-4'-(trans-4-propylcyclohexyl)-biphenyl,
- 8% of 4-ethyl-4'-(trans-4-pentylcyclohexyl)-biphenyl,
- 4% of 4,4'-bis-(trans-4-propylcyclohexyl)-2-fluorobiphenyl,
- 4% of 4,4'-bis-(trans-4-pentylcyclohexyl)-2-fluorobiphenyl, and
- 15 6% of 4-(trans-4-pentylcyclohexyl)-4'-(trans-4-propylcyclohexyl)-2-fluorobiphenyl

has a clear point of 99.5°, a Δn of 0.100, a mean DC of 4.2 and a resistivity of $7.5 \times 10^{13} \Omega \text{ cm}$. This mixture is particularly suitable for operation in the first minimum according to Gooch and Tarry at a threshold voltage of 2.7 V.

20

Example 8

- A nematic mixture consisting of
- 25 17% of p-trans-4-propylcyclohexylbenzonitrile,
- 13% of trans,trans-4-pentyl-4'-fluoromethyl-cyclohexyl-cyclohexane,
- 13% of trans,trans-4-propyl-4'-fluoromethyl-cyclohexyl-cyclohexane,
- 30 9% of trans-1-p-propylphenyl-4-pentylcyclohexane,
- 4% of 1-[trans-4-(trans-4-propylcyclohexyl)-cyclohexyl]-2-(p-methylphenyl)-ethane,
- 4% of 1-[trans-4-(trans-4-propylcyclohexyl)-cyclohexyl]-2-(p-ethylphenyl)-ethane,
- 35 4% of 1-[trans-4-(trans-4-propylcyclohexyl)-cyclohexyl]-2-(p-propylphenyl)-ethane,
- 4% of 1-[trans-4-(trans-4-propylcyclohexyl)-cyclohexyl]-2-(p-pentylphenyl)-ethane,
- 9% of 4-ethyl-4'-(trans-4-propylcyclohexyl)-biphenyl,

9% of 4-ethyl-4'-(trans-4-pentylcyclohexyl)-biphenyl,
4% of 4,4'-bis-(trans-4-propylcyclohexyl)-2-fluorobi-
phenyl,
4% of 4,4'-bis-(trans-4-pentylcyclohexyl)-2-fluorobi-
phenyl, and
6% of 4-(trans-4-pentylcyclohexyl)-4'-(trans-4-propyl-
cyclohexyl)-2-fluorobiphenyl

has a clear point of 93.4°, a Δn of 0.108, a mean DC of
4.4 and a resistivity of $1.3 \times 10^{13} \Omega \text{ cm}$. The viscosity at
20° is 18.4 mPa.s.

Example 9

A nematic mixture consisting of
17% of p-trans-4-propylcyclohexylbenzonitrile,
13% of trans,trans-4-pentyl-4'-fluoromethyl-cyclohexyl-
cyclohexane,
13% of trans,trans-4-propyl-4'-fluoromethyl-cyclohexyl-
cyclohexane,
11% of trans-1-p-propylphenyl-4-pentylcyclohexane,
4% of 1-[trans-4-(trans-4-propylcyclohexyl)-cyclo-
hexyl]-2-(p-methylphenyl)-ethane,
4% of 1-[trans-4-(trans-4-propylcyclohexyl)-cyclo-
hexyl]-2-(p-ethylphenyl)-ethane,
4% of 1-[trans-4-(trans-4-propylcyclohexyl)-cyclo-
hexyl]-2-(p-propylphenyl)-ethane,
4% of 1-[trans-4-(trans-4-propylcyclohexyl)-cyclo-
hexyl]-2-(p-pentylphenyl)-ethane,
8% of 4-ethyl-4'-(trans-4-propylcyclohexyl)-biphenyl,
8% of 4-ethyl-4'-(trans-4-pentylcyclohexyl)-biphenyl,
4% of 4,4'-bis-(trans-4-propylcyclohexyl)-2-fluorobi-
phenyl,
4% of 4,4'-bis-(trans-4-pentylcyclohexyl)-2-fluorobi-
phenyl, and
6% of 4-(trans-4-pentylcyclohexyl)-4'-(trans-4-propyl-
cyclohexyl)-2-fluorobiphenyl
has a clear point of 89.8°, a Δn of 0.102, a mean DC of
4.4, a resistivity of $1.5 \times 10^{13} \Omega \text{ cm}$ and a viscosity of
18.1 mPa.s.

Example 10

A nematic mixture consisting of

- 8% of p-trans-4-propylcyclohexyl-fluorobenzene,
 - 7% of p-trans-4-pentylcyclohexyl-fluorobenzene,
 - 8% of p-trans-4-hexylcyclohexyl-fluorobenzene,
 - 7% of p-trans-4-heptylcyclohexyl-fluorobenzene,
 - 5 5% of 1-[trans-4-(trans-4-propylcyclohexyl)-cyclohexyl]-2-(2,3',4'-trifluorobiphenyl-4-yl)-ethane,
 - 5% of 1-[trans-4-(trans-4-pentylcyclohexyl)-cyclohexyl]-2-(2,3',4'-trifluorobiphenyl-4-yl)-ethane,
 - 8% of trans,trans-1-(p-ethylphenyl)-4-propyl-cyclohexylcyclohexane,
 - 10 7% of trans,trans-1-(p-propylphenyl)-4-pentyl-cyclohexylcyclohexane,
 - 8% of trans,trans-1-(p-fluorophenyl)-4-propyl-cyclohexylcyclohexane,
 - 15 7% of trans,trans-1-(p-fluorophenyl)-4-pentyl-cyclohexylcyclohexane,
 - 6% of trans,trans-1-(p-trifluoromethoxyphenyl)-4-propyl-cyclohexylcyclohexane,
 - 4% of trans,trans-1-(p-trifluoromethoxyphenyl)-4-pentyl-cyclohexylcyclohexane,
 - 20 6% of trans,trans-1-[p-(1,1,2,2-tetrafluoroethoxy)-phenyl]-4-propyl-cyclohexylcyclohexane,
 - 4% of trans,trans-1-[p-(1,1,2,2-tetrafluoroethoxy)-phenyl]-4-pentyl-cyclohexylcyclohexane,
 - 25 3% of 4,4'-bis-(trans-4-propylcyclohexyl)-2-fluorobiphenyl,
 - 3% of 4,4'-bis-(trans-4-pentylcyclohexyl)-2-fluorobiphenyl and
 - 4% of 4-(trans-4-pentylcyclohexyl)-4'-(trans-4-propylcyclohexyl)-2-fluorobiphenyl
 - 30
- has a clear point of 92°, a Δn of 0.099, a mean DC of 4.1, a resistivity of $5.4 \times 10^{13} \Omega \text{ cm}$ and a viscosity of only 14 mPa.s.

Example 11

- 35 A nematic mixture consisting of
- 10% of p-trans-4-propylcyclohexylbenzonitrile,
- 22% of trans-1-p-propylphenyl-4-pentylcyclohexane,
- 5% of 4,4'-bis-propylbiphenyl,
- 5% of trans,trans-4-propyl-4'-methyl-cyclohexylcyclo-

- hexane,
- 4% of 1-[trans-4-(trans-4-propylcyclohexyl)-cyclohexyl]-2-(p-methylphenyl)-ethane,
- 4% of 1-[trans-4-(trans-4-propylcyclohexyl)-cyclohexyl]-2-(p-ethylphenyl)-ethane,
- 4% of 1-[trans-4-(trans-4-propylcyclohexyl)-cyclohexyl]-2-(p-propylphenyl)-ethane,
- 4% of 1-[trans-4-(trans-4-propylcyclohexyl)-cyclohexyl]-2-(p-pentylphenyl)-ethane,
- 5% of 1,4-bis-(trans-4-propylcyclohexyl)-benzene,
- 9% of 4-ethyl-4'-(trans-4-propylcyclohexyl)-biphenyl,
- 9% of 4-ethyl-4'-(trans-4-pentylcyclohexyl)-biphenyl,
- 5% of 1-(trans-4-propylcyclohexyl)-2-(4'-ethyl-2'-fluorobiphenyl-4-yl)-ethane,
- 4% of 4,4'-bis-(trans-4-propylcyclohexyl)-2-fluorobiphenyl,
- 4% of 4,4'-bis-(trans-4-pentylcyclohexyl)-2-fluorobiphenyl and
- 6% of 4-(trans-4-pentylcyclohexyl)-4'-(trans-4-propylcyclohexyl)-2-fluorobiphenyl

has a clear point of 95°, a viscosity of 16 mPa.s, a Δn of 0.113, a mean DC of 3.8 and a resistivity of $7 \times 10^{13} \Omega \text{ cm}$.

Example 12

- A nematic mixture consisting of
- 17% of p-trans-4-propylcyclohexylbenzonitrile,
- 11% of trans-1-p-propylphenyl-4-pentylcyclohexane,
- 13% of trans,trans-4-pentyl-4'-fluoromethyl-cyclohexyl-cyclohexane,
- 13% of trans,trans-4-propyl-4'-fluoromethyl-cyclohexyl-cyclohexane,
- 4% of 1-[trans-4-(trans-4-propylcyclohexyl)-cyclohexyl]-2-(p-methylphenyl)-ethane,
- 4% of 1-[trans-4-(trans-4-propylcyclohexyl)-cyclohexyl]-2-(p-ethylphenyl)-ethane,
- 4% of 1-[trans-4-(trans-4-propylcyclohexyl)-cyclohexyl]-2-(p-propylphenyl)-ethane,
- 4% of 1-[trans-4-(trans-4-propylcyclohexyl)-cyclohexyl]-2-(p-pentylphenyl)-ethane,

- 8% of 4-ethyl-4'-(trans-4-propylcyclohexyl)-biphenyl,
8% of E-ethyl-4'-(trans-4-pentylcyclohexyl)-biphenyl
[sic],
4% of 4,4'-bis-(trans-4-propylcyclohexyl)-2-fluorobi-
phenyl,
4% of 4,4'-bis-(trans-4-pentylcyclohexyl)-2-fluorobi-
phenyl and
6% of 4-(trans-4-pentylcyclohexyl)-4'-(trans-4-propyl-
cyclohexyl)-2-fluorobiphenyl
10 has a clear point of 90°, a viscosity of 18 mPa.s and a
 Δn of 0.102.

Example 13

- A nematic mixture consisting of
14% of p-trans-4-propylcyclohexylbenzonitrile,
15 14% of trans-1-p-fluorophenyl-4-pentylcyclohexane,
14% of trans-1-p-fluorophenyl-4-heptylcyclohexane,
10% of trans-1-p-propylphenyl-4-pentylcyclohexane,
6% of 1-[trans-4-(trans-4-propylcyclohexyl)-cyclo-
hexyl]-2-(p-fluorophenyl)-ethane,
20 6% of 1-[trans-4-(trans-4-pentylcyclohexyl)-cyclo-
hexyl]-2-(p-fluorophenyl)-ethane,
5% of 1-[trans-4-(trans-4-pentylcyclohexyl)-cyclo-
hexyl]-2-(p-trifluoromethylphenyl)-ethane,
5% of 4,4'-bis-(trans-4-propylcyclohexyl)-biphenyl,
25 5% of 4,4'-bis-(trans-4-propylcyclohexyl)-2-fluorobi-
phenyl,
5% of 4,4'-bis-(trans-4-pentylcyclohexyl)-2-fluorobi-
phenyl,
5% of 4,4'-bis-(trans-4-pentylcyclohexyl)-biphenyl,
30 5% of 4-(trans-4-pentylcyclohexyl)-4'-(trans-4-propyl-
cyclohexyl)-biphenyl and
6% of 4-(trans-4-pentylcyclohexyl)-4'-(trans-4-propyl-
cyclohexyl)-2-fluorobiphenyl
has a clear point of 95°, a viscosity of 17 mPa.s and a
35 Δn of 0.105.

The following mixtures are very suitable for MLC displays:

Example 14

A nematic mixture is prepared which consists of:

- 10% of 1-(trans-4-pentylcyclohexyl)-2-(4'-fluorobiphenyl-4-yl)-ethane,
- 17% of trans-1-p-propylphenyl-4-pentylcyclohexane,
- 10% of 1-[trans-4-(trans-4-propylcyclohexyl)-cyclohexyl]-2-(p-trifluoromethylphenyl)-ethane,
- 5 10% of 1-(trans-4-pentylcyclohexyl)-2-[trans-4-(3,4-difluorophenyl)-cyclohexyl]-ethane,
- 10% of 1-[trans-4-(trans-4-propylcyclohexyl)-cyclohexyl]-2-(3,4-difluorophenyl)-ethane,
- 10 20% of 1-[trans-4-(trans-4-propylcyclohexyl)-cyclohexyl]-2-(p-trifluoromethoxyphenyl)-ethane,
- 20% of 1-[trans-4-(trans-4-pentylcyclohexyl)-cyclohexyl]-2-(p-trifluoromethoxyphenyl)-ethane, and
- 3% of 4-(trans-4-pentylcyclohexyl)-4'-(trans-4-propylcyclohexyl)-2-fluorobiphenyl.
- 15

Example 15

A nematic mixture is prepared which consists of:

- 4% of 4,4'-bis-(trans-4-propylcyclohexyl)-2-fluorobiphenyl,
- 20 10% of p-trans-4-pentylcyclohexyl-fluorobenzene,
- 12% of trans,trans-4-propyl-4'-methoxymethyl-cyclohexyl-cyclohexane,
- 10% of 1-[trans-4-(trans-4-propylcyclohexyl)-cyclohexyl]-2-(p-trifluoromethylphenyl)-ethane,
- 25 10% of 1-[trans-4-(trans-4-pentylcyclohexyl)-cyclohexyl]-2-(3,4-difluorophenyl)-ethane,
- 10% of 1-[trans-4-(trans-4-propylcyclohexyl)-cyclohexyl]-2-(3,4-difluorophenyl)-ethane,
- 20% of 1-[trans-4-(trans-4-propylcyclohexyl)-cyclohexyl]-2-(p-trifluoromethoxyphenyl)-ethane,
- 30 20% of 1-[trans-4-(trans-4-pentylcyclohexyl)-cyclohexyl]-2-(p-trifluoromethoxyphenyl)-ethane, and
- 4% of 4-(trans-4-pentylcyclohexyl)-4'-(trans-4-propylcyclohexyl)-2-fluorobiphenyl.

