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(54) Title: LIQUID-CRYSTALLINE MEDIUM AND LIQUID-CRYSTAL DISPLAY COMPRISING THE SAME

(57) Abstract: The present invention relates to a liquid-crystalline medium (LC medium) comprising a polymerizable piperidine derivative as an additive for stabilization, to the use thereof for electro-optical purposes, and to LC displays containing this medium, particularly to liquid-crystal displays which use the IPS (in-plane switching) or the FFS (fringe field switching) effect using dielectrically positive liquid crystals.



Liquid-crystalline medium and liquid-crystal display comprising the same

5 The present invention relates to a liquid-crystalline medium (LC medium) comprising a polymerizable piperidine derivative as an additive for stabilization, to the use thereof for electro-optical purposes, and to LC displays containing this medium, particularly to liquid-crystal displays which use the IPS (in-plane switching) or the FFS (fringe field switching) effect using dielectrically positive liquid crystals.

10 Liquid crystals are used principally as dielectrics in display devices, since the optical properties of such substances can be modified by an applied voltage. Electro-optical devices based on liquid crystals are extremely well known to the person skilled in the art and can be based on various effects. 15 Examples of such devices are cells having dynamic scattering, DAP (deformation of aligned phases) cells, guest/host cells, TN cells having a "twisted nematic" structure, STN ("super-twisted nematic") cells, SBE ("superbirefringence effect") cells and OMI ("optical mode interference") cells. The commonest display devices are based on the Schadt-Helfrich effect and have a twisted nematic structure. In addition, there are also 20 cells which work with an electric field parallel to the substrate and liquid-crystal plane, such as, for example, IPS ("in-plane switching") cells. TN, STN, FFS (fringe field switching) and IPS cells, in particular, are currently commercially interesting areas of application for the media according to 25 the invention.

The liquid-crystal materials must have good chemical and thermal stability and good stability to electric fields and electromagnetic radiation. Furthermore, the liquid-crystal materials should have low viscosity and produce 30 short addressing times, low threshold voltages and high contrast in the cells.

They should furthermore have a suitable mesophase, for example a nematic or cholesteric mesophase for the above-mentioned cells, at the 35 usual operating temperatures, i.e. in the broadest possible range above and below room temperature. Since liquid crystals are generally used as

5 mixtures of a plurality of components, it is important that the components are readily miscible with one another. Further properties, such as the electrical conductivity, the dielectric anisotropy and the optical anisotropy, have to satisfy various requirements depending on the cell type and area of application. For example, materials for cells having a twisted nematic structure should have positive dielectric anisotropy and low electrical conductivity.

10 For example, for matrix liquid-crystal displays with integrated non-linear elements for switching individual pixels (MLC displays), media having large positive dielectric anisotropy, broad nematic phases, relatively low birefringence, very high specific resistance, good UV and temperature stability and low vapour pressure are desired.

15 Matrix liquid-crystal displays of this type are known. Examples of non-linear elements which can be used to individually switch the individual pixels are active elements (i.e. transistors). The term "active matrix" is then used, where a distinction can be made between two types:

- 20 1. MOS (metal oxide semiconductor) or other diodes on silicon wafers as substrate.
2. Thin-film transistors (TFTs) on a glass plate as substrate.

25 The use of single-crystal silicon as substrate material restricts the display size, since even modular assembly of various part-displays results in problems at the joints.

30 In the case of the more promising type 2, which is preferred, the electro-optical effect used is usually the TN effect. A distinction is made between two technologies: TFTs comprising compound semiconductors, such as, for example, CdSe, or TFTs based on polycrystalline or amorphous silicon. Intensive work is being carried out worldwide on the latter technology.

35 The TFT matrix is applied to the inside of one glass plate of the display, while the other glass plate carries the transparent counterelectrode on its

inside. Compared with the size of the pixel electrode, the TFT is very small and has virtually no adverse effect on the image. This technology can also be extended to fully colour-capable displays, in which a mosaic of red, green and blue filters is arranged in such a way that a filter element is
5 opposite each switchable pixel.

The TFT displays usually operate as TN cells with crossed polarisers in transmission and are backlit.

10 The term MLC displays here encompasses any matrix display with integrated non-linear elements, i.e., besides the active matrix, also displays with passive elements, such as varistors or diodes (MIM = metal-insulator-metal).

15 MLC displays of this type are particularly suitable for TV applications (for example pocket televisions) or for high-information displays for computer applications (laptops) and in automobile or aircraft construction. Besides problems regarding the angle dependence of the contrast and the response times, difficulties also arise in MLC displays due to insufficiently high specific resistance of the liquid-crystal mixtures [TOGASHI, S., SEKI-
20 GUCHI, 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, pp. 141 ff., Paris; STROMER, M., Proc. Eurodisplay 84, Sept. 1984: Design of Thin Film Transistors for Matrix Addressing of Television Liquid Crystal Displays, pp. 145 ff., Paris]. With decreasing resistance, the contrast of an
25 MLC display deteriorates, and the problem of after-image elimination may occur. Since the specific resistance of the liquid-crystal mixture generally drops over the life of an MLC display owing to interaction with the interior surfaces of the display, a high (initial) resistance is very important in order
30 to obtain acceptable lifetimes. In particular in the case of low-volt mixtures, it was hitherto impossible to achieve very high specific resistance values. It is furthermore important that the specific resistance exhibits the smallest possible increase with increasing temperature and after heating and/or UV exposure. The low-temperature properties of the mixtures from the prior
35 art are also particularly disadvantageous. It is demanded that no crystallisation and/or smectic phases occur, even at low temperatures, and

the temperature dependence of the viscosity is as low as possible. The MLC displays from the prior art thus do not satisfy today's requirements.

5 Besides liquid-crystal displays which use backlighting, i.e. are operated transmissively and if desired transreflectively, reflective liquid-crystal displays are also particularly interesting. These reflective liquid-crystal displays use the ambient light for information display. They thus consume significantly less energy than backlit liquid-crystal displays having a corresponding size and resolution. Since the TN effect is characterised by very
10 good contrast, reflective displays of this type can even be read well in bright ambient conditions. This is already known of simple reflective TN displays, as used, for example, in watches and pocket calculators. However, the principle can also be applied to high-quality, higher-resolution active matrix-addressed displays, such as, for example, TFT displays.
15 Here, as already in the transmissive TFT-TN displays which are generally conventional, the use of liquid crystals of low birefringence (Δn) is necessary in order to achieve low optical retardation ($d \cdot \Delta n$). This low optical retardation results in usually acceptably low viewing-angle dependence of the contrast (cf. DE 30 22 818). In reflective displays, the use of liquid
20 crystals of low birefringence is even more important than in transmissive displays since the effective layer thickness through which the light passes is approximately twice as large in reflective displays as in transmissive displays having the same layer thickness.

25 For TV and video applications, displays having fast response times are required in order to be able to reproduce multimedia content, such as, for example, films and video games, in near-realistic quality. Such short response times can be achieved, in particular, if liquid-crystal media having low values for the viscosity, in particular the rotational viscosity γ_1 ,
30 and having high optical anisotropy (Δn) are used.

In order to achieve 3D effects by means of shutter spectacles, use is made of, in particular, fast-switching mixtures having low rotational viscosities and correspondingly high optical anisotropy (Δn). Electro-
35 optical lens systems by means of which a 2-dimensional representation of a display can be converted into a 3-dimensional autostereoscopic

representation can be achieved using mixtures having high optical anisotropy (Δn).

5 In the case of TN (Schadt-Helfrich) cells, media are desired which facilitate the following advantages in the cells:

- extended nematic phase range (in particular down to low temperatures)
- 10 - the ability to switch at extremely low temperatures (outdoor use, automobiles, avionics)
- increased resistance to UV radiation (longer lifetime)
- low threshold voltage.

15 The media available from the prior art do not enable these advantages to be achieved while simultaneously retaining the other parameters.

20 In the case of supertwisted (STN) cells, media are desired which facilitate greater multiplexability and/or lower threshold voltages and/or broader nematic phase ranges (in particular at low temperatures). To this end, a further widening of the available parameter latitude (clearing point, smectic-nematic transition or melting point, viscosity, dielectric parameters, elastic parameters) is urgently desired.