35 Example 16

A nematic mixture is prepared which consists of:

- 13% of 1-(trans-4-propylcyclohexyl)-2-(p-cyanophenyl)-ethane,
- 8% of p-[trans-4-(trans-4-pentylcyclohexyl)-cyclo-

- hexyl]-benzonitrile,
- 18% of trans,trans-4-pentyl-4'-fluoromethyl-cyclohexyl-cyclohexane,
- 17% of trans,trans-4-propyl-4'-fluoromethyl-cyclohexyl-cyclohexane,
- 5 4% of 1-(trans-4-propylcyclohexyl)-2-(trans-4-pentyl-cyclohexyl)-ethane,
- 4% of 1-[p-(trans-4-propylcyclohexyl-phenyl)-2-(trans-4-pentylcyclohexyl)-ethane,
- 10 4% of 1-[trans-4-(trans-4-propylcyclohexyl)-cyclohexyl]-2-(p-propylphenyl)-ethane,
- 4% of 1-[trans-4-(trans-4-propylcyclohexyl)-cyclohexyl]-2-(p-pentylphenyl)-ethane,
- 9% of 4-ethyl-4'-(trans-4-propylcyclohexyl)-biphenyl,
- 15 7% of 4-ethyl-4'-(trans-4-pentylcyclohexyl)-biphenyl,
- 4% of 4,4'-bis-(trans-4-propylcyclohexyl)-2-fluorobiphenyl,
- 4% of 4,4'-bis-(trans-4-pentylcyclohexyl)-2-fluorobiphenyl, and
- 20 6% of 4-(trans-4-pentylcyclohexyl)-4'-(trans-4-propyl-cyclohexyl)-2-fluorobiphenyl.

Example 17

A nematic mixture is prepared which consists of:

- 13% of p-trans-4-propylcyclohexylbenzonitrile,
- 25 13% of trans,trans-4-pentyl-4'-fluoromethyl-cyclohexyl-cyclohexane,
- 15% of trans,trans-4-propyl-4'-fluoromethyl-cyclohexyl-cyclohexane,
- 12% of 1-(trans-4-pentylcyclohexyl)-4-propylcyclohex-1-ene,
- 30 4% of 1-[trans-4-(trans-4-pentylcyclohexyl)-cyclohexyl]-4-propylcyclohex-1-ene,
- 4% of 1-[trans-4-(trans-4-propylcyclohexyl)-cyclohexyl]-2-(p-ethylphenyl)-ethane,
- 35 4% of 1-[trans-4-(trans-4-propylcyclohexyl)-cyclohexyl]-2-(p-propylphenyl)-ethane,
- 4% of 1-[trans-4-(trans-4-propylcyclohexyl)-cyclohexyl]-2-(p-pentylphenyl)-ethane,
- 9% of 4-ethyl-4'-(trans-4-propylcyclohexyl)-biphenyl,

- 8% of 4-ethyl-4'-(trans-4-pentylcyclohexyl)-biphenyl,
4% of 4,4'-bis-(trans-4-propylcyclohexyl)-2-fluorobi-
phenyl,
4% of 4,4'-bis-(trans-4-pentylcyclohexyl)-2-fluorobi-
phenyl, and
6% of 4-(trans-4-pentylcyclohexyl)-4'-(trans-4-propyl-
cyclohexyl)-2-fluorobiphenyl.

Example 18

- A nematic mixture is prepared which consists of:
- 16% of p-trans-4-propylcyclohexylbenzonitrile,
13% of trans,trans-4-pentyl-4'-fluoromethyl-cyclohexyl-
cyclohexane,
13% of trans,trans-4-propyl-4'-fluoromethyl-cyclohexyl-
cyclohexane,
11% of trans,trans-4-pentyl-4'-(2-fluoroethyl)-cyclo-
hexylcyclohexane,
4% of 1-(trans-4-propylcyclohexyl)-2-(4-pentylbiphenyl-
4'-yl)-ethane,
4% of 1-[p-(trans-4-pentylcyclohexyl)-phenyl]-2-(p-
propylphenyl)-ethane,
4% of 1-(trans-4-pentylcyclohexyl)-2-[trans-4-(p-
propylphenyl)-cyclohexyl]-ethane,
4% of 1-[trans-4-(trans-4-propylcyclohexyl)-cyclo-
hexyl]-2-(p-pentylphenyl)-ethane,
9% of 4-ethyl-4'-(trans-4-propylcyclohexyl)-biphenyl,
8% of 4-ethyl-4'-(trans-4-pentylcyclohexyl)-biphenyl,
4% of 4,4'-bis-(trans-4-propylcyclohexyl)-2-fluorobi-
phenyl,
4% of 4,4'-bis-(trans-4-pentylcyclohexyl)-2-fluorobi-
phenyl, and
6% of 4-(trans-4-pentylcyclohexyl)-4'-(trans-4-propyl-
cyclohexyl)-2-fluorobiphenyl.

Example 19

- A nematic mixture is prepared which consists of:
- 17% of p-trans-4-propylcyclohexylbenzonitrile,
13% of trans,trans-4-pentyl-4'-ethoxy-cyclohexylcyclo-
hexane,
13% of trans,trans-4-propyl-4'-fluoromethyl-cyclohexyl-
cyclohexane,

- 9% of trans-1-p-propylphenyl-4-pentylcyclohexane,
- 4% of 1-[trans-4-(trans-4-propylcyclohexyl)-cyclohexyl]-2-(p-methylphenyl)-ethane,
- 4% of 1-[trans-4-(trans-4-propylcyclohexyl)-cyclohexyl]-2-(p-ethylphenyl)-ethane,
- 4% of 1-[trans-4-(trans-4-propylcyclohexyl)-cyclohexyl]-2-(p-propylphenyl)-ethane,
- 4% of 1-[trans-4-(trans-4-propylcyclohexyl)-cyclohexyl]-2-(p-pentylphenyl)-ethane,
- 9% of 4-ethyl-4'-(trans-4-propylcyclohexyl)-biphenyl,
- 9% of 4-ethyl-4'-(trans-4-pentylcyclohexyl)-biphenyl,
- 4% of 4,4'-bis-(trans-4-propylcyclohexyl)-2-fluorobiphenyl,
- 4% of 4,4'-bis-(trans-4-pentylcyclohexyl)-2-fluorobiphenyl, and
- 6% of 4-(trans-4-pentylcyclohexyl)-4'-(trans-4-propylcyclohexyl)-2-fluorobiphenyl.

Example 20

A nematic mixture is prepared which consists of:

- 17% of p-trans-4-propylcyclohexylbenzonitrile,
- 13% of trans,trans-4-pentyl-4'-methoxy-cyclohexylcyclohexane,
- 13% of trans,trans-4-propyl-4'-propoxy-cyclohexylcyclohexane,
- 11% of trans-1-p-propylphenyl-4-pentylcyclohexane,
- 4% of 1-[trans-4-(trans-4-propylcyclohexyl)-cyclohexyl]-2-(p-methylphenyl)-ethane,
- 4% of 1-[trans-4-(trans-4-propylcyclohexyl)-cyclohexyl]-2-(p-ethylphenyl)-ethane,
- 4% of 1-[trans-4-(trans-4-propylcyclohexyl)-cyclohexyl]-2-(p-propylphenyl)-ethane,
- 4% of 1-[trans-4-(trans-4-propylcyclohexyl)-cyclohexyl]-2-(p-pentylphenyl)-ethane,
- 8% of 4-ethyl-4'-(trans-4-propylcyclohexyl)-biphenyl,
- 8% of 4-ethyl-4'-(trans-4-pentylcyclohexyl)-biphenyl,
- 4% of 4,4'-bis-(trans-4-propylcyclohexyl)-2-fluorobiphenyl,
- 4% of 4,4'-bis-(trans-4-pentylcyclohexyl)-2-fluorobiphenyl, and

6% of 4-(trans-4-pentylcyclohexyl)-4'-(trans-4-propylcyclohexyl)-2-fluorobiphenyl.

Example 21

A nematic liquid-crystal mixture is prepared which consists of:

- 17% of p-trans-4-propylcyclohexylbenzonitrile,
- 13% of p-trans-4-butylcyclohexylbenzonitrile,
- 22% of trans-1-p-propylphenyl-4-pentylcyclohexane,
- 4% of 1-(trans-4-propylcyclohexyl)-2-(4-ethyl-2,3-difluorobiphenyl-4'-yl)-ethane,
- 4% of 1-[trans-4-(trans-4-propylcyclohexyl)-cyclohexyl]-2-(p-ethylphenyl)-ethane,
- 4% of 1-[trans-4-(trans-4-propylcyclohexyl)-cyclohexyl]-2-(p-propylphenyl)-ethane,
- 4% of 1-[trans-4-(trans-4-propylcyclohexyl)-cyclohexyl]-2-(p-pentylphenyl)-ethane,
- 9% of 4-ethyl-4'-(trans-4-propylcyclohexyl)-biphenyl,
- 9% of 4-ethyl-4'-(trans-4-pentylcyclohexyl)-biphenyl,
- 4% of 4,4'-bis-(trans-4-propylcyclohexyl)-2-fluorobiphenyl,
- 4% of 4,4'-bis-(trans-4-pentylcyclohexyl)-2-fluorobiphenyl, and
- 6% of 4-(trans-4-pentylcyclohexyl)-4'-(trans-4-propylcyclohexyl)-2-fluorobiphenyl.

Example 22

A nematic mixture is prepared which consists of:

- 15% of p-trans-4-propylcyclohexylbenzonitrile,
- 11% of p-trans-4-butylcyclohexylbenzonitrile,
- 11% of trans,trans-4-pentyl-4'-fluoromethyl-cyclohexylcyclohexane,
- 11% of trans,trans-4-propyl-4'-fluoromethyl-cyclohexylcyclohexane,
- 4% of 1-[trans-4-(trans-4-propylcyclohexyl)-cyclohexyl]-2-(p-methylphenyl)-ethane,
- 4% of 1-[trans-4-(trans-4-propylcyclohexyl)-cyclohexyl]-2-(p-ethylphenyl)-ethane,
- 4% of 1-[trans-4-(trans-4-propylcyclohexyl)-cyclohexyl]-2-(p-propylphenyl)-ethane,
- 4% of 1-[trans-4-(trans-4-propylcyclohexyl)-cyclo-

- hexyl]-2-(p-pentylphenyl)-ethane,
 4% of 2-p-fluorophenyl-5-hexylpyrimidine,
 4% of 2-p-fluorophenyl-5-pentylpyridine,
 7% of 4-ethyl-4'-(trans-4-propylcyclohexyl)-biphenyl,
 5 7% of 4-ethyl-4'-(trans-4-pentylcyclohexyl)-biphenyl,
 4% of 4,4'-bis-(trans-4-propylcyclohexyl)-2-fluorobi-
 phenyl,
 4% of 4,4'-bis-(trans-4-pentylcyclohexyl)-2-fluorobi-
 phenyl, and
 10 6% of 4-(trans-4-pentylcyclohexyl)-4'-(trans-4-propyl-
 cyclohexyl)-2-fluorobiphenyl.

Example 23

A nematic mixture consisting of:

- 14% of p-trans-4-propylcyclohexylbenzonitrile,
 15 10% of p-trans-4-pentylcyclohexyl-fluorobenzene,
 10% of p-trans-4-heptylcyclohexyl-fluorobenzene,
 20% of p-trans-4-pentylcyclohexyl-difluoromethoxy-
 benzene,
 6% of 1-[trans-4-(trans-4-propylcyclohexyl)-cyclo-
 20 hexyl]-2-(p-fluorophenyl)-ethane,
 6% of 1-[trans-4-(trans-4-pentylcyclohexyl)-cyclo-
 hexyl]-2-(p-fluorophenyl)-ethane,
 5% of 1-[trans-4-(trans-4-propylcyclohexyl)-cyclo-
 hexyl]-2-(p-propylphenyl)-ethane,
 25 5% of 4,4'-bis-(trans-4-propylcyclohexyl)-biphenyl,
 4% of 4,4'-bis-(trans-4-pentylcyclohexyl)-biphenyl,
 5% of 4,4'-bis-(trans-4-pentylcyclohexyl)-2-fluorobi-
 phenyl,
 5% of 4,4'-bis-(trans-4-propylcyclohexyl)-2-fluorobi-
 30 phenyl,
 5% of 4-(trans-4-pentylcyclohexyl)-4'-(trans-4-propyl-
 cyclohexyl)-biphenyl, and
 5% of 4-(trans-4-pentylcyclohexyl)-4'-(trans-4-propyl-
 cyclohexyl)-2-fluorobiphenyl
 35 has a clear point of 93°, a viscosity of 17 mPa.s, a Δn
 of 0.105 and a high resistivity.

Example 24

A nematic mixture consisting of

- 10% of p-trans-4-pentylcyclohexyl-fluorobenzene,

- 10% of p-trans-4-hexylcyclohexyl-fluorobenzene,
10% of p-trans-4-heptylcyclohexyl-fluorobenzene,
20% of p-[trans-4-(trans-4-propylcyclohexyl)-cyclo-
hexyl]-trifluoromethoxybenzene,
5 10% of 1-[trans-4-(trans-4-propylcyclohexyl)-cyclo-
hexyl]-2-(p-trifluoromethylphenyl)-ethane,
10% of 1-[trans-4-(trans-4-propylcyclohexyl)-cyclo-
hexyl]-2-(p-trifluoromethoxyphenyl)-ethane,
20% of 1-[trans-4-(trans-4-pentylcyclohexyl)-cyclo-
10 hexyl]-2-(p-trifluoromethoxyphenyl)-ethane, and
10% of 4-trifluoromethoxy-4'-(trans-4-pentylcyclohexyl)-
biphenyl

has a clear point of 80°, a Δn of 0.079, a threshold
voltage $V_{(10/0/20)}$ of 2.27 volt and a very low viscosity.

15 Example 25

A nematic mixture consisting of

- 25% of p-trans-4-propylcyclohexyl-trifluoromethoxy-
benzene,
20% of 4-trifluoromethoxy-4'-(trans-4-pentylcyclohexyl)-
20 biphenyl,
15% of p-[trans-4-(trans-4-propylcyclohexyl)-cyclo-
hexyl]-trifluoromethoxybenzene,
20% of 1-[trans-4-(trans-4-propylcyclohexyl)-cyclo-
hexyl]-2-(p-trifluoromethoxyphenyl)-ethane, and
25 20% of 1-[trans-4-(trans-4-pentylcyclohexyl-cyclohexyl)]-
2-(p-trifluoromethoxyphenyl)-ethane

has a clear point of 54°, a Δn of 0.088, a threshold
voltage $V_{(10/0/20)}$ of 2.18 volt and a very low viscosity.

Example 26

30

A nematic mixture consisting of

- 10% of p-trans-4-pentylcyclohexyl-fluorobenzene,
10% of p-trans-4-hexylcyclohexyl-fluorobenzene,
12% of p-trans-4-hexylcyclohexyl-difluoromethoxybenzene,
10% of 1-[trans-4-(trans-4-propylcyclohexyl)-cyclo-
35 hexyl]-2-(p-fluorophenyl)-ethane,
11% of 1-[trans-4-(trans-4-pentylcyclohexyl)-cyclo-
hexyl]-2-(p-fluorophenyl)-ethane,
11% of 1-[trans-4-(trans-4-propylcyclohexyl)-cyclo-
hexyl]-2-(p-trifluoromethoxyphenyl)-ethane,

- 11% of 1-[trans-4-(trans-4-pentylcyclohexyl)-cyclohexyl]-2-(p-trifluoromethoxyphenyl)-ethane,
11% of 1-[trans-4-(trans-4-propylcyclohexyl)-cyclohexyl]-2-(p-trifluoromethylphenyl)-ethane,
5 10% of p-[trans-4-(trans-4-propylcyclohexyl)-trifluoromethoxybenzene and
4% of 4,4'-bis-(trans-4-pentylcyclohexyl)-biphenyl
has a clear point of 87°, a Δn of 0.0798; a dielectric anisotropy of +6.5, a threshold voltage of $V_{(10/0/20)}$ of 2.25
10 volt and a very low viscosity.

Example 27

- A nematic mixture consisting of
10% of p-trans-4-propylcyclohexyl-trifluoromethoxybenzene,
15 10% of p-trans-4-propylcyclohexyl-difluoromethoxybenzene,
10% of 1-[trans-4-(trans-4-pentylcyclohexyl)-cyclohexyl]-2-(p-trifluoromethylphenyl)-ethane [sic],
10% of 1-[trans-4-(trans-4-propylcyclohexyl)-cyclohexyl]-2-(p-fluorophenyl)-ethane [sic],
20 10% of 1-[trans-4-(trans-4-pentylcyclohexyl)-cyclohexyl]-2-(p-fluorophenyl)-ethane [sic],
10% of 1-[trans-4-(trans-4-propylcyclohexyl)-cyclohexyl]-2-(p-trifluoromethoxyphenyl)-ethane [sic],
25 15% of 1-[trans-4-(trans-4-pentylcyclohexyl)-cyclohexyl]-2-(p-trifluoromethoxyphenyl)-ethane [sic],
10% of 1-[trans-4-(trans-4-propylcyclohexyl)-cyclohexyl]-2-(p-trifluoromethylphenyl)-ethane [sic],
10% of p-[trans-4-(trans-4-pentylcyclohexyl)-cyclohexyl]-trifluoromethoxybenzene [sic] and
30 5% of 4-trifluoromethoxy-4'-(trans-4-pentylcyclohexyl)-biphenyl

has a clear point of 81°, a Δn of 0.0795, a threshold voltage $V_{(10/0/20)}$ of 2.47 volt and a very low viscosity.

35 Example 28

- A nematic mixture consisting of
10% of p-trans-4-propylcyclohexyl-trifluoromethoxybenzene,
25% of p-trans-4-pentylcyclohexyl-difluoromethoxy-

- benzene,
- 15% of p-[trans-4-(trans-4-propylcyclohexyl)-cyclohexyl]-trifluoromethoxybenzene,
- 15% of 1-[trans-4-(trans-4-propylcyclohexyl)-cyclohexyl]-2-(p-trifluoromethoxyphenyl)-ethane,
- 15% of 1-[trans-4-(trans-4-propylcyclohexyl)-cyclohexyl]-2-(p-trifluoromethylphenyl)-ethane, and
- 20% of 4-trifluoromethoxy-4'-trans-4-pentylcyclohexyl-biphenyl
- has a clear point of 71°, a Δn of 0.0878, a $\Delta \epsilon$ of +6.1, a threshold voltage $V_{(10/0/20)}$ of 2.09 volt and a viscosity of 12 mPa.s at 20°C.

Example 29

- A nematic mixture consisting of
- 10% of p-trans-4-pentylcyclohexyl-fluorobenzene,
- 15% of p-trans-4-hexylcyclohexyl-fluorobenzene,
- 15% of p-trans-4-heptylcyclohexyl-fluorobenzene [sic],
- 20% of p-[trans-4-(trans-4-propylcyclohexyl)-cyclohexyl]-trifluoromethoxybenzene,
- 20% of 1-[trans-4-(trans-4-propylcyclohexyl)-cyclohexyl]-2-(p-trifluoromethoxyphenyl)-ethane, and
- 20% of 1-[trans-4-(trans-4-pentylcyclohexyl)-cyclohexyl]-2-(p-trifluoromethoxyphenyl)-ethane,
- has a clear point of 65°, a viscosity of 11 mPa.s at 20°, a Δn of 0.074, a $\Delta \epsilon$ of +5.6 and a threshold voltage $V_{(10/0/20)}$ of 2.06 volt.

The composition of the mixtures of Examples 30 to 58 is given below, the individual compounds being coded as follows:

- PCH-301: trans-1-p-methoxyphenyl-4-propylcyclohexane
- CCH-301: trans, trans-4-methoxy-4'-propylcyclohexylcyclohexane
- CBC-33F: 4,4'-bis-(trans-4-propylcyclohexyl)-2-fluorobiphenyl
- CBC-55F: 4,4'-bis-(trans-4-pentylcyclohexyl)-2-fluorobiphenyl
- CBC-53F: 4-(trans-4-pentylcyclohexyl)-4'-(trans-4-propylcyclohexyl)-2-fluorobiphenyl [sic]

	CBC-33:	4,4'-bis-(trans-4-propylcyclohexyl)-biphenyl
	CBC-55:	4,4'-bis-(trans-4-pentylcyclohexyl)-biphenyl
5	CBC-53:	4-(trans-4-pentylcyclohexyl)-4'-(trans-4-propylcyclohexyl)-biphenyl
	ECCP-33:	1-[trans-4-(trans-4-propylcyclohexyl)-cyclohexyl]-2-(p-propylphenyl)-ethane
	CCH-51F:	trans,trans-4-fluoromethyl-4'-pentylcyclohexylcyclohexane
10	CCH-31F:	trans,trans-4-fluoromethyl-4'-propylcyclohexylcyclohexane
	PTP-102:	4-methyl-4'-ethoxy-tolan
	PTP-201:	4-methoxy-4'-ethyl-tolan
15	CPTP-301:	4-(trans-4-propylcyclohexyl)-4'-methoxy-tolan
	CPTP-302:	4-(trans-4-propylcyclohexyl)-4'-ethoxy-tolan
	CPTP-303:	4-(trans-4-propylcyclohexyl)-4'-propoxy-tolan
20	PCH-5F:	trans-1-p-fluorophenyl-4-pentylcyclohexane
	PCH-6F:	trans-1-p-fluorophenyl-4-hexylcyclohexane
	PCH-7F:	trans-1-p-fluorophenyl-4-heptylcyclohexane
25	EPCH-20CF ₃ :	1-(trans-4-ethylcyclohexyl)-2-(p-trifluoromethoxyphenyl)-ethane
	EPCH-30CF ₃ :	1-(trans-4-propylcyclohexyl)-2-(p-trifluoromethoxyphenyl)-ethane
30	EPCH-50CF ₃ :	1-(trans-4-pentylcyclohexyl)-2-(p-trifluoromethoxyphenyl)-ethane
	EPCH-70CF ₃ :	1-(trans-4-heptylcyclohexyl)-2-(p-trifluoromethoxyphenyl)-ethane
	PCH-30CF ₃ :	trans-1-p-trifluoromethoxyphenyl-4-propylcyclohexane
35	PCH-50CF ₃ :	trans-1-p-trifluoromethoxyphenyl-4-pentylcyclohexane
	ECCP-30CF ₃ :	1-[trans-4-(trans-4-propylcyclohexyl)-cyclohexyl]-2-(p-trifluoromethoxyphenyl)-

		ethane
	ECCP-50CF ₃ :	1-[trans-4-(trans-4-pentylcyclohexyl)-cyclohexyl]-2-(p-trifluoromethoxyphenyl)-ethane
5	CCP-20CF ₃ :	p-[trans-4-(trans-4-ethylcyclohexyl)-cyclohexyl]-trifluoromethoxybenzene
	CCP-30CF ₃ :	p-[trans-4-(trans-4-propylcyclohexyl)-cyclohexyl]-trifluoromethoxybenzene
	CCP-40CF ₃ :	p-[trans-4-(trans-4-butylcyclohexyl)-cyclohexyl]-trifluoromethoxybenzene
10	CCP-50CF ₃ :	p-[trans-4-(trans-4-pentylcyclohexyl)-cyclohexyl]-trifluoromethoxybenzene
	BCH-30CF ₃ :	4-trifluoromethoxy-4'-(trans-4-propylcyclohexyl)-biphenyl
15	ECCP-3F.F:	1-[trans-4-(trans-4-propylcyclohexyl)-cyclohexyl]-2-(3,4-difluorophenyl)-ethane
	ECCP-5F.F:	1-[trans-4-(trans-4-pentylcyclohexyl)-cyclohexyl]-2-(3,4-difluorophenyl)-ethane
	CCP-3F.F:	4-[trans-4-(trans-4-propylcyclohexyl)-cyclohexyl]-1,2-difluorobenzene
20	CCP-5F.F:	4-[trans-4-(trans-4-pentylcyclohexyl)-cyclohexyl]-1,2-difluorobenzene
	CCP-3F:	4-[trans-4-(trans-4-propylcyclohexyl)-cyclohexyl]-fluorobenzene
25	ECCP-3F:	1-[trans-4-(trans-4-propylcyclohexyl)-cyclohexyl]-2-(p-fluorophenyl)-ethane
	ECCP-5F:	1-[trans-4-(trans-4-pentylcyclohexyl)-cyclohexyl]-2-(p-fluorophenyl)-ethane
	CP-3F:	p-fluorophenyl trans-4-(trans-4-propylcyclohexyl)-cyclohexanecarboxylate
30	CP-5F:	p-fluorophenyl trans-4-(trans-4-propylcyclohexyl)-cyclohexanecarboxylate
	PYP-5F:	2-p-fluorophenyl-5-pentylpyrimidine
	PYP-6F:	2-p-fluorophenyl-5-hexylpyrimidine
35	PYP-7F:	2-p-fluorophenyl-5-heptylpyrimidine
	PYP-30CF ₃ :	2-p-trifluoromethoxyphenyl-5-propylpyrimidine
	PYP-50CF ₃ :	2-p-trifluoromethoxyphenyl-5-pentylpyrimidine

	PYP-70CF ₃ :	2 - p - trifluoromethoxyphenyl - 5 - heptylpyrimidine
	PCH-3:	p-trans-4-propylcyclohexyl-benzonitrile
	PCH-4:	p-trans-4-butylcyclohexyl-benzonitrile
5	PCH-5:	p-trans-4-pentylcyclohexyl-benzonitrile
	ECCP-3:	1 - [trans-4 - (trans-4-propylcyclohexyl) - cyclohexyl] - 2 - (p-cyanophenyl) - ethane
	ECCP-3CF ₃ :	1 - [trans-4 - (trans-4-propylcyclohexyl) - cyclohexyl] - 2 - (p-trifluoromethylphenyl) - ethane
10	ECCP-5CF ₃ :	1 - [trans-4 - (trans-4-pentylcyclohexyl) - cyclohexyl] - 2 - (p-trifluoromethylphenyl) - ethane
	PYP-5N.F:	2 - (3 - fluoro - 4 - cyanophenyl) - 5 - pentylpyrimidine
15	PYP-7N.F:	2 - (3 - fluoro - 4 - cyanophenyl) - 5 - heptylpyrimidine
	PCH-30CF ₂ :	trans-1-p-difluoromethoxyphenyl-4-propyl-cyclohexane
20	PCH-50CF ₂ :	trans-1-p-difluoromethoxyphenyl-4-pentyl-cyclohexane
	PCH-30CF ₂ :	trans-1-p-difluoromethoxyphenyl-4-propyl-cyclohexane
25	PCH-53	trans - 1 - p - propylphenyl - 4 - pentylcyclohexane