25 One of the most important properties of modern LCDs is correct reproduction of moving images. If the response speed of the liquid-crystalline medium used is too slow, this causes undesired artefacts in the display of such content. The physical parameters which essentially determine the
30 response time of a liquid-crystal mixture are the rotational viscosity γ_1 and the elastic constants. The latter are also particularly important for ensuring a good black state of the LCD. In general, however, it is observed that the clearing point of the mixture and thus the rotational viscosity of the mixture is also increased with an increase in the elastic constants, meaning that
35 an improvement in the response time is not possible. In particular in the case of LC displays for TV and video applications (for example LCD TVs,

- monitors, PDAs, notebooks, games consoles), a significant reduction in the response times is desired. A reduction in the layer thickness d ("cell gap") of the LC medium in the LC cell theoretically results in faster response times, but requires LC media having higher birefringence Δn in order to ensure an adequate optical retardation ($d \cdot \Delta n$). However, the LC materials of high birefringence known from the prior art generally also have high rotational viscosity at the same time, which in turn has an adverse effect on the response times.
- There is thus still a great need for liquid-crystalline media having good reliability properties, such as, for example, high VHR (voltage holding ratio), which do not exhibit these properties or only do so to a lesser extent.
- The invention is based on the object of providing media, in particular for IPS, FFS, HB (= high brightness)-FFS, PS (= polymer stabilised)-FFS, PS-IPS displays of this type, which have the desired properties indicated above and do not exhibit the disadvantages indicated above or only do so to a reduced extent. In particular, the LC media should have fast response times and low rotational viscosities at the same time as relatively high birefringence. In addition, the LC media should have a high clearing point and very good low-temperature stability (LTS).
- According to the present application, however, the IPS or the FFS effect with dielectrically positive liquid crystalline media in a homogeneous alignment are preferred.
- Liquid crystalline media having a positive dielectric anisotropy for IPS and FFS displays have already been disclosed. In the following some examples will be given.
- WO 2012/079676 A1 discloses liquid crystalline media with highly positive dielectric anisotropy. The publication WO 2013/182271 A1 discloses liquid crystalline media with a positive dielectric anisotropy, which is additionally stabilized by Tinuvin 770®. Polymerizable piperidine derivatives as

disclosed herein have been proposed as additives in polymerizable liquid crystalline media in WO 2016/116119 A1.

- 5 Industrial application of this effect in electro-optical display elements requires LC phases which have to meet a multiplicity of requirements. Particularly important here are chemical resistance to moisture, air and physical influences, such as heat, radiation in the infrared, visible and ultraviolet regions, and direct (DC) and alternating (AC) electric fields.
- 10 The term MLC displays here encompasses any matrix display having integrated non-linear elements, i.e., besides the active matrix, also displays with passive elements, such as varistors or diodes (MIM = metal-insulator-metal).
- 15 MLC displays of this type are particularly suitable for TV applications, monitors and notebooks or for displays with a high information density, for example in automobile manufacture or aircraft construction. Besides problems regarding the angle dependence of the contrast and the response times, difficulties also arise in MLC displays due to insufficiently high specific resistance 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
- 20 Matrix LCD Controlled by Double Stage Diode Rings, pp. 141 ff., Paris; STROMER, M., Proc. Eurodisplay 84, Sept. 1984: Design of Thin Film
- 25 Transistors for Matrix Addressing of Television Liquid Crystal Displays, pp. 145 ff., Paris]. With decreasing resistance, the contrast of an MLC display deteriorates. Since the specific resistance of the liquid-crystal mixture generally drops over the life of an MLC display owing to interaction with the inside surfaces of the display, a high (initial) resistance is very important
- 30 for displays that have to have acceptable resistance values over a long operating period.

Media of this type can be used, in particular, for electro-optical displays having active-matrix addressing for IPS - or FFS displays.

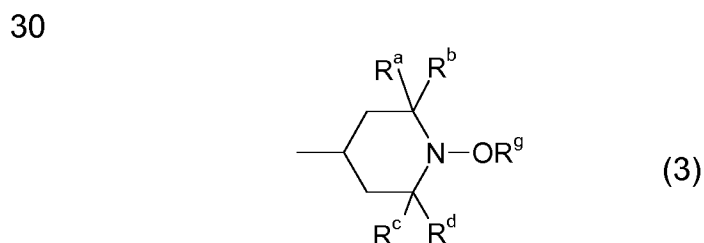
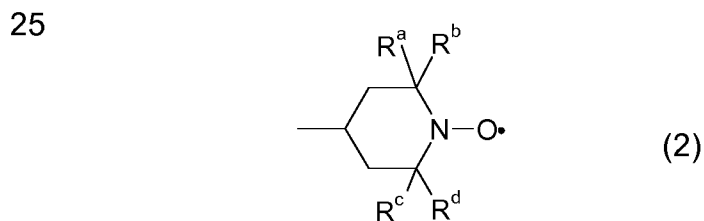
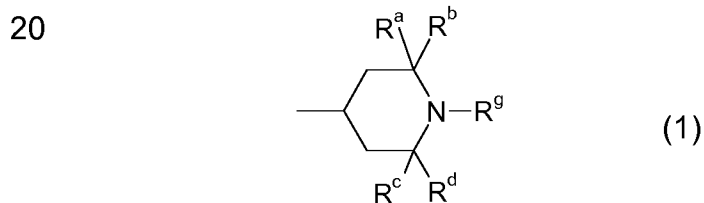
It has now been found that this object can be achieved if LC media comprising one or more compounds of the formula I are used.

Surprisingly, it has been found that it is possible to achieve liquid-crystal displays which have, in particular in IPS and FFS displays, a low threshold voltage with short response times, a sufficiently broad nematic phase, favourable birefringence (Δn) and, at the same time, a high transmission, good stability to decomposition by heating and by UV exposure, and a stable, high VHR if use is made of nematic liquid-crystal mixtures which comprise at least one compound of formula I as below, or a polymer comprising its polymerized form,



wherein the groups, independently of each other, and on each occurrence identically or differently, have the following meanings

T a group selected from the following formulae



	R ^g	H or straight chain or branched alkyl or alkoxyalkyl with 1 to 10 C atoms, preferably with 1 to 6 C atoms, very preferably with 1 to 4 C atoms, or benzyl, most preferably H,
5	R ^a , R ^b , R ^c , R ^d	straight chain or branched alkyl with 1 to 10 C atoms, preferably with 1 to 6 C atoms, very preferably with 1 to 4 C atoms,
10	P	vinylloxy, acrylate, methacrylate, fluoroacrylate, chloroacrylate, oxetane or epoxy, preferably acrylate, methacrylate, fluoroacrylate, chloroacrylate, and more preferably acrylate or methacrylate, most preferably methacrylate,
15	Sp	a spacer group or a single bond,
20	A ¹ , A ²	an alicyclic, heterocyclic, aromatic or heteroaromatic group with 4 to 30 ring atoms, which may also contain fused rings, and is optionally substituted by one or more groups L or R-(A ³ -Z ³) _{m2} -, and one of A ¹ and A ² may also denote a single bond,
	A ³	an alicyclic, heterocyclic, aromatic or heteroaromatic group with 4 to 30 ring atoms, which may also contain fused rings, and is optionally substituted by one or more groups L,
25	Z ¹	-O-, -S-, -CO-, -CO-O-, -O-CO-, -O-CO-O-, -OCH ₂ -, -CH ₂ O-, -SCH ₂ -, -CH ₂ S-, -CF ₂ O-, -OCF ₂ -, -CF ₂ S-, -SCF ₂ -, -(CH ₂) _n -, -CF ₂ CH ₂ -, -CH ₂ CF ₂ -, -(CF ₂) _n -, -CH=CH-, -CF=CF-, -CH=CF-, -CF=CH-, -C≡C-, -CH=CH-CO-O-, -O-CO-CH=CH-, -CH ₂ -CH ₂ -CO-O-, -O-CO-CH ₂ -CH ₂ -, -CR ⁰⁰ R ⁰⁰⁰ -, or a single bond,
30		with the proviso that, if m ₁ is 0, Z ¹ is a single bond,
35	Z ² , Z ³	-O-, -S-, -CO-, -CO-O-, -O-CO-, -O-CO-O-, -OCH ₂ -, -CH ₂ O-, -SCH ₂ -, -CH ₂ S-, -CF ₂ O-, -OCF ₂ -, -CF ₂ S-, -SCF ₂ -, -(CH ₂) _n -, -CF ₂ CH ₂ -, -CH ₂ CF ₂ -, -(CF ₂) _n -, -CH=CH-, -CF=CF-, -CH=CF-, -CF=CH-, -C≡C-, -CH=CH-CO-O-, -O-CO-CH=CH-, -CH ₂ -CH ₂ -CO-O-, -O-CO-CH ₂ -CH ₂ -, -CR ⁰⁰ R ⁰⁰⁰ -, or a single bond,