Example 30

PCH-301	10.00
PCH-7F	4.00
EPCH-30CF ₃	9.00
EPCH-70CF ₃	5.00
CCP-30CF ₃	13.00
CCP-50CF ₃	12.00
ECCP-30CF ₃	12.00
ECCP-50CF ₃	8.00
ECCP-3F.F	12.00
ECCP-3F	8.00
CBC-33F	2.00
CBC-53F	3.00
CBC-55F	2.00

Example 31

PCH-30CF ₂	9.00
PCH-40CF ₂	8.00
PCH-50CF ₂	9.00
CCH-301	7.00
CCP-30CF ₃	13.00
CCP-50CF ₃	12.00
ECCP-30CF ₃	8.00
ECCP-50CF ₃	6.00
ECCP-3F.F	9.00
ECCP-3F	6.00
CBC-33F	5.00
CBC-53F	4.00
CBC-55F	4.00

Example 32

CCH-301	7.00
PCH-5F	12.00
PCH-7F	9.00
CCP-30CF ₃	13.00
CCP-50CF ₃	12.00
ECCP-30CF ₃	11.00
ECCP-50CF ₃	8.00
ECCP-3F.F	12.00
ECCP-3F	7.00
CBC-33F	3.00
CBC-53F	3.00
CBC-55F	3.00

Example 33

PCH-5F	13.0
PCH-7F	10.0
CCP-30CF ₃	13.0
CCP-40CF ₃	11.0
CCP-50CF ₃	12.0
ECCP-30CF ₃	11.0
ECCP-50CF ₃	8.0
ECCP-3F.F	9.0
ECCP-5F.F	6.0
CBC-33F	3.0
CBC-53F	2.0
CBC-55F	2.0

Example 34

PCH-5F	11.0
PCH-6F	4.0
PCH-7F	10.0
CCP-20CF ₃	9.0
CCP-30CF ₃	13.0
CCP-40CF ₃	7.0
CCP-50CF ₃	11.0
ECCP-30CF ₃	10.0
ECCP-50CF ₃	8.0
ECCP-3F.F	8.0
CBC-33F	3.0
CBC-53F	3.0
CBC-55F	3.0

Example 35

PCH-5F	13.0
PCH-7F	10.0
CCP-20CF ₃	10.0
CCP-30CF ₃	13.0
CCP-40CF ₃	7.0
CCP-50CF ₃	11.0
ECCP-30CF ₃	11.0
ECCP-3F.F	10.0
ECCP-3F	8.0
CBC-33F	3.0
CBC-53F	2.0
CBC-55F	2.0

Example 36

PCH-5F	13.0
PCH-7F	10.0
CCP-20CF ₃	10.0
CCP-30CF ₃	13.0
CCP-40CF ₃	7.0
CCP-50CF ₃	11.0
ECCP-30CF ₃	11.0
ECCP-3F.F	10.0
ECCP-5F.F	7.0
CBC-33F	3.0
CBC-53F	3.0
CBC-55F	2.0

Example 37

PCH-5F	13.0
PCH-7F	10.0
CCP-20CF ₃	10.0
CCP-30CF ₃	13.0
CCP-40CF ₃	7.0
CCP-50CF ₃	11.0
ECCP-3F.F	10.0
ECCP-5F.F	8.0
ECCP-3F	11.0
CBC-33F	3.0
CBC-53F	2.0
CBC-55F	2.0

Example 38

PCH-5F	12.0
PCH-7F	10.0
CCP-20CF ₃	11.0
CCP-30CF ₃	13.0
CCP-40CF ₃	7.0
CCP-50CF ₃	12.0
ECCP-30CF ₃	9.0
ECCP-3F.F	9.0
ECCP-5F.F	5.0
ECCP-3F	6.0
CBC-33F	3.0
CBC-53F	2.0

Example 39

PCH-5F	12.0
PCH-6F	9.0
PCH-7F	10.0
CCP-20CF ₃	11.0
CCP-30CF ₃	13.0
CCP-40CF ₃	5.0
CCP-50CF ₃	12.0
ECCP-3F.F	9.0
ECCP-5F.F	5.0
ECCP-3F	5.0
CBC-33F	3.0
CBC-53F	3.0
CBC-55F	3.0

Example 40

PCH-5F	12.0
PCH-6F	8.0
PCH-7F	10.0
CCP-20CF ₃	11.0
CCP-30CF ₃	13.0
CCP-40CF ₃	5.0
CCP-50CF ₃	12.0
ECCP-3F.F	11.0
ECCP-5F.F	8.0
CBC-33F	4.0
CBC-53F	3.0
CBC-55F	3.0

Example 41

PCH-5F	10.0
PCH-6F	5.0
PCH-7F	7.0
CCP-20CF ₃	11.0
CCP-30CF ₃	13.0
CCP-40CF ₃	6.0
CCP-50CF ₃	11.0
ECCP-30CF ₃	7.0
ECCP-50CF ₃	3.0
ECCP-3F.F	9.0
ECCP-5F.F	4.0
ECCP-3F	7.0
CBC-33F	3.0
CBC-53F	2.0
CBC-55F	2.0

Example 42

PCH-3	19.0
PCH-7F	7.0
CCP-20CF ₃	11.0
CCP-30CF ₃	13.0
CCP-40CF ₃	6.0
CCP-50CF ₃	12.0
ECCP-30CF ₃	7.0
ECCP-3F.F	10.0
ECCP-5F.F	8.0
ECCP-3F	7.0

Example 44

PCH-3	20.00
PCH-5F	9.00
PCH-6F	9.00
PCH-7F	9.00
ECCP-3F	8.00
ECCP-5F	8.00
CP-3F	12.00
CP-5F	12.00
ECCP-3	13.00

Example 43

PCH-3	20.00
PCH-4	8.00
PCH-5F	8.00
PCH-6F	8.00
PCH-7F	7.00
ECCP-3F	7.00
ECCP-5F	7.00
CP-3F	12.00
CP-5F	12.00
ECCP-3	11.00

Example 45

PCH-3	14.00
PCH-5F	14.00
PCH-7F	14.00
PCH-53	10.00
ECCP-3F	6.00
ECCP-5F	6.00
ECCP-3CF ₃	5.00
CBC-33	5.00
CBC-53	5.00
CBC-55	5.00
CBC-33F	5.00
CBC-53F	6.00
CBC-55F	5.00

Example 46

PCH-5F	20.00
PCH-6F	15.00
PCH-7F	15.00
ECCP-3F	10.00
ECCP-5F	10.00
CBC-33	5.00
CBC-53	5.00
CBC-55	5.00
CBC-33F	5.00
CBC-53F	5.00
CBC-55F	5.00

Example 47

PCH-3	24.00
PCH-5F	9.00
PCH-7F	8.00
ECCP-3F	8.00
ECCP-5F	8.00
ECCP-30CF ₃	11.00
ECCP-50CF ₃	11.00
ECCP-3CF ₃	11.00
ECCP-3	10.00

Example 48

PCH-3	24.00
PCH-5F	7.00
PCH-7F	6.00
CCH-31F	6.00
ECCP-3F	5.00
ECCP-5F	5.00
ECCP-30CF ₃	11.00
ECCP-50CF ₃	11.00
ECCP-3CF ₃	11.00
ECCP-3	4.00
CP-3F	5.00
CP-5F	5.00

Example 49

PCH-3	24.00
CCH-31F	7.00
CCH-51F	7.00
ECCP-3F	8.00
ECCP-5F	8.00
ECCP-30CF ₃	11.00
ECCP-50CF ₃	11.00
ECCP-3CF ₃	11.00
ECCP-3	13.00

Example 50

PYP-5N.F	5.00
PYP-7N.F	5.00
PCH-3	14.00
PCH-5F	5.00
CCH-31F	7.00
CCH-51F	7.00
ECCP-3F	5.00
ECCP-5F	5.00
ECCP-30CF ₃	11.00
ECCP-50CF ₃	11.00
ECCP-3CF ₃	11.00
ECCP-3	4.00
CP-3F	5.00
CP-5F	5.00

Example 52

PCH-5F	10.00
PCH-6F	10.00
PCH-7F	10.00
ECCP-3F	13.00
ECCP-5F	14.00
ECCP-3CF ₃	13.00
CP-3F	15.00
CP-5F	15.00

Example 51

PCH-5F	10.00
PCH-6F	12.00
PCH-7F	12.00
ECCP-3F	14.00
ECCP-5F	14.00
CP-3F	15.00
CP-5F	15.00
ECCP-3	8.00

Example 53

PCH-3	16.00
PCH-301	8.00
CCP-30CF ₃	9.00
CCP-50CF ₃	8.00
ECCP-30CF ₃	8.00
ECCP-50CF ₃	7.00
ECCP-3F.F	7.00
ECCP-3F	6.00
ECCP-3CF ₃	7.00
BCH-30CF ₃	7.00
PTP-102	4.00
PTP-201	4.00
CPTP-301	2.00
CPTP-302	2.00
CPTP-303	3.00

Example 54

PCH-3	18.00
PCH-301	8.00
PYP-3F	5.00
PYP-50CF ₃	5.00
PYP-70CF ₃	5.00
CCP-30CF ₃	9.00
CCP-50CF ₃	8.00
ECCP-30CF ₃	8.00
ECCP-50CF ₃	7.00
ECCP-3F.F	5.00
ECCP-3F	5.00
BCH-30CF ₃	7.00
CPTP-301	3.00
CPTP-302	3.00
CPTP-303	4.00

Example 55

PCH-3	20.00
PCH-301	10.00
PCH-30CF ₂	5.60
PCH-40CF ₂	5.60
PCH-50CF ₂	5.60
CCP-30CF ₃	7.00
CCP-50CF ₃	6.30
ECCP-30CF ₃	6.30
ECCP-50CF ₃	5.60
ECCP-3F.F	5.60
ECCP-3CF ₃	5.60
BCH-30CF ₃	7.00
CPTP-301	3.50
CPTP-302	2.80
CPTP-303	3.50

Example 56

PCH-3	20.00
PCH-301	10.00
PYP-3F	5.60
PYP-5F	5.60
PYP-50CF ₃	5.60
PYP-70CF ₃	5.60
CCP-30CF ₃	7.00
CCP-50CF ₃	6.30
ECCP-30CF ₃	6.30
ECCP-50CF ₃	5.60
ECCP-3F.F	5.60
ECCP-3CF ₃	5.60
CPTP-301	3.50
CPTP-302	3.50
CPTP-303	4.20

Example 57

PCH-3	18.00
PCH-5F	12.00
PCH-6F	12.00
PCH-7F	10.00
ECCP-3F	7.00
ECCP-5F	7.00
ECCP-33	5.00
CBC-33	5.00
CBC-53	5.00
CBC-55	4.00
CBC-33F	5.00
CBC-53F	5.00
CBC-55F	5.00

Example 58

PCH-3	10.00
PCH-5F	18.00
PCH-6F	14.00
PCH-7F	10.00
ECCP-3F	9.00
ECCP-5F	7.00
CBC-33	5.00
CBC-53	6.00
CBC-55	5.00
CBC-33F	5.00
CBC-53F	6.00
CBC-55F	5.00

The properties of the mixtures from Examples 30 to 58 are listed in the table below:

Property	Example 30	31	32	33	34	35	36	37	38		
Clear point [°C]	100	101	100	103	100	101	101	100	101		
Viscosity at 20° (mPa.s)	15	15	15					15	15		
$\Delta\epsilon$	+4.0	+6.6	+5.9					+4.0	+4.6		
ϵ_{11}	7.0							6.8	7.5		
Δn	0.090	0.090	0.084	0.076	0.087	0.084	0.085	0.081	0.081		
$V_{(10,0,20)}$ [Volt]	2.44	2.40	2.57	2.52	2.27	2.29	2.20	2.26	2.27		
Property	Example 39	40	41	42	43	44	45	46	47		
Clear point [°C]	88	90	102	98	82	84	95	89	87		
Viscosity at 20° (mPa.s)	14	14	15	17	18	18	17	15	16		
$\Delta\epsilon$	+4.0	+4.0	+3.9		+8.0	+7.3	+4.6	+2.7	+8.7		
ϵ_{11}	6.9	7.0	6.6		11.9	11.0	7.6		12.1		
Δn	0.081	0.079	0.081	0.090	0.094	0.090	0.105	0.093	0.094		
$V_{(10,0,20)}$ [Volt]	2.13	2.20	2.33	1.90	1.71	1.75	2.15	2.98	1.82		
Property	Example 48	49	50	51	52	53	54	55	56	57	58
Clear point [°C]	84	101	85	94	94	106	91	81	73	95	94
Viscosity at 20° (mPa.s)	16	20	19	17	17					17	
$\Delta\epsilon$	+7.9	+8.3	+10.2			+6.9	+8.1	+6.5	+8.7	+5.2	
ϵ_{11}	11.5	11.8	14.3			10.4	11.8	10.8	12.8	8.4	
Δn	0.089	0.094	0.096	0.074	0.072	0.132	0.125	0.113	0.125	0.105	0.101
$V_{(10,0,20)}$ [Volt]	1.86	1.98	1.56	2.42	2.58	2.51	2.12	2.15	1.85	2.03	2.23

Further mixtures according to the invention are listed below:

Example 59

CCH-301	7.00
PCH-5F	12.00
PCH-7F	9.00
CCP-3F.F	13.00
CCP-5F.F	12.00
ECCP-30CF ₃	11.00
ECCP-50CF ₃	8.00
ECCP-3F.F	12.00
ECCP-3F	7.00
CBC-33F	3.00
CBC-53F	3.00
CBC-55F	3.00

Example 60

PCH-5F	13.0
PCH-7F	10.0
CCP-30CF ₃	13.0
CCP-40CF ₃	11.0
CCP-50CF ₃	12.0
ECCP-30CF ₃	11.0
ECCP-50CF ₃	8.0
CCP-3F.F	9.0
CCP-5F.F	6.0
CBC-33F	3.0
CBC-53F	2.0
CBC-55F	2.0

Example 61

PCH-5F	11.0
PCH-6F	4.0
PCH-7F	10.0
CCP-20CF ₃	9.0
CCP-30CF ₃	13.0
CCP-40CF ₃	7.0
CCP-50CF ₃	11.0
CCP-3F.F	10.0
CCP-5F.F	8.0
CCP-3F	8.0
CBC-33F	3.0
CBC-53F	3.0
CBC-55F	3.0

Example 62

PCH-3	20.0
PCH-4	8.0
PCH-5	8.0
PCH-6F	8.0
PCH-7F	7.0
CCP-3F.F	7.0
CCP-5F.F	7.0
CP-3F	12.0
CCP-3F	12.0
ECCP-3	11.00

Example 63

PCH-3	14.00
PCH-5F	14.00
PCH-7F	14.00
PCH-53	10.00
CCP-3F	6.00
CCP-5F	6.00
CCP-3F.F	5.00
CBC-33	5.00
CBC-53	5.00
CBC-55	5.00
CBC-33F	5.00
CBC-53F	6.00
CBC-55F	5.00

Example 64

PCH-5F	20.00
PCH-6F	15.00
PCH-7F	15.00
CCP-3F.F	10.00
CCP-5F.F	10.00
CBC-33	5.00
CBC-53	5.00
CBC-55	5.00
CBC-33F	5.00
CBC-53F	5.00
CBC-55F	5.00

Example 65

PCH-3	16.00
PCH-301	8.00
CCP-30CF ₃	9.00
CCP-50CF ₃	8.00
CCP-3F.F	8.00
CCP-5F.F	7.00
ECCP-3F.F	7.00
CCP-3F	6.00
ECCP-3CF ₃	7.00
BCH-30CF ₃	7.00
PTP-102	4.00
PTP-201	4.00
CPTP-301	2.00
CPTP-302	2.00
CPTP-303	3.00

Example 66

PCH-3	18.00
PCH-5F	12.00
PCH-6F	12.00
PCH-7F	10.00
CCP-3F.F	7.00
CCP-5F.F	7.00
ECCP-33	5.00
CBC-33	5.00
CBC-53	5.00
CBC-55	4.00
CBC-33F	5.00
CBC-53F	5.00
CBC-55F	5.00

Example 67

PCH-3	10.00
PCH-5F	18.00
PCH-6F	14.00
PCH-7F	10.00
CCP-3F.F	9.00
CCP-5F.F	7.00
CBC-33	5.00
CBC-53	6.00
CBC-55	5.00
CBC-33F	5.00
CBC-53F	6.00
CBC-55F	5.00

Example 68

Composition:

5	PCH-3	10.0	%
	PCH-5F	18.0	%
	PCH-6F	14.0	%
	PCH-7F	10.0	%
	ECCP-3F	9.0	%
10	ECCP-5F	7.0	%
	CBC-33	5.0	%
	CBC-53	6.0	%
	CBC-55	5.0	%
	CBC-33F	5.0	%
15	CBC-53F	6.0	%
	CBC-55F	5.0	%
	S → N	<-20	°C
	Clearing point	+94	°C
	Viscosity	ν	+20°C
20			16
			mm ² s ⁻¹
	Dielectric anisotropy Δε	1 kHz, 20°C	+4.1
	ε	1 kHz, 20°C	7.1
	ε _⊥	1 kHz, 20°C	3.0
	Optical anisotropy	Δn	+0.1006
	(20°C, 589 nm)	n _e	1.5932
		n _o	1.4926

Example 69

Composition:

5	PCH-3	18.0	%
	PCH-5F	12.0	%
	PCH-6F	12.0	%
	PCH-7F	10.0	%
	ECCP-3F	7.0	%
10	ECCP-5F	7.0	%
	ECCP-33	5.0	%
	CBC-33	5.0	%
	CBC-53	5.0	%
	CBC-55	4.0	%
15	CBC-33F	5.0	%
	CBC-53F	5.0	%
	CBC-55F	5.0	%

S → N	<-40	°C
Clearing point	+95	°C

Viscosity	η	+20°C	17	mm ² s ⁻¹
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20	Dielectric anisotropy $\Delta\epsilon$	1 kHz, 20°C	+5.2
	$\epsilon_{\parallel}$	1 kHz, 20°C	8.4
	$\epsilon_{\perp}$	1 kHz, 20°C	3.2

Optical anisotropy	Δn	+0.1050
(20°C, 589 nm)	n_o	1.5981
	n_e	1.4931

Example 70

Composition:

5	PCH-3	7.0	%
	PCH-5F	12.0	%
	PCH-6F	12.0	%
	PCH-7F	10.0	%
	ECCP-3F	7.0	%
10	ECCP-5F	7.0	%
	PCH-53	8.0	%
	ECCP-33	5.0	%
	CBC-33	5.0	%
	CBC-53	6.0	%
15	CBC-55	5.0	%
	CBC-33F	5.0	%
	CBC-53F	6.0	%
	CBC-55F	5.0	%
S → N			<-20 °C
Clearing point			+98 °C
Viscosity		+20°C	16 mm ² s ⁻¹
20	Dielectric anisotropy Δε	1 kHz, 20°C	+3.2
	ε	1 kHz, 20°C	6.0
	ε _⊥	1 kHz, 20°C	2.8
25	Optical anisotropy		Δn +0.1008
	(20°C, 589 nm)		n _e 1.5942
			n _o 1.4934

Examples		71	72
S → N [°]		<0	<0
Clearing point [°C]		+100	+101
Viscosity [mm ² s ⁻¹] 20°C		16	16
5	Δn (20°C, 589 nm)	+0.086	+0.086
	n _e (20°C, 589 nm)	1.558	1.556
	V _(10,0,20)	2.33	2.38
	V _(50,0,20)	2.86	2.92
	V _(20,0,20)	3.52	3.62
10	Composition [%]:	EPCH-30CP3 15.0	EPCH-30CP3 13.0
		PCH-7F 10.0	EPCH-30CP3 10.0
		CCP-20CF3 10.0	CCP-20CP3 10.0
		CCP-30CF3 13.0	CCP-30CP3 13.0
		CCP-40CF3 7.0	CCP-40CP3 7.0
		CCP-50CF3 11.0	CCP-50CF3 11.0
		ECCP-3F.F 10.0	ECCP-3F.F 10.0
		ECCP-5F.F 8.0	ECCP-5F.F 8.0
		ECCP-3F 11.0	ECCP-3F 11.0
		CDC-33F 3.0	CBC.33F 3.0
		CDC-53F 2.0	CBC.53F 2.0
		CBC-55F 2.0	CBC.55F 2.0

In addition to component B and, if used, A and C, the liquid-crystal mixtures according to the invention can also contain other additives, such as, for example, chiral dopes, isotropic additives for modifying various parameters, pleochroic dyes, etc. Components A, B and C preferably comprise predominantly the compounds mentioned (i.e. more than 50%, in particular more than 60% thereof). Preferably, however, components A, B and C essentially consist of the compounds mentioned (i.e. more than 80%, in particular 100% thereof).

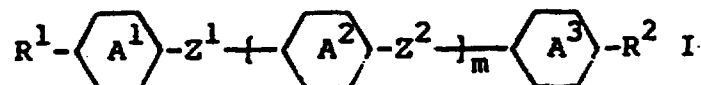


Patent Claims

1. Matrix liquid-crystal display containing
- two plane parallel support plates which together with a frame form a cell,
 - integrated non-linear elements for switching individual picture elements on the support plates and
 - a nematic liquid-crystal mixture which is present in the cell and has a positive dielectric anisotropy and high resistivity,

characterized in that the liquid-crystal mixture is based on the following components:

- a) at least 10% by weight of a liquid-crystalline component B comprising one or more compounds having a dielectric anisotropy of more than +1.5,
- b) up to 90% by weight of a liquid-crystalline component A comprising one or more compounds having a dielectric anisotropy of -1.5 to +1.5 of the general formula I



in which

R^1 and R^2 are each, independently of one another, n-alkyl, ω -fluoroalkyl or n-alkenyl having up to 9 carbon atoms,

the rings A^1 , A^2 and A^3

are each, independently of one another, 1,4-phenylene, 2- or 3-fluoro-1,4-phenylene, trans-1,4-cyclohexylene or 1,4-cyclohexenylene,

Z^1 and Z^2 are each, independently of one another, $-\text{CH}_2\text{CH}_2-$ or a single bond,

and

m is 0, 1 or 2, and

- c) 0 to 20% by weight of a liquid-crystalline component C comprising one or more compounds having a dielectric anisotropy of less than -1.5,

and the nematic liquid-crystal mixture has a nematic phase range of at least 60°C, a maximum viscosity at 20°C



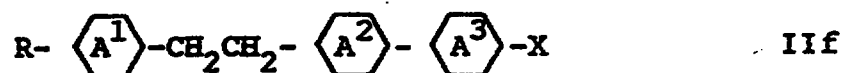
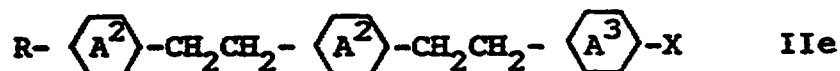
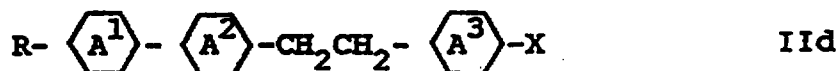
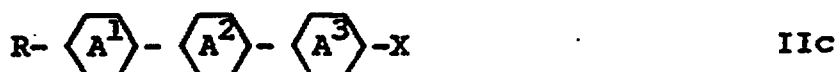
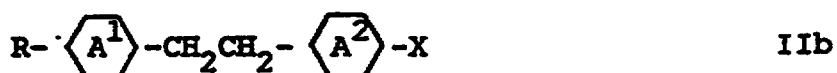
of 30 mPa.s and a mean dielectricity constant $\bar{\epsilon} \leq 8$.

2. Display according to Claim 1, characterized in that component B essentially consists of nitrile-containing compounds.

3. Display according to Claim 1, characterized in that component B contains nitrile-containing and nitrile-free, fluorinated compounds.

4. Display according to Claim 1, characterized in that component B essentially consists of nitrile-free, fluorinated compounds.

5. Display according to one of Claims 1 to 4, characterized in that component B contains one or more compounds selected from the group consisting of compounds of the formulae IIa to IIf



in which

R is n-alkyl or n-alkenyl of up to 9 carbon atoms,

X is cyano, -NCS, F, Cl, -CF₃, -CHF₂, -OCF₃, -OCHF₂, -OCF₂CF₂H or -OC₂F₅, and

the rings A¹, A² and A³

are each, independently of one another, 1,4-phenylene, 2- or 3-fluoro-1,4-phenylene, 2,3-difluoro-1,4-phenylene, trans-1,4-cyclohexylene or 1,4-cyclohexenylene,

the ratio of nitrile-free to nitrile-containing compounds in component B being >2:1.

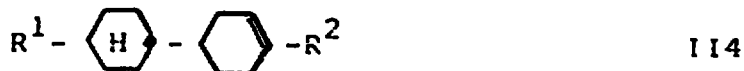
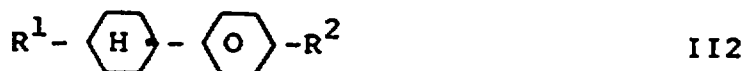


6. Display according to Claim 5, characterized in that component B contains compounds of the formulae IIa to IIf in which X is cyano and compounds of the formulae IIa to IIf in which X is -NCS, F, Cl, -CF₃, -CHF₂, -OCF₃, -OCHF₂, -OCF₂CF₂H or -OC₂F₅ and the amount of cyano compounds in component B is 0 to 50% by weight.

7. Display according to Claim 6, characterized in that component B does not contain any compounds of the formulae IIa to IIf in which X is cyano.

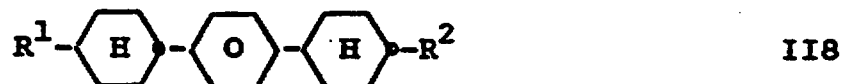
8. Display according to at least one of Claims 5 to 7, characterized in that X is F, Cl, CF₃, -OCF₃, -OCHF₂ or -CHF₂.