R^{00} , R^{000} H or alkyl having 1 to 12 C atoms,

5 R P-Sp-, H, F, Cl, CN, or straight chain, branched or cyclic alkyl
 having 1 to 25 C atoms, wherein one or more non-adjacent
 CH₂-groups are optionally replaced by -O-, -S-, -CO-, -CO-O-, -
 O-CO-, -O-CO-O- in such a manner that O- and/or S-atoms are
 not directly connected with each other, and wherein one or
10 more H atoms are each optionally replaced by F, Cl or P-Sp-, or
 a group T,

 L P-Sp-, F, Cl, CN, or straight chain, branched or cyclic alkyl
 having 1 to 25 C atoms, wherein one or more non-adjacent CH₂-
 groups are optionally replaced by -O-, -S-, -CO-, -CO-O-, -O-CO-
15 , -O-CO-O- in such a manner that O- and/or S-atoms are not
 directly connected with each other, and wherein one or more H
 atoms are each optionally replaced by F, Cl or P-Sp-, or a group
 selected from formula 1, 2 and 3,

20 m1 0, 1, 2, 3 or 4,

 m2 0, 1, 2, 3 or 4, and

25 n 1, 2, 3 or 4.

 The invention relates to a liquid-crystalline medium having a nematic
 phase and a dielectric anisotropy ($\Delta\epsilon$) of 1.5 or more, characterised in that
 it comprises one or more compounds of the formula I as described above
 and below or comprises a polymer comprising one or more compounds of
30 the formula I polymerized form.

 The invention more specifically relates to an liquid-crystalline medium
 comprising

35 - a polymerisable component A) comprising one or more polymerisable
 compounds, at least one of which is a compound of formula I, and

- a liquid-crystalline component B), hereinafter also referred to as "LC host mixture", comprising, preferably consisting of, one or more mesogenic or liquid-crystalline compounds.

5 The liquid-crystalline component B) of an liquid-crystalline medium according to the present invention is hereinafter also referred to as "LC host mixture", and preferably comprises one or more, preferably at least two mesogenic or LC compounds selected from low-molecular-weight compounds which are unpolymerisable.

10

The invention furthermore relates to an liquid-crystalline medium as described above and below, wherein the LC host mixture or component B) comprises at least one mesogenic or LC compound comprising an alkenyl group.

15

The invention furthermore relates to an liquid-crystalline medium or LC display as described above and below, wherein the compounds of formula I, or the polymerisable compounds of component A), are polymerised.

20 The invention furthermore relates to a process for preparing an liquid-crystalline medium as described above and below, comprising the steps of mixing one or more mesogenic or LC compounds, or an LC host mixture or LC component B) as described above and below, with one or more compounds of formula I, and optionally with further LC compounds and/or
25 additives.

Media of this type can be used, in particular, for electro-optical displays having active-matrix addressing for IPS - or FFS displays.

30 The media according to the present invention preferably additionally comprise a one or more compounds selected from the group of compounds of formulae II and III, preferably one or more compounds of formula II, more preferably in addition one or more compounds of formula III and, most preferably, additionally one or more compounds selected
35 from the group of the compounds of formulae IV and V.

5 The mixtures according to the invention exhibit very broad nematic phase ranges with clearing points $\geq 70^{\circ}\text{C}$, relatively high values for the voltage holding ratio (VHR), very favourable values for the capacitive threshold and at the same time good low-temperature stabilities at -20°C and -30°C ,
10 as well as very low rotational viscosities. The mixtures according to the invention are furthermore distinguished by a good ratio of clearing point and rotational viscosity and by a relatively high positive dielectric anisotropy. Remarkably, the reliability of the mixtures is improved. Little image burning is observed. The voltage holding ratio is high even after
15 extended use or, similarly after standard ageing tests like accelerated light load, heat or UV test.

20 Preferably the liquid-crystalline media according to the present invention, on the one hand, have a value of the dielectric anisotropy of 2 or more, preferably of 3.5 or more preferably of 4.5 or more. At the other hand, they preferably have a dielectric anisotropy of 25 or less.

25 The liquid crystalline media according to the present invention in a preferred embodiment have a positive dielectric anisotropy, preferably in the range from 2.0 or more to 25 or less, more preferably in the range from 3.0 or more to 22 or less and, most preferably in the range from 8.0 or more to 20 or less.

30 The compounds of formula I are preferably employed in the liquid crystalline media in a concentration in the range from 0.0005 % by weight to 2 %, more preferably in the range from 0.001 % to 1 %, particularly preferably in the range from 0.005 % to 0.05 %, all % by weight.

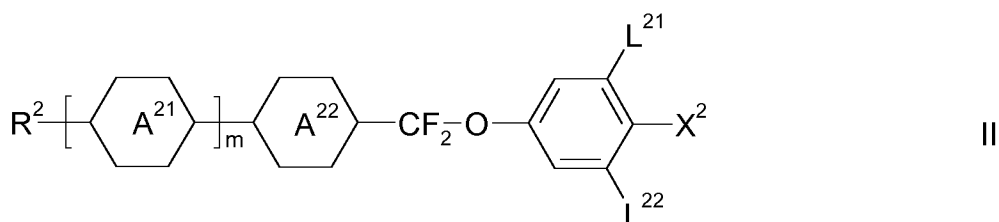
35 The total content of polymerizable or polymerized components in the liquid crystalline medium according to the invention is preferably below 0.1 % by weight, more preferably below 0.05 %, and most preferably lower than 0.02 % (200 ppm).

The liquid crystalline medium preferably comprises

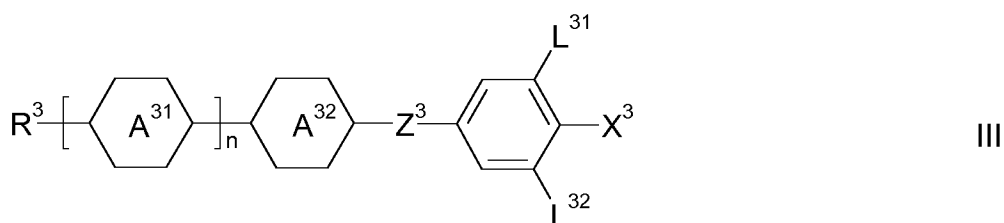
- 35 a) one or more compounds of formula I,

- b) one or more dielectrically positive compounds selected from the group of compounds of formulae II and III, preferably of compounds having a dielectric anisotropy of greater than 3 each:

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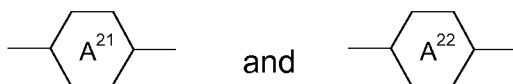


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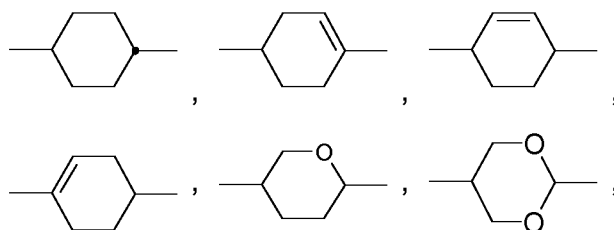
- 20 R^2 denotes alkyl, alkoxy, fluorinated alkyl or fluorinated alkoxy having 1 to 7 C atoms, alkenyl, alkenyloxy, alkoxyalkyl or fluorinated alkenyl having 2 to 7 C atoms and preferably alkyl or alkenyl,