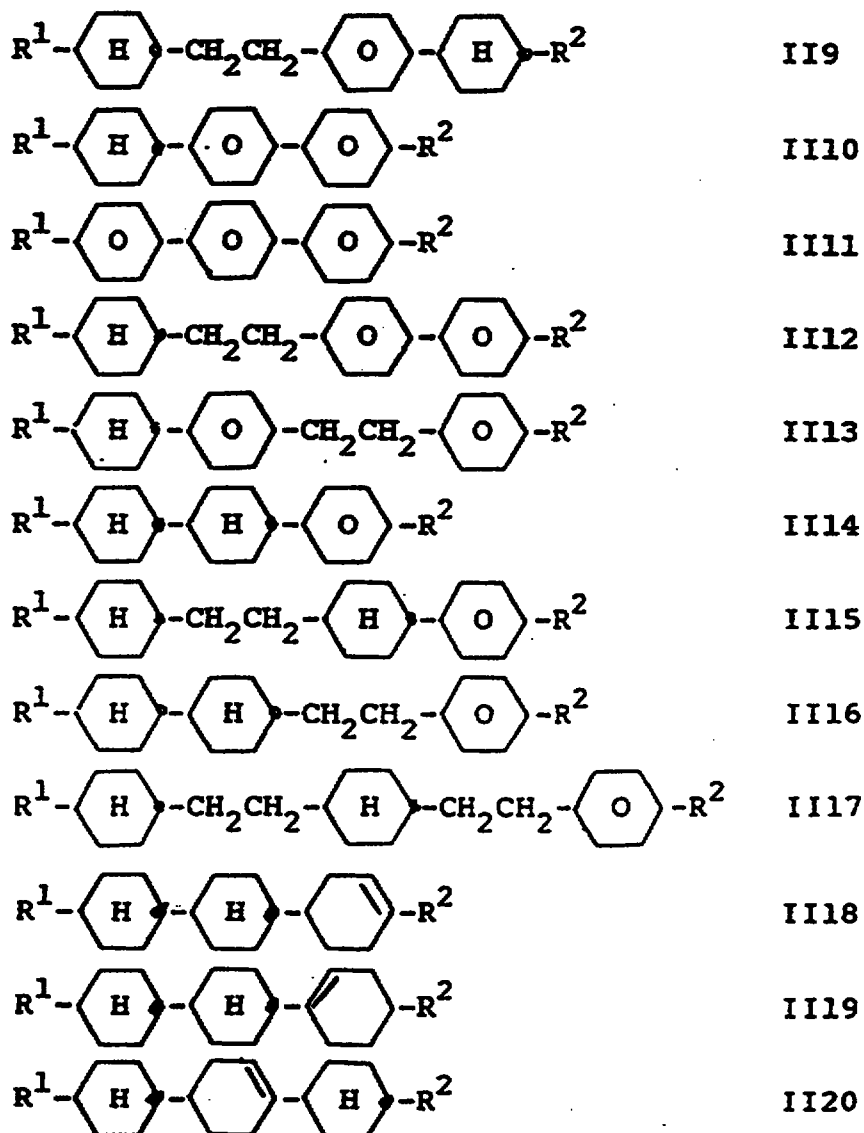
9. Display according to at least one of Claims 1 to 8, characterized in that component A contains one or more compounds selected from the group consisting of II1 to II7:



in which R¹ and R² have the meaning given in Claim 1.

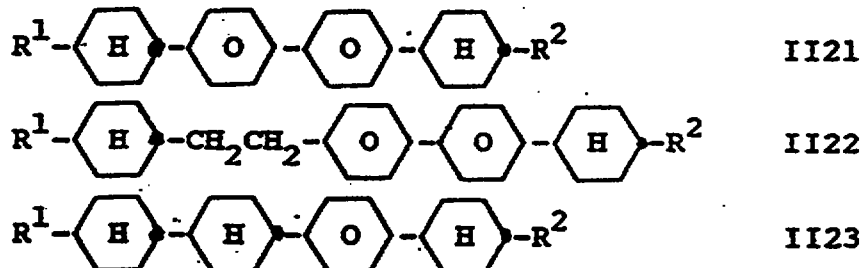
10. Display according to Claim 9, characterized in that component A additionally contains one or more compounds selected from the group consisting of II8 to II20:

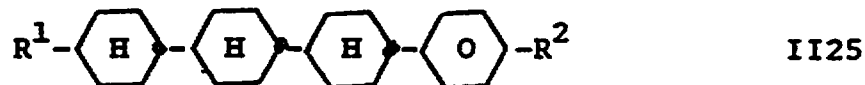
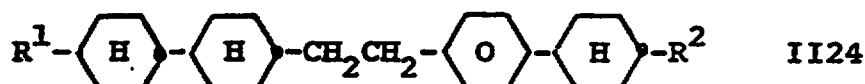




in which R¹ and R² have the meaning given in Claim 1 and the 1,4-phenylene groups in II18 to II17 can each, independently of one another, also be mono- or polysubstituted by fluorine.

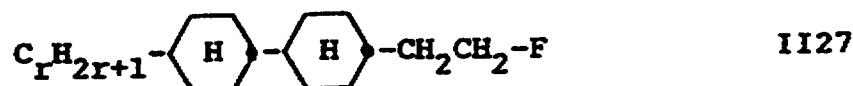
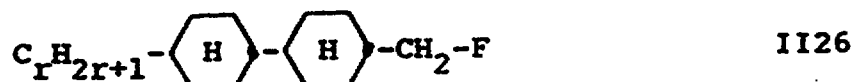
11. Display according to Claim 9 or 10, characterized in that component A additionally contains one or more compounds selected from the group consisting of II21 to II25:





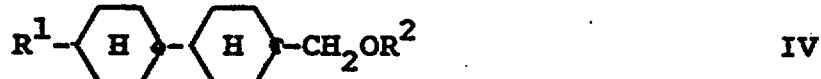
in which R^1 and R^2 have the meaning given in Claim 1 and the 1,4-phenylene groups in II21 to II25 can each, independently of one another, also be mono- or polysubstituted by fluorine.

12. Display according to at least one of Claims 1 to 11, characterized in that component A contains one or more compounds selected from the group consisting of II26 and II27:



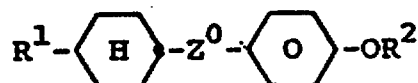
in which $\text{C}_r\text{H}_{2r+1}$ is a straight-chain alkyl group of up to 7 carbon atoms.

13. Display according to at least one of Claims 1 to 12, characterized in that the liquid-crystal mixture additionally contains, in addition to components A, B and C, one or more compounds selected from the group consisting of III and IV:



in which R^1 and R^2 have the meaning given in Claim 1.

14. Display according to at least one of Claims 1 to 13, characterized in that the liquid-crystal mixture additionally contains, in addition to components A, B and C, one or more compounds of the formula





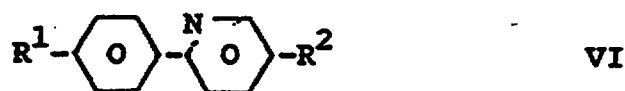
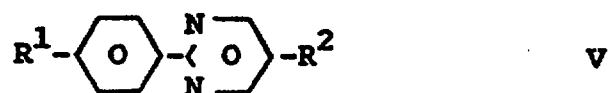
in which

R^1 and R^2 have the meaning given in Claim 1

and

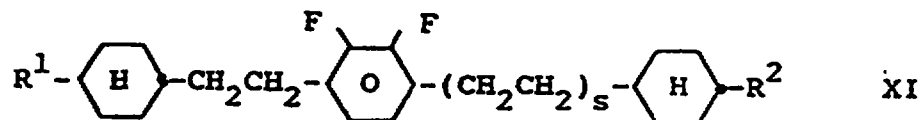
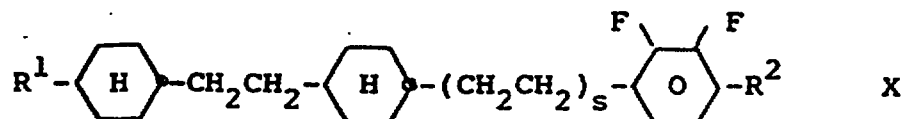
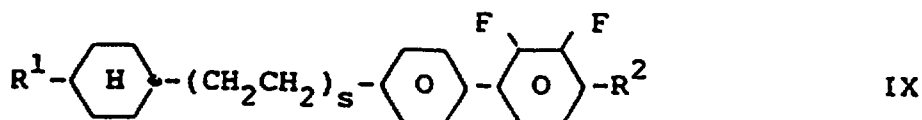
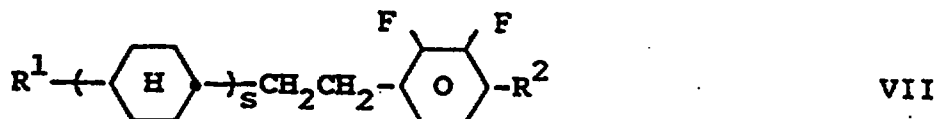
Z^0 is a single bond, $-\text{CH}_2\text{CH}_2-$, $-\text{H}-$ or $-\text{H}-\text{CH}_2\text{CH}_2-$

15. Display according to at least one of Claims 1-14, characterized in that the liquid-crystal mixture additionally contains, in addition to compounds A, B and C, one or more compounds selected from the group consisting of V and VI:



in which R^1 and R^2 have the meaning given in Claim 1.

16. Display according to at least one of Claims 1-15, characterized in that the liquid-crystal mixture additionally contains, in addition to components A, B and C, one or more compounds selected from the group consisting of VII to XI:





in which

R^1 and R^2 have the meaning given in Claim 1

and

s is 0 or 1.

17. Liquid-crystal mixture of the composition defined in Claim 5.

18. Liquid-crystal mixture according to Claim 17, characterized in that it is free from dielectrically neutral components containing aromatically bonded alkoxy or ester functions.

19. Liquid-crystal mixture according to Claim 17 or 18, characterized in that it is based only on component B.

20. Liquid-crystal mixture according to Claim 19, characterized in that X in the sub-formulae IIa to IIf is F, Cl, CF_3 , OCF_3 , $OCHF_2$ or CHF_2 .



[As printed]

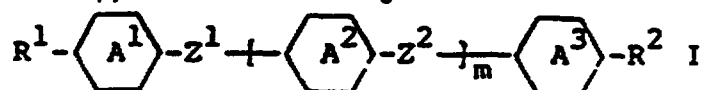
Claims

1. Matrix liquid-crystal display containing

- two plane parallel support plates which together with a frame form a cell,
- integrated non-linear elements for switching individual picture elements on the support plates and
- a nematic liquid-crystal mixture which is present in the cell and has a positive dielectric anisotropy and high resistivity,

characterized in that the liquid-crystal mixture is based on the following components:

- a) at least 10% by weight of a liquid-crystalline component B comprising one or more compounds having a dielectric anisotropy of more than +1.5,
- b) up to 90% by weight of a liquid-crystalline component A comprising one or more compounds having a dielectric anisotropy of -1.5 to +1.5 of the general formula I



in which

R¹ and R²

are each, independently of one another, n-alkyl, ω-fluoroalkyl or n-alkenyl having up to 9 carbon atoms,

the rings A¹, A² and A³

are each, independently of one another, 1,4-phenylene, 2- or 3-fluoro-1,4-phenylene, trans-1,4-cyclohexylene or 1,4-cyclohexenylene,

Z¹ and Z²

are each, independently of one another, -CH₂CH₂- or a single bond,

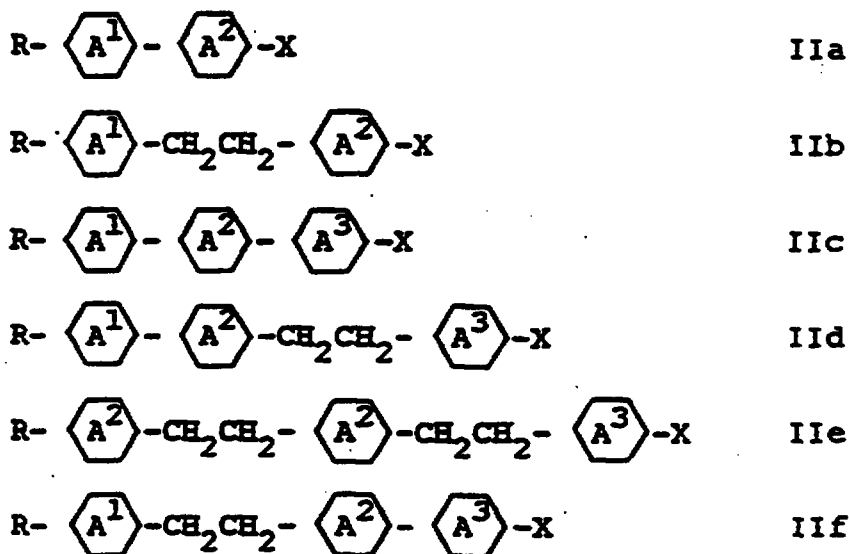
and

m is 0, 1 or 2, and

- c) 0 to 20% by weight of a liquid-crystalline component C comprising one or more compounds having a dielectric anisotropy of less than -1.5,

and the nematic liquid-crystal mixture has a nematic phase range of at least 60°C, a maximum viscosity at 20°C of 30 mPa.s and a mean dielectricity constant $\epsilon \leq 8$.

- 2. Display according to Claim 1, characterized in that component B essentially consists of nitrile-containing compounds.
- 3. Display according to Claim 1, characterized in that component B contains nitrile-containing and nitrile-free, fluorinated compounds.
- 4. Display according to Claim 1, characterized in that component B essentially consists of nitrile-free, fluorinated compounds.
- 5. Display according to one of Claims 1 to 4, characterized in that component B contains one or more compounds selected from the group consisting of compounds of the formulae IIa to IIf



in which

R

is n-alkyl or n-alkenyl of up to 9 carbon atoms,

X

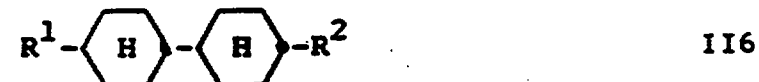
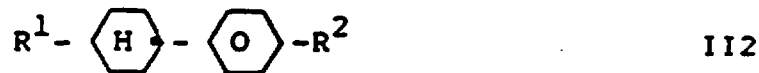
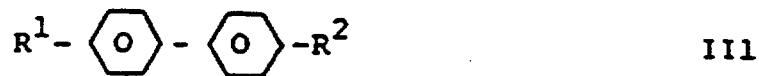
is cyano, -NCS, F, Cl, -CF₃, -CHF₂, -OCF₃, -OCHF₂, -OCF₂CF₂H or -OC₂F₅, and

the rings A¹, A² and A³

are each, independently of one another, 1,4-phenylene, 2- or 3-fluoro-1,4-phenylene, 2,3-difluoro-1,4-phenylene, trans-1,4-cyclohexylene or 1,4-cyclohexenylene,

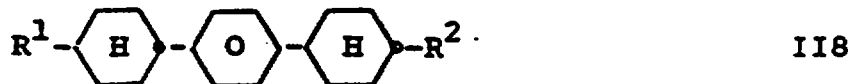
the ratio of nitrile-free to nitrile-containing compounds in component B being >2:1.

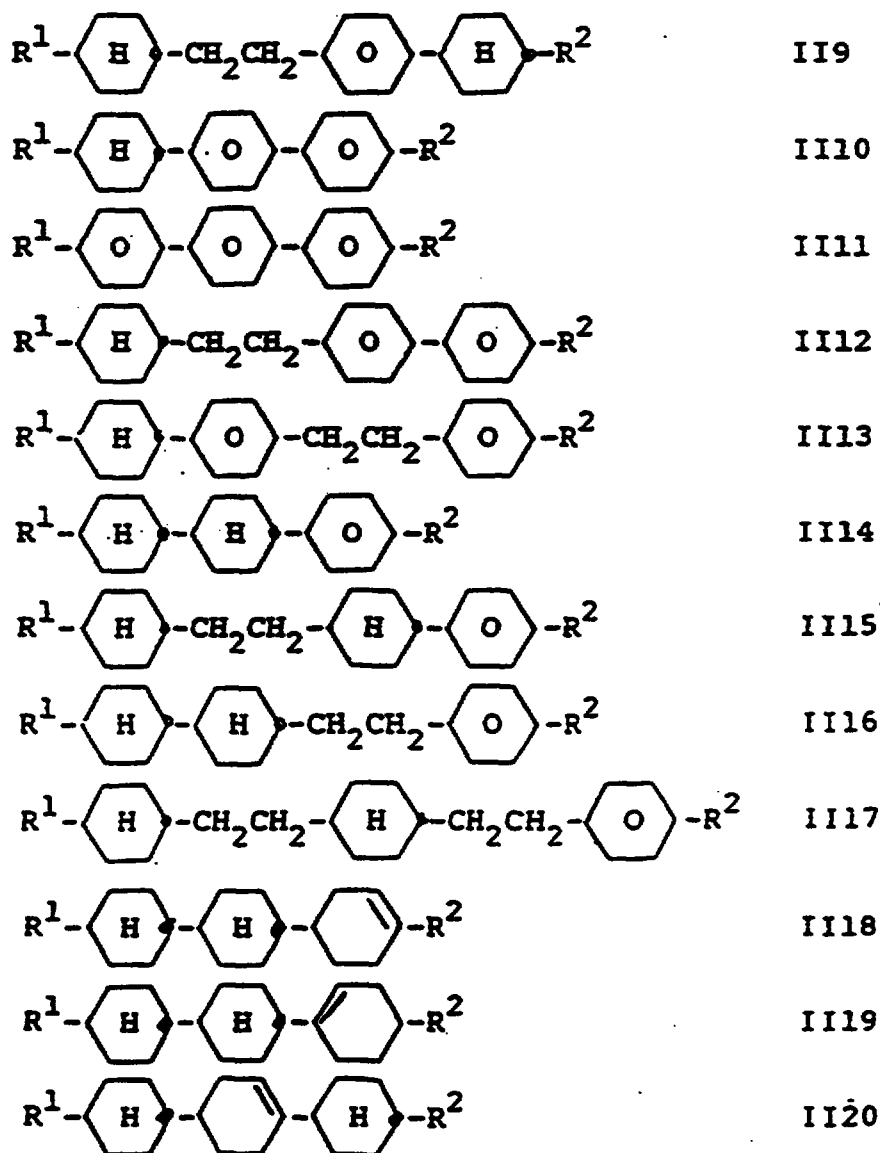
6. Display according to Claim 5, characterized in that component B contains compounds of the formulae IIa to IIIf in which X is cyano and compounds of the formulae IIa to IIIf in which X is -NCS, F, Cl, -CF₃, -CHF₂, -OCF₃, -OCHF₂, -OCF₂CF₂H or -OC₂F₅ and the amount of cyano compounds in component B is 0 to 50% by weight.
7. Display according to Claim 6, characterized in that component B does not contain any compounds of the formulae IIa to IIIf in which X is cyano.
8. Display according to at least one of Claims 5 to 7, characterized in that X is F, Cl, CF₃, -OCF₃, -OCHF₂ or -CHF₂.
9. Display according to at least one of Claims 1 to 8, characterized in that component A contains one or more compounds selected from the group consisting of II1 to II7:



in which R¹ and R² have the meaning given in Claim 1.

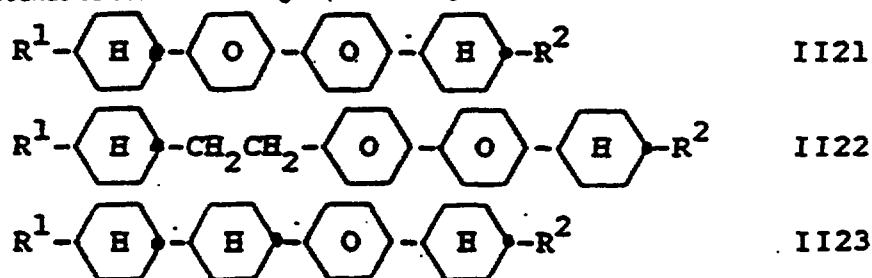
10. Display according to Claim 9, characterized in that component A additionally contains one or more compounds selected from the group consisting of II8 to II20:

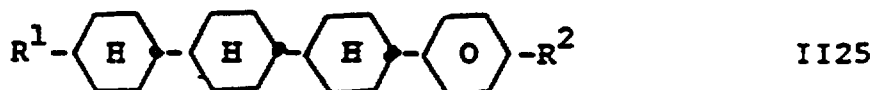
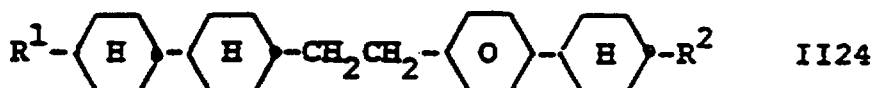




in which R^1 and R^2 have the meaning given in Claim 1 and the 1,4-phenylene groups in II18 to II17 can each, independently of one another, also be mono- or polysubstituted by fluorine.

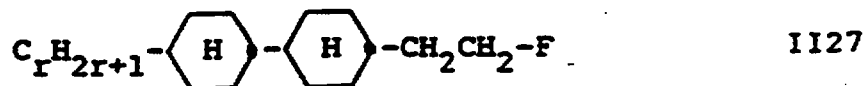
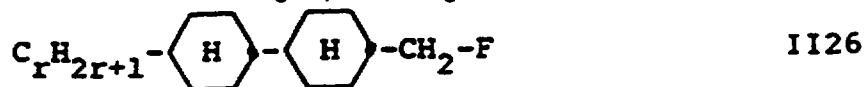
11. Display according to Claim 9 or 10, characterized in that component A additionally contains one or more compounds selected from the group consisting of II21 to II25:





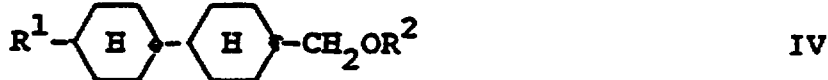
in which R^1 and R^2 have the meaning given in Claim 1 and the 1,4-phenylene groups in II21 to II25 can each, independently of one another, also be mono- or polysubstituted by fluorine.

12. Display according to at least one of Claims 1 to 11, characterized in that component A contains one or more compounds selected from the group consisting of II26 and II27:



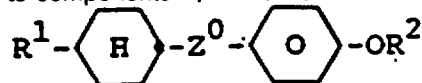
in which C_rH_{2r+1} is a straight-chain alkyl group of up to 7 carbon atoms.

13. Display according to at least one of Claims 1 to 12, characterized in that the liquid-crystal mixture additionally contains, in addition to components A, B and C, one or more compounds selected from the group consisting of III and IV:



in which R^1 and R^2 have the meaning given in Claim 1.

14. Display according to at least one of Claims 1 to 13, characterized in that the liquid-crystal mixture additionally contains, in addition to components A, B and C, one or more compounds of the formula



in which

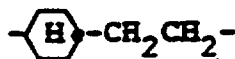
R^1 and R^2 have the meaning given in Claim 1

and

Z^0 is a single bond, $-\text{CH}_2\text{CH}_2-$,



or



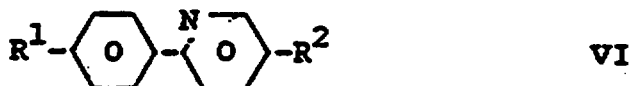
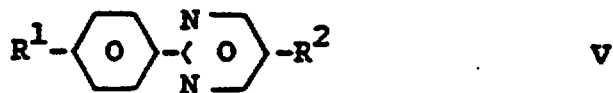


* C L M S *

- 66 -

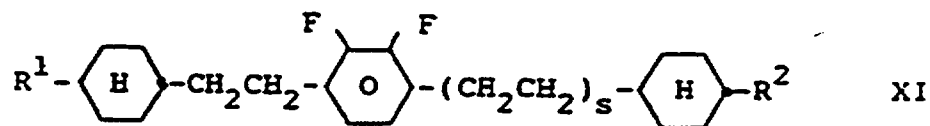
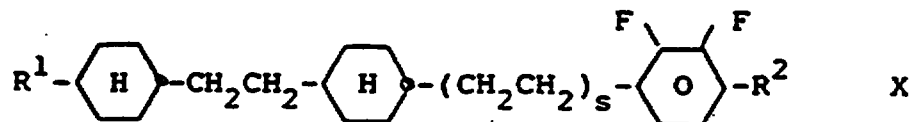
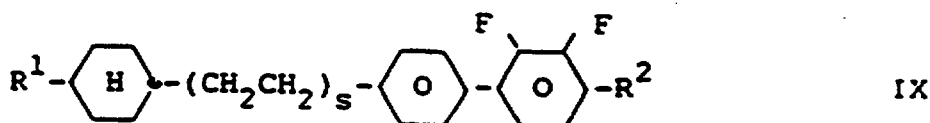
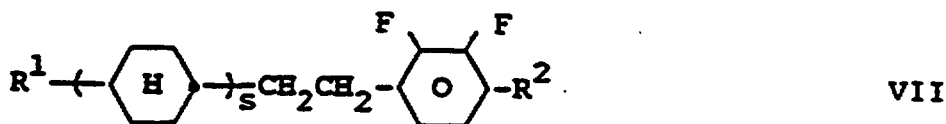
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15. Display according to at least one of Claims 1-14, characterized in that the liquid-crystal mixture additionally contains, in addition to compounds A, B and C, one or more compounds selected from the group consisting of V and VI:



in which R^1 and R^2 have the meaning given in Claim 1.

16. Display according to at least one of Claims 1-15, characterized in that the liquid-crystal mixture additionally contains, in addition to components A, B and C, one or more compounds selected from the group consisting of VII to XI:



in which

R^1 and R^2 have the meaning given in Claim 1

and

s is 0 or 1.

17. Liquid-crystal mixture of the composition defined in Claim 5.
18. Liquid-crystal mixture according to Claim 17, characterized in that it is free from dielectrically neutral components containing aromatically bonded alkoxy or ester functions.
19. Liquid-crystal mixture according to Claim 17 or 18, characterized in that it is based only on component B.
20. Liquid-crystal mixture according to Claim 19, characterized in that X in the sub-formulae IIa to IIf is F, Cl, CF_3 , OCF_3 , OCHF_2 or CHF_2 .



[As printed]

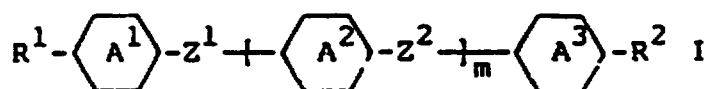
Revendications

1. Afficheur matriciel à cristaux liquides comportant

- deux plaques de support à faces parallèles qui, avec un bord, forment une cellule,
- des éléments non linéaires pour la commutation de points d'image individuels sur les plaques de support et
- une composition de cristaux liquides nématiques se trouvant dans la cellule, à anisotropie diélectrique positive et haute résistance spécifique,

caractérisé en ce que la composition de cristaux liquides est à base des composants suivants:

- au moins 10 % en poids d'un composant B de type cristal liquide, constitué d'un ou plusieurs composés ayant une anisotropie diélectrique supérieure à +1,5,
- jusqu'à 90 % en poids d'un composant A de type cristal liquide, constitué d'un ou plusieurs composés ayant une anisotropie diélectrique de -1,5 à +1,5, de formule générale I



dans laquelle

R¹ et R²

les cycles A¹, A² et A³

Z¹ et Z²

m

représentent chacun, indépendamment l'un de l'autre, un groupe n-alkyle, ω-fluoroalkyle ou n-alcényle ayant jusqu'à 9 atomes de carbone,

représentent chacun, indépendamment les uns des autres, un groupe 1,4-phénylène, 2- ou 3-fluoro-1,4-phénylène, *trans*-1,4-cyclohexylène ou 1,4-cyclohexénylène,

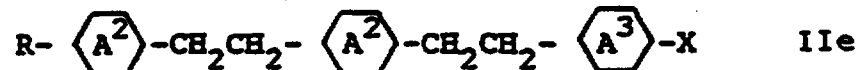
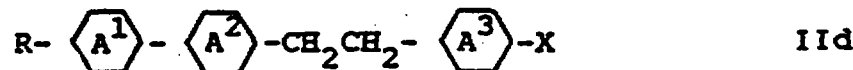
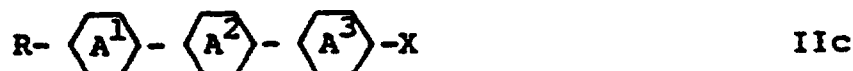
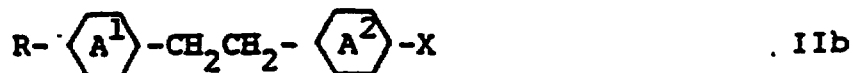
représentent chacun, indépendamment l'un de l'autre, -CH₂CH₂- ou une simple liaison, et

représente 0, 1 ou 2, et

- 0 à 20 % en poids d'un composant C de type cristal liquide, constitué d'un ou plusieurs composés ayant une anisotropie diélectrique inférieure à -1,5,

et la composition de cristaux liquides nématiques présente une plage de phase nématique d'au moins 60 °C, une viscosité à 20 °C d'au maximum 30 mPa.s et une constante diélectrique moyenne ε ≤ 8.