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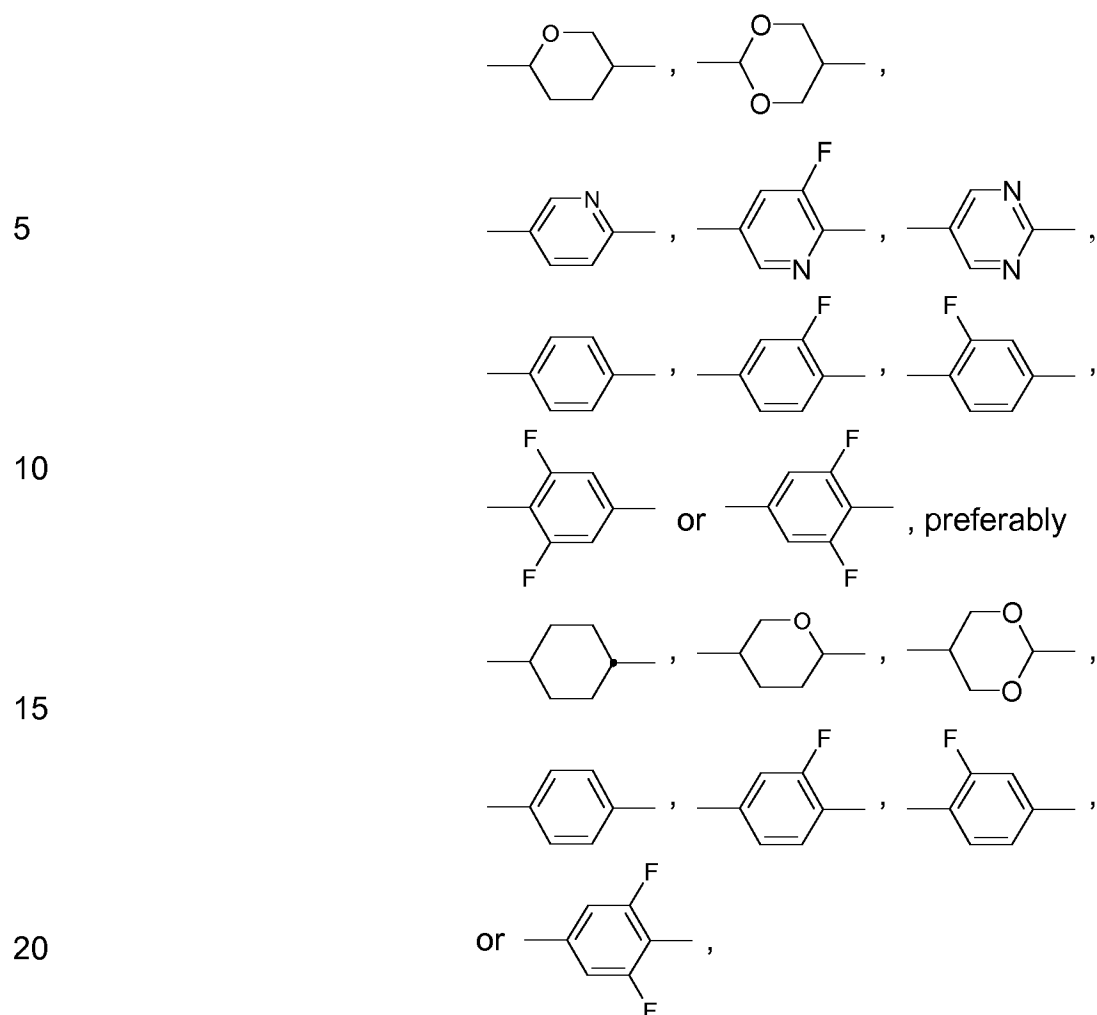


on each appearance, independently of one another, denote

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L^{21} and L^{22} denote H or F, preferably L^{21} denotes F,

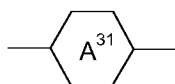
25 X² denotes halogen, halogenated alkyl or alkoxy having 1 to 3 C atoms or halogenated alkenyl or alkenyloxy having 2 or 3 C atoms, preferably F, Cl, -OCF₃, -O-CH₂CF₃, -O-CH=CH₂, -O-CH=CF₂ or -CF₃, very preferably F, Cl, CF₃, -O-CH=CF₂ or -OCF₃,

m denotes 0, 1, 2 or 3, preferably 1 or 2 and particularly preferably 1,

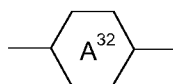
35 R³ denotes alkyl, alkoxy, fluorinated alkyl or fluorinated alkoxy having 1 to 7 C atoms, alkenyl, alkenyloxy,

alkoxyalkyl or fluorinated alkenyl having 2 to 7 C atoms
and preferably alkyl or alkenyl,

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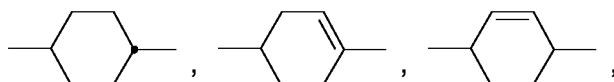


and

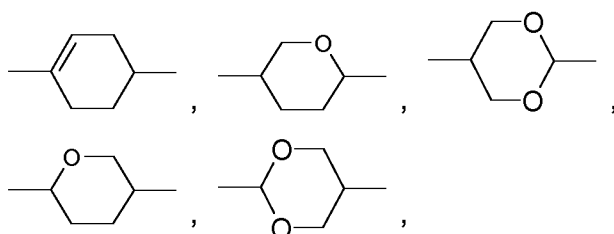


on each appearance, independently of one another, are

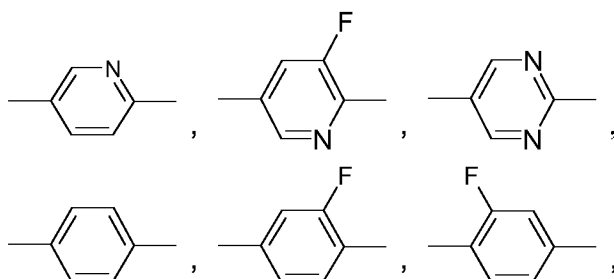
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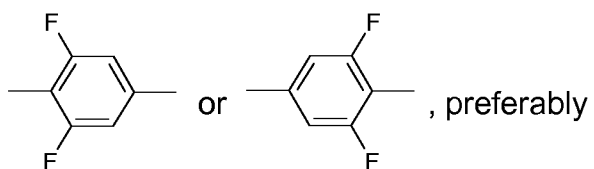
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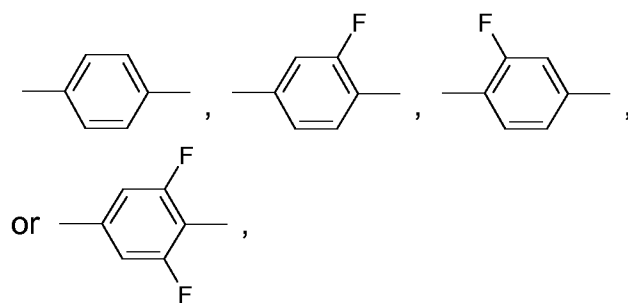
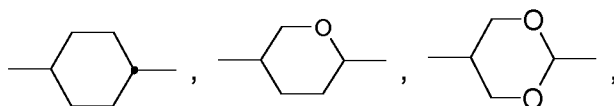
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35

L^{31} and L^{32} , independently of one another, denote H or F, preferably L^{31} denotes F,

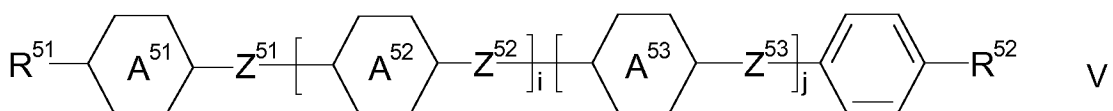
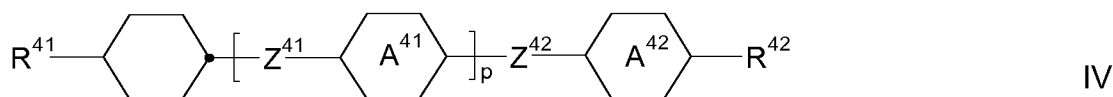
5 X^3 denotes halogen, halogenated alkyl or alkoxy having 1 to 3 C atoms or halogenated alkenyl or alkenyloxy having 2 or 3 C atoms, F, Cl, $-OCF_3$, $-OCHF_2$, $-O-CH_2CF_3$, $-O-CH=CF_2$, $-O-CH=CH_2$ or $-CF_3$, very preferably F, Cl, $-O-CH=CF_2$, $-OCHF_2$ or $-OCF_3$,

10 Z^3 denotes $-CH_2CH_2-$, $-CF_2CF_2-$, $-COO-$, *trans*- $CH=CH-$, *trans*- $CF=CF-$, $-CH_2O-$ or a single bond, preferably $-CH_2CH_2-$, $-COO-$, *trans*- $CH=CH-$ or a single bond and very preferably $-COO-$, *trans*- $CH=CH-$ or a single bond, and

15 n denotes 0, 1, 2 or 3, preferably 1, 2 or 3 and particularly preferably 1, and

and

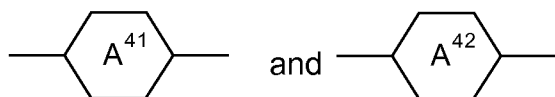
20 c) optionally one or more dielectrically neutral compounds selected from the group of formulae IV and V:



30 in which

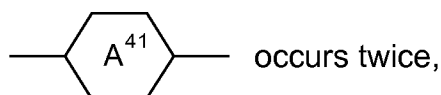
R^{41} and R^{42} , independently of one another, have the meaning indicated above for R^2 under formula II, preferably R^{41} denotes alkyl and R^{42} denotes alkyl or alkoxy or R^{41} denotes alkenyl and R^{42} denotes alkyl,

35



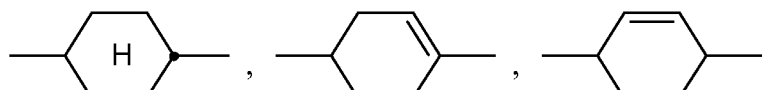
independently of one another and, if

5

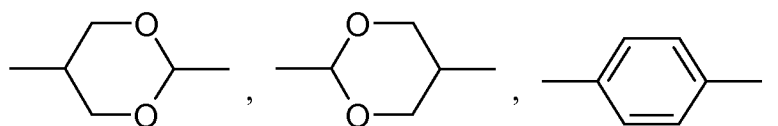
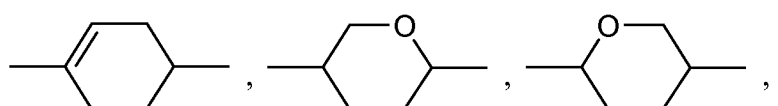


also these independently of one another, denote

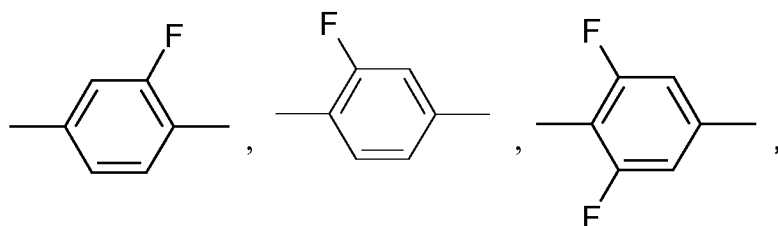
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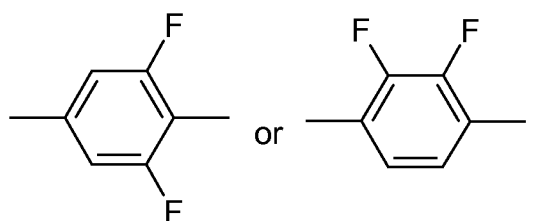
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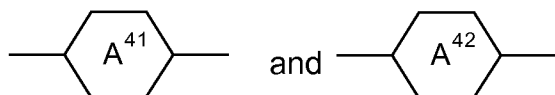
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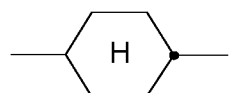


preferably one or more of



denotes or denote,

30



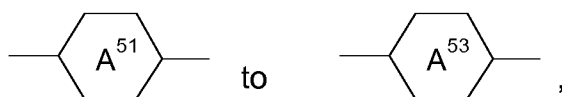
Z^{41} and Z^{42} , independently of one another and, if Z^{41} occurs twice, also
 these independently of one another,
 denote $-CH_2CH_2-$, $-COO-$, *trans*- $CH=CH-$, *trans*-
 $CF=CF-$, $-CH_2O-$, $-CF_2O-$, $-C\equiv C-$ or a single bond,

35

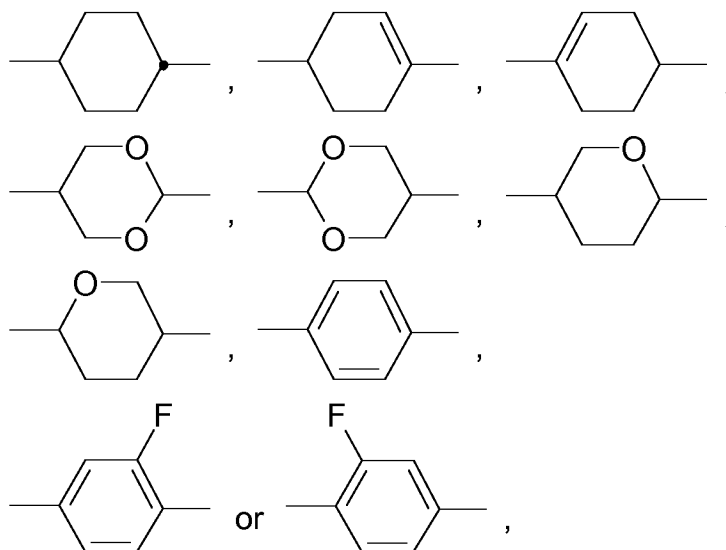
preferably one or more thereof denotes/denote a single bond, and

p denotes 0, 1 or 2, preferably 0 or 1, and

R^{51} and R^{52} , independently of one another, have one of the meanings given for R^{41} and R^{42} and preferably denote alkyl having 1 to 7 C atoms, preferably *n*-alkyl, particularly preferably *n*-alkyl having 1 to 5 C atoms, alkoxy having 1 to 7 C atoms, preferably *n*-alkoxy, particularly preferably *n*-alkoxy having 2 to 5 C atoms, alkoxyalkyl, alkenyl or alkenyloxy having 2 to 7 C atoms, preferably having 2 to 4 C atoms, preferably alkenyloxy,



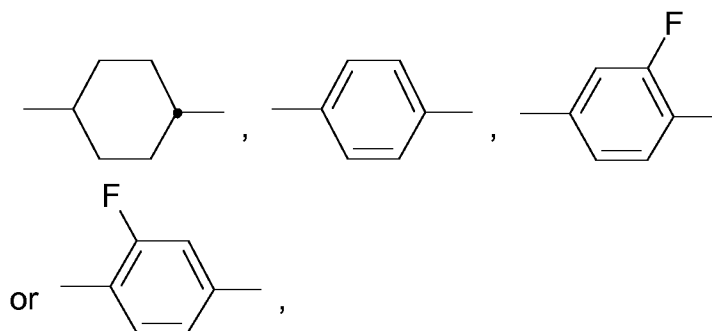
if present, each, independently of one another, denote



preferably

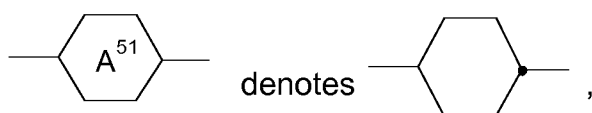
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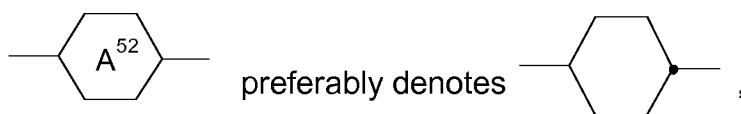
preferably

10



15

and, if present,



20

Z^{51} to Z^{53} each, independently of one another, denote $-\text{CH}_2-\text{CH}_2-$, $-\text{CH}_2-\text{O}-$, $-\text{CH}=\text{CH}-$, $-\text{C}\equiv\text{C}-$, $-\text{COO}-$ or a single bond, preferably $-\text{CH}_2-\text{CH}_2-$, $-\text{CH}_2-\text{O}-$ or a single bond and particularly preferably a single bond,

25

i and j each, independently of one another, denote 0 or 1,

$(i + j)$ preferably denotes 0, 1 or 2, more preferably 0 or 1 and, most preferably, 1.

30

The liquid-crystalline media in accordance with the present application preferably have a nematic phase.

35

Throughout this application and especially for the definition of R^1 alkyl means an alkyl group, which may be straight-chain or branched. Each of

these radicals is preferably straight-chain and preferably has 1, 2, 3, 4, 5, 6, 7 or 8 C atoms and is accordingly preferably methyl, ethyl, *n*-propyl, *n*-butyl, *n*-pentyl, *n*-hexyl or *n*-heptyl.

- 5 In case alkyl means a branched alkyl group it preferably means 2-alkyl, 2-methylalkyl or 2-(2-ethyl)-alkyl, preferably 2-butyl (=1-methylpropyl), 2-methylbutyl, 2-methylpentyl, 3-methylpentyl, 2-ethylhexyl, 2-propylpentyl, in particular 2-methylbutyl, 2-methylbutoxy 4-methylhexyl, 2-hexyl, 2-octyl, 2-nonyl, 2-decyl and 2-dodecyl. Most preferred of these groups are 2-
10 hexyl and 2-octyl.

- Respective branched groups, especially for R¹, which lead to chiral compounds are also called chiral groups in this application. Particularly preferred chiral groups are 2-alkyl, 2-alkoxy, 2-methylalkyl, 2-methylalkoxy, 2-
15 fluoroalkyl, 2-fluoroalkoxy, 2-(2-ethin)-alkyl, 2-(2-ethin)-alkoxy, 1,1,1-trifluoro-2-alkyl and 1,1,1-trifluoro-2-alkoxy.

- Particularly preferred chiral groups are 2-butyl (=1-methylpropyl), 2-methylbutyl, 2-methylpentyl, 3-methylpentyl, 2-ethylhexyl, 2-propylpentyl, in particular 2-methylbutyl, 2-methylbutoxy, 2-methylpentoxy, 3-
20 methylpentoxy, 2-ethylhexoxy, 1-methylhexoxy, 2-octyloxy, 2-oxa-3-methylbutyl, 3-oxa-4-methylpentyl, 4-methylhexyl, 2-hexyl, 2-octyl, 2-nonyl, 2-decyl, 2-dodecyl, 6-methoxyoctoxy, 6-methyloctoxy, 6-methyloctanoyloxy, 5-methylheptyloxycarbonyl, 2-methylbutyryloxy, 3-
25 methylvaleryloxy, 4-methylhexanoyloxy, 2-chloropropionyloxy, 2-chloro-3-methylbutyryloxy, 2-chloro-4-methylvaleryloxy, 2-chloro-3-methylvaleryloxy, 2-methyl-3-oxapentyl, 2-methyl-3-oxahexyl, 1-methoxypropyl-2-oxy, 1-ethoxypropyl-2-oxy, 1-propoxypropyl-2-oxy, 1-butoxypropyl-2-oxy, 2-fluorooctyloxy, 2-fluorodecyloxy, 1,1,1-trifluoro-2-
30 octyloxy, 1,1,1-trifluoro-2-octyl, 2-fluoromethyloctyloxy for example. Very preferred are 2-hexyl, 2-octyl, 2-octyloxy, 1,1,1-trifluoro-2-hexyl, 1,1,1-trifluoro-2-octyl and 1,1,1-trifluoro-2-octyloxy.

- The compounds of formula I are prepared according to WO 2016/116119
35 A1 or are commercially available.

The invention furthermore relates to the use of liquid-crystal mixtures and liquid-crystalline media according to the invention in IPS and FFS displays, in particular the use in IPS displays containing a liquid-crystalline medium, for improving the voltage-holding-ratio.

5

The invention furthermore relates to a liquid-crystal display containing a liquid-crystalline medium according to the invention, in particular an IPS or FFS display, particularly preferably a IPS display.

10

The displays in accordance with the present invention are preferably addressed by an active matrix (active matrix LCDs, AMDs for short), preferably by a matrix of thin-film transistors (TFTs). However, the liquid crystals according to the invention can also be used in an advantageous manner in displays having other known addressing means.

15

The invention furthermore relates to a process for the preparation of a liquid-crystalline medium according to the invention by mixing one or more compounds of formula I with one or more low-molecular-weight liquid-crystalline compounds, or a liquid-crystal mixture and optionally with further liquid-crystalline compounds and/or additives, resulting in a liquid crystalline medium having a nematic phase and a dielectric anisotropy ($\Delta\epsilon$) of 1.5 or more.

20

The following meanings apply above and below:

25

As used herein, the terms "reactive mesogen" and "RM" will be understood to mean a compound containing a mesogenic or liquid-crystalline skeleton, and one or more functional groups attached thereto which are suitable for polymerisation. Such groups are also referred to as "polymerisable group" or "P".

30

Unless stated otherwise, the term "polymerisable compound" as used herein will be understood to mean a polymerisable monomeric compound.

35

As used herein, the term "low-molecular-weight compound" will be understood to mean to a compound that is monomeric and/or is not

prepared by a polymerisation reaction, as opposed to a "polymeric compound" or a "polymer".

5 The term "halogen" refers to fluorine, chlorine or bromine, preferably fluorine or chlorine and in particular to fluorine. The term halogenated is used analogously.

10 As used herein, the term "unpolymerisable compound" will be understood to mean a compound that does not contain a functional group that is suitable for polymerisation under the conditions usually applied for the polymerisation of the RMs.

15 The term "mesogenic group" is known to the person skilled in the art and is described in the literature, and denotes a group which, due to the anisotropy of its attracting and repelling interactions, essentially contributes to causing a liquid-crystalline (LC) phase in low-molecular-weight or polymeric substances. Compounds containing mesogenic groups (mesogenic compounds) do not necessarily have to have a liquid-crystalline phase themselves. It is also possible for mesogenic compounds to exhibit liquid-crystalline phase behaviour only after mixing with other compounds and/or after polymerisation. Typical mesogenic groups are, for example, rigid rod- or disc-shaped units. An overview of the terms and definitions used in connection with mesogenic or liquid-crystalline compounds is given in Pure Appl. Chem. 73(5), 888 (2001) and C. Tschierske, G. Pelzl, S. Diele, Angew. Chem. 2004, 116, 6340-6368.

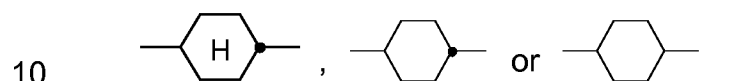
20 The term "spacer group" or "spacer" for short, also referred to as "Sp" above and below, is known to the person skilled in the art and is described in the literature, see, for example, Pure Appl. Chem. 73(5), 888 (2001) and C. Tschierske, G. Pelzl, S. Diele, Angew. Chem. 2004, 116, 6340-6368.

30 Unless indicated otherwise, the term "spacer group" or "spacer" above and below denotes a flexible group which connects the mesogenic group and the polymerisable group(s) to one another in a polymerisable mesogenic compound. Whereas the mesogenic group generally contains rings, the spacer group is generally without ring systems, i.e. is in chain form, where

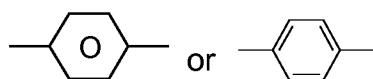
35 the chain may also be branched. The term chain is applied, for example,

to an alkylene group. Substitutions on and in the chain, for example by -O- or -COO-, are generally included. In functional terms, the spacer (the spacer group) is a linker between functional structural parts of a molecule which facilitates a certain spatial flexibility between these parts. In a preferred embodiment a spacer denotes an alkylene (like $-(CH_2)_n-$ and $n=1$ to 10) or alkyleneoxy group, preferably with 2 to 5 carbon atoms.

Above and below,



denote a trans-1,4-cyclohexylene ring, and



denote a 1,4-phenylene ring.

15

For the purposes of this invention, the term "liquid-crystalline medium" is intended to denote a medium which comprises a liquid-crystal mixture and one or more polymerisable compounds (such as, for example, of formula I or reactive mesogens). The term "liquid-crystal mixture" (or "host mixture") is intended to denote a liquid-crystalline mixture which consists exclusively of unpolymerisable, low-molecular-weight compounds, preferably of two or more liquid-crystalline compounds and optionally further additives, such as, for example, chiral dopants or stabilisers.

25

Particular preference is given to liquid-crystal mixtures and liquid-crystalline media which have a nematic phase, in particular at room temperature.

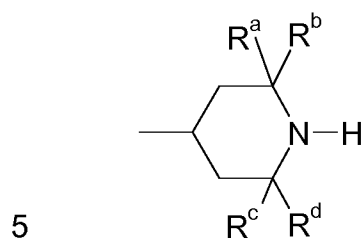
Furthermore, preferred embodiments of the additives of formula I are presented.

30

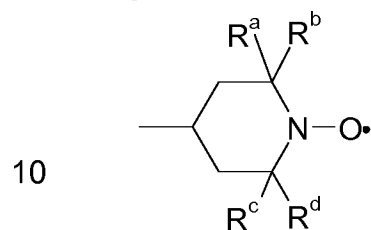
Preferably m_1 in formula I is 0 or 1, most preferably 0.

Further preferred are compounds of formula I selected from the group of compounds of formulae wherein T is a group selected from the formulae

35



or



in which

15 R^a, b, c, d are independently straight chain or branched alkyl with 1 to 10 C atoms.

Preferably Z^1 in formula I denotes -CO-O-, -O-CO- or a single bond, very preferably -CO-O- or a single bond.

20 Preferably Z^2 and Z^3 in formula I denote -CO-O-, -O-CO- or a single bond, very preferably a single bond.

Preferably P in formula I is an acrylate or methacrylate group.

25 Preferably S_p in formula I is a single bond.

30 Preferably A^3 in formula I denotes an aromatic or heteroaromatic group with 6 to 24 ring atoms, which may also contain fused rings, and is optionally substituted by one or more groups L.

Very preferably A^3 in formula I denotes benzene or naphthalene, which is optionally substituted by one or more groups L.

35 Preferably A^1 and A^2 in formula I denote an aromatic or heteroaromatic group with 6 to 24 ring atoms, which may also contain fused rings, and is

optionally substituted by one or more groups L or $R-(A^3-Z^3)_{m2-}$, or A^1 is a single bond.

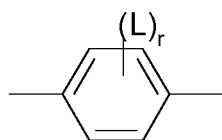
5 Very preferably A^1 and A^2 in formula I denote benzene, cyclohexylene, naphthalene, phenanthrene or anthracene, which is optionally substituted by one or more groups L or $R-(A^3-Z^3)_{m2-}$, or A^1 is a single bond.

10 Preferably $-(A^2-Z^2-A^1)_{m1-}$ in formula I denotes benzene, biphenylene, p-terphenylene (1,4-diphenylbenzene), m-terphenylene (1,3-diphenylbenzene), naphthylene, 2-phenyl-naphthylene, phenanthrene or anthracene, all of which are optionally substituted by one or more groups L.

15 Very preferably $-(A^2-Z^2-A^1)_{m1-}$ denotes biphenylene, p-terphenylene or m-terphenylene, all of which are optionally substituted by one or more groups L.

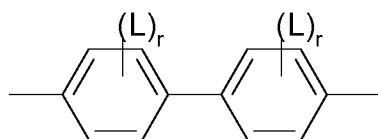
Preferred groups $-(A^2-Z^2-A^1)_{m1-}$ are selected from the following formulae

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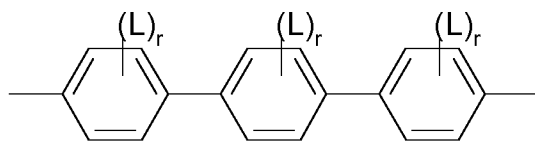
A1

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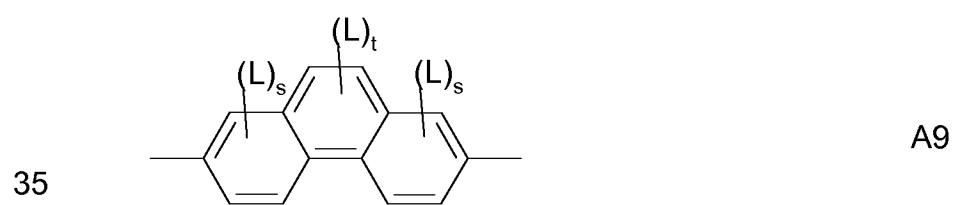
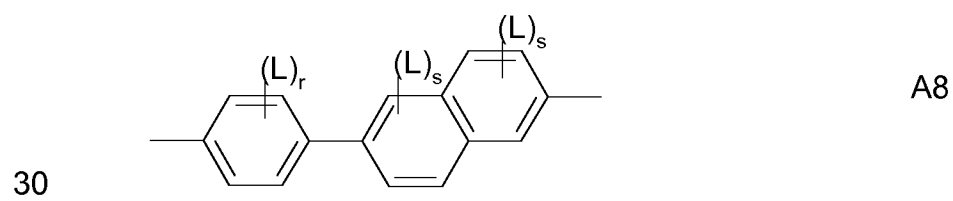
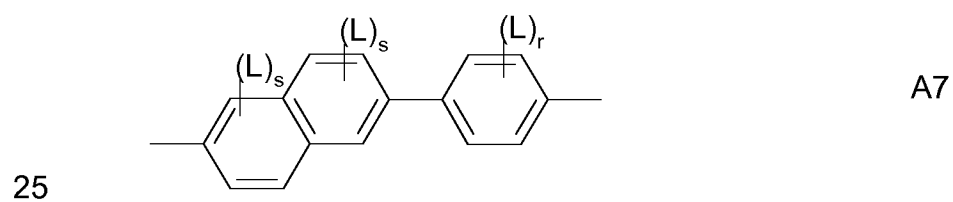
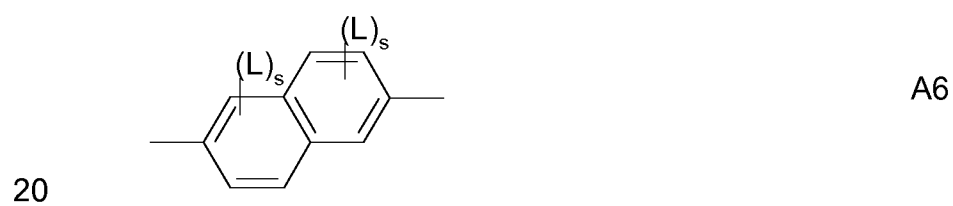
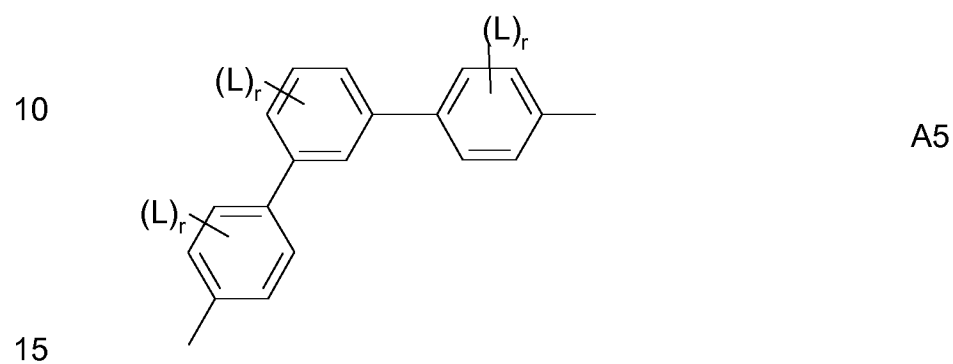
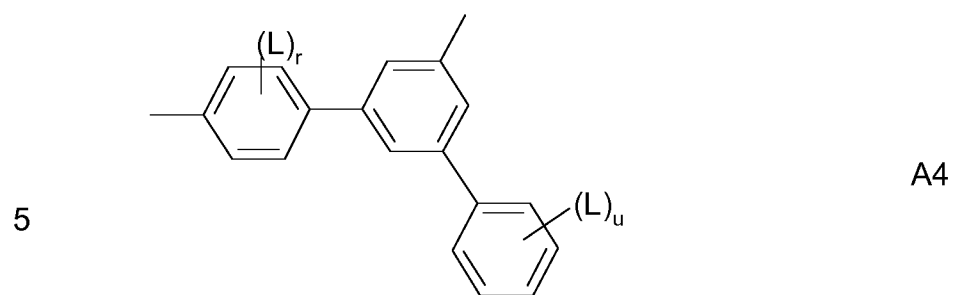
A2

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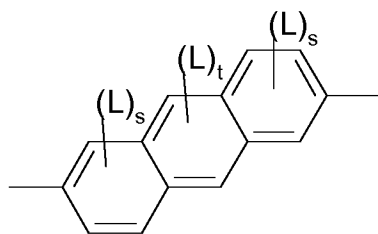


A3

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A10

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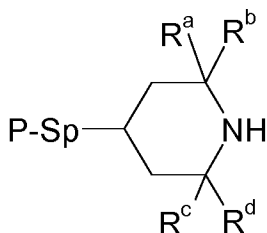
wherein L is as defined in formula I or has one of the preferred meanings as described above and below, r is 0, 1, 2, 3 or 4, s is 0, 1, 2 or 3, t is 0, 1 or 2, and u is 0, 1, 2, 3, 4 or 5.

Particular preference is given to the groups of formula A1, A2, A3, A4 and A5.

15

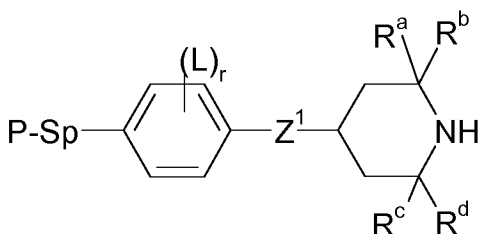
Preferred compounds of formula I are selected from the following subformulae

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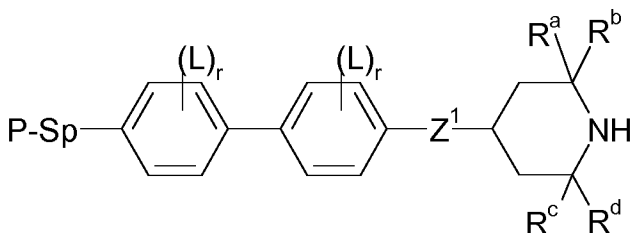
I-1

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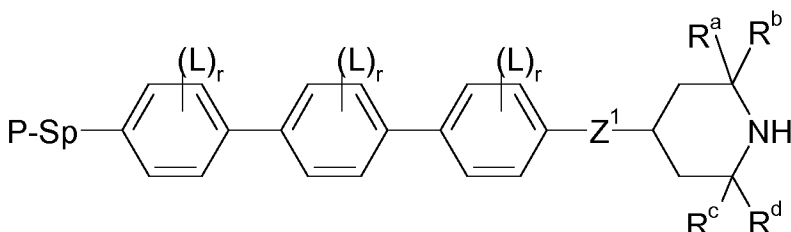
I-2

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I-3

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I-4



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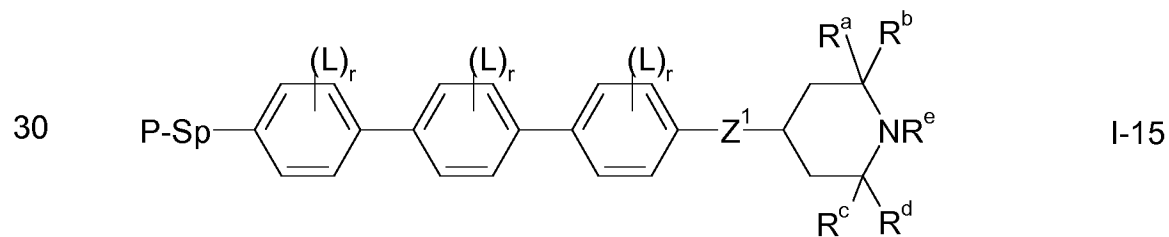
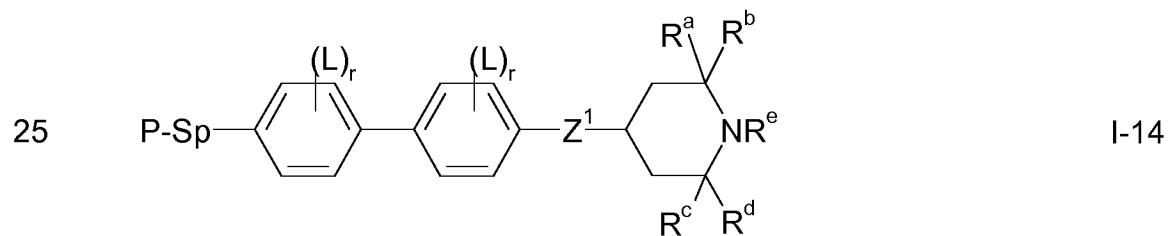
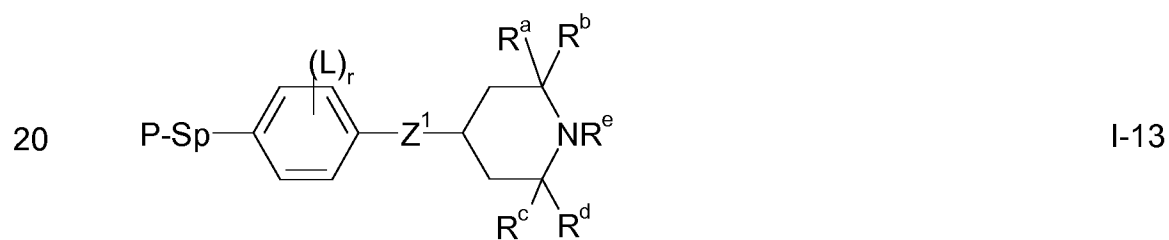
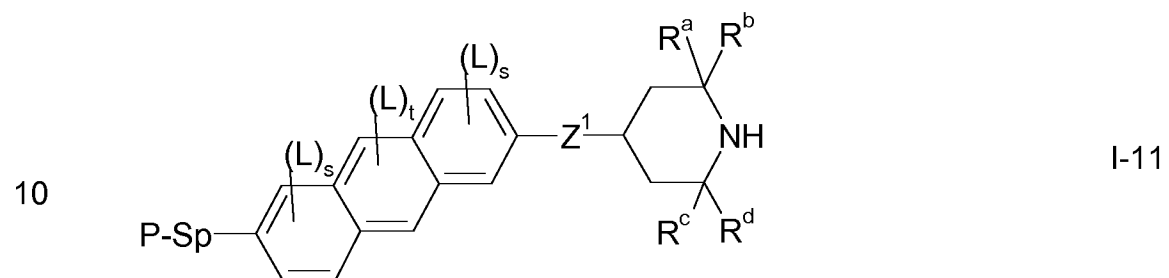
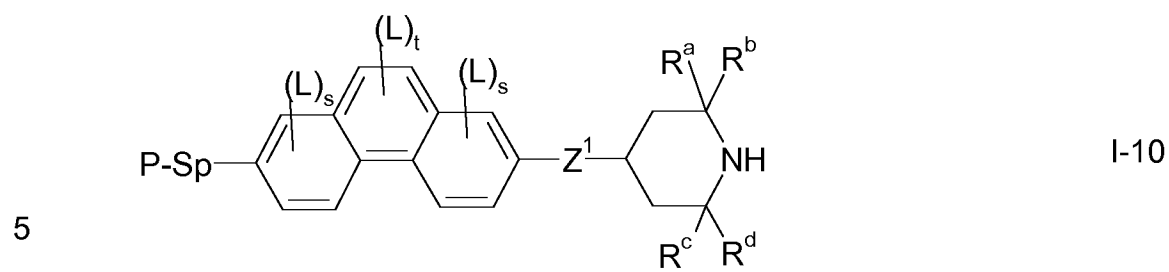
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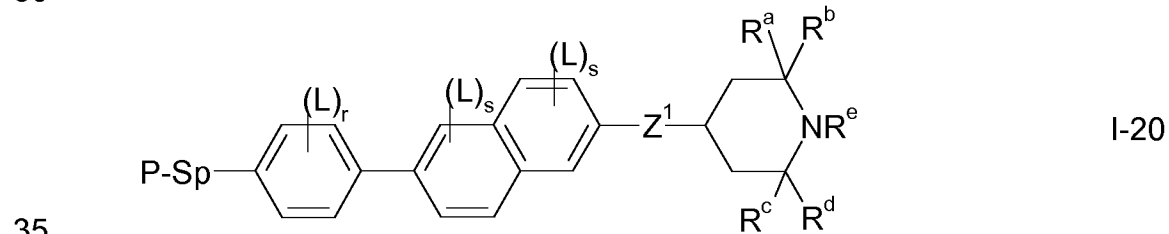