- Afficheur selon la revendication 1, caractérisé en ce que le composant B est essentiellement constitué de composés contenant des groupes nitrile.
- Afficheur selon la revendication 1, caractérisé en ce que le composant B contient des composés fluorés exempts de groupe nitrile et des composés fluorés contenant des groupes nitrile.
- Afficheur selon la revendication 1, caractérisé en ce que le composant B consiste essentiellement en composés fluorés exempts de groupe nitrile.
- Afficheur selon l'une des revendications 1 à 4, caractérisé en ce que le composant B contient un ou plusieurs composés choisis parmi des composés de formules IIa à IIf



dans lesquelles

R représente un groupe n-alkyle ou n-alcényle ayant jusqu'à 9 atomes de carbone,

X représente F, Cl ou le groupe cyano, -NCS, -CF₃, -CHF₂, -OCF₃, -OCHF₂, -OCF₂CF₂H ou -OC₂F₅,

et

les cycles A¹, A² et A³ représentent chacun, indépendamment les uns des autres, le groupe 1,4-phénylène, 2- ou 3-fluoro-1,4-phénylène, 2,3-difluoro-1,4-phénylène, *trans*-1,4-cyclohexylène ou 1,4-cyclohexénylène,

le rapport des composés exempts de groupe nitrile aux composés contenant des groupes nitriles du composant B est > 2:1.

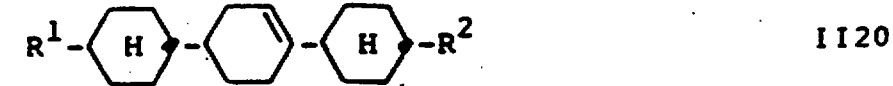
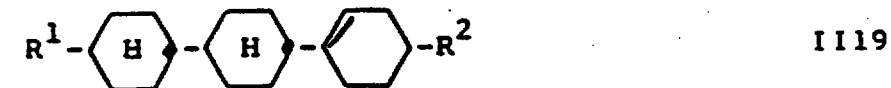
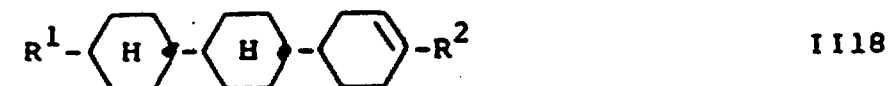
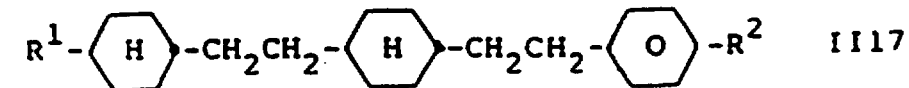
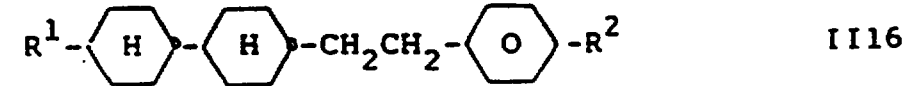
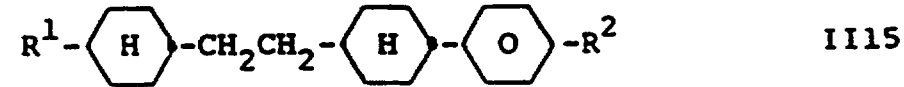
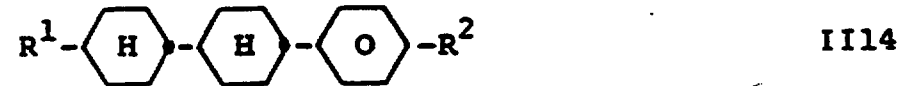
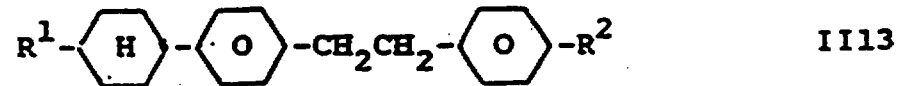
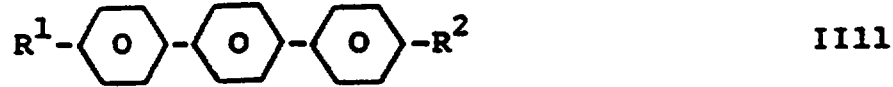
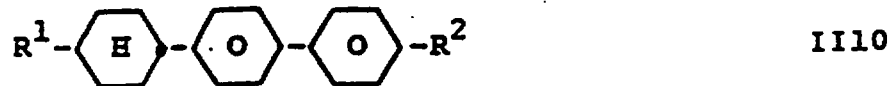
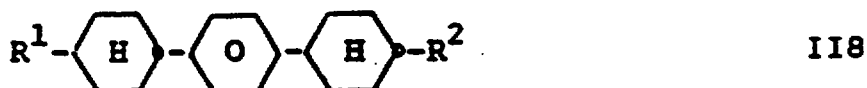
6. Afficheur selon la revendication 5, caractérisé en ce que le composant B contient des composés de formules IIa à II f, dans lesquelles X représente le groupe cyano, et des composés de formules IIa à II f dans lesquelles X représente -NCS, F, Cl, -CF₃, -CHF₂, -OCF₃, -OCHF₂, -OCF₂CF₂H ou -OC₂F₅, et la proportion des groupes cyano dans le composant B va de 0 à 50 % en poids.
7. Afficheur selon la revendication 6, caractérisé en ce que le composant B ne contient pas de composés de formules IIa à II f dans lesquelles X représente le groupe cyano.
8. Afficheur selon au moins l'une des revendications 5 à 7, caractérisé en ce que X représente F, Cl, -CF₃, -OCF₃, -OCHF₂ ou -CHF₂.
9. Afficheur selon au moins l'un des revendications 1 à 8, caractérisé en ce que le composant A contient un ou plusieurs composés choisis parmi ceux de formules III1 à III7:





dans lesquelles R^1 et R^2 ont les significations données dans la revendication 1.

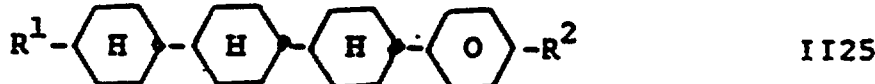
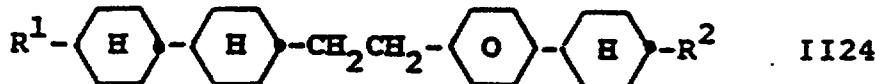
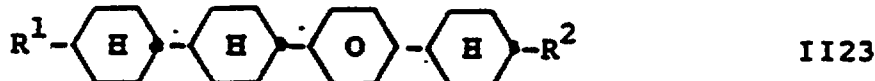
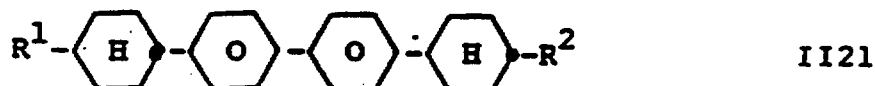
10. Afficheur selon la revendication 9, caractérisé en ce que le composant A contient en outre un ou plusieurs composés choisis parmi ceux de formules II18 à II20:





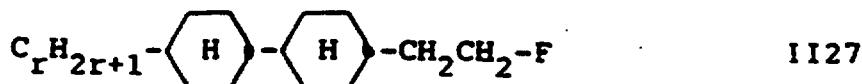
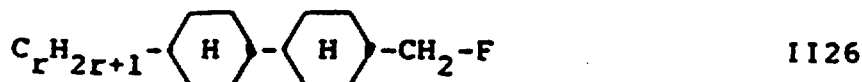
dans lesquelles R^1 et R^2 ont les significations données dans la revendication 1 et les groupes 1,4-phénylène dans les formules II8 à II17 peuvent également être une ou plusieurs fois substitués chacun, indépendamment les uns des autres, par le fluor.

11. Afficheur selon la revendication 9 ou 10, caractérisé en ce que le composant A contient en outre un ou plusieurs composés choisis parmi ceux de formules II21 à II25:



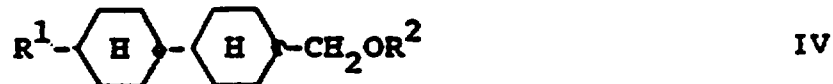
dans lesquelles R^1 et R^2 ont les significations données dans la revendication 1 et les groupes 1,4-phénylène dans les formules II21 à II25 peuvent également être une ou plusieurs fois substitués chacun, indépendamment les uns des autres, par le fluor.

12. Afficheur selon au moins l'une des revendications 1 à 11, caractérisé en ce que le composant A contient un ou plusieurs composés choisis parmi ceux de formules II26 et II27:



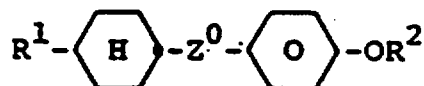
dans lesquelles $\text{C}_r\text{H}_{2r+1}$ est un groupe alkyle à chaîne droite ayant jusqu'à 7 atomes de carbone.

13. Afficheur selon au moins l'une des revendications 1 à 12, caractérisé en ce que, en plus des composants A, B et C, la composition de cristaux liquides contient en outre un ou plusieurs composés choisis parmi ceux de formules III et IV:



dans lesquelles R^1 et R^2 ont les significations données dans la revendication 1.

14. Afficheur selon au moins l'une des revendications 1 à 13, caractérisé en ce que, en plus des composants A, B et C, la composition de cristaux liquides contient en outre un ou plusieurs composés de formule

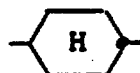


dans laquelle

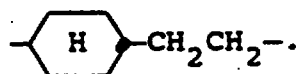
R^1 et R^2

Z^0

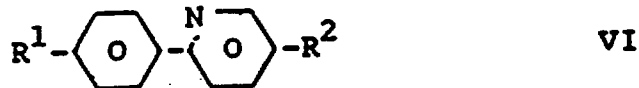
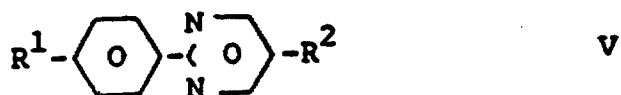
ont les significations données dans la revendication 1 et représente une simple liaison, $-\text{CH}_2\text{CH}_2-$,



ou

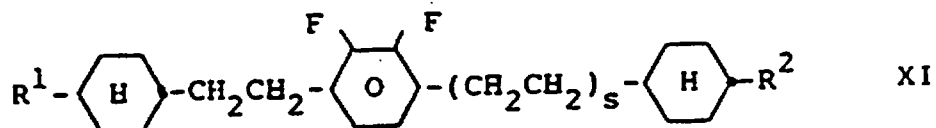
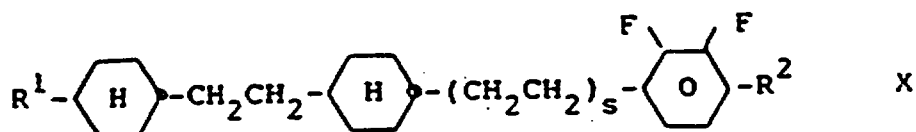
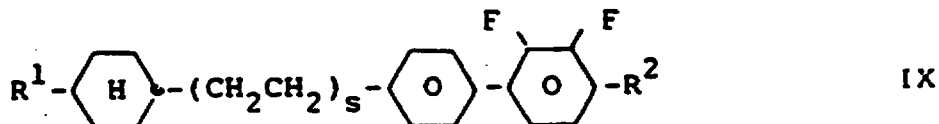
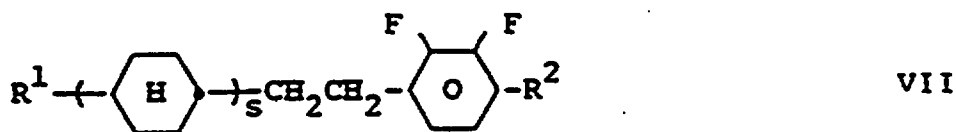


15. Afficheur selon au moins l'une des revendications 1 à 14, caractérisé en ce que, en plus des composants A, B et C, la composition de cristaux liquides contient en outre un ou plusieurs composés choisis parmi ceux de formules V et VI:



dans lesquelles R^1 et R^2 ont les significations données dans la revendication 1.

16. Afficheur selon au moins l'une des revendications 1 à 15, caractérisé en ce que, en plus des composants A, B et C, la composition de cristaux liquides contient en outre un ou plusieurs composés choisis parmi ceux de formules VII à XI:



dans lesquelles

R^1 et R^2 ont les significations données dans la revendication 1 et
 s est 0 ou 1.

17. Composition de cristaux liquides ayant la composition définie dans la revendication 5.
18. Composition de cristaux liquides selon la revendication 17, caractérisée en ce qu'elle est exempte de composants diélectriquement neutres qui contiennent des fonctions ester ou alcoxy liées à un groupe aromatique.
19. Composition de cristaux liquides selon la revendication 17 ou 18, caractérisée en ce qu'elle est seulement à base du composant B.
20. Composition de cristaux liquides selon la revendication 19, caractérisée en ce que, dans les sous-formules IIa à IIf, X représente F, Cl, CF_3 , OCF_3 , OCHF_2 ou CHF_2 .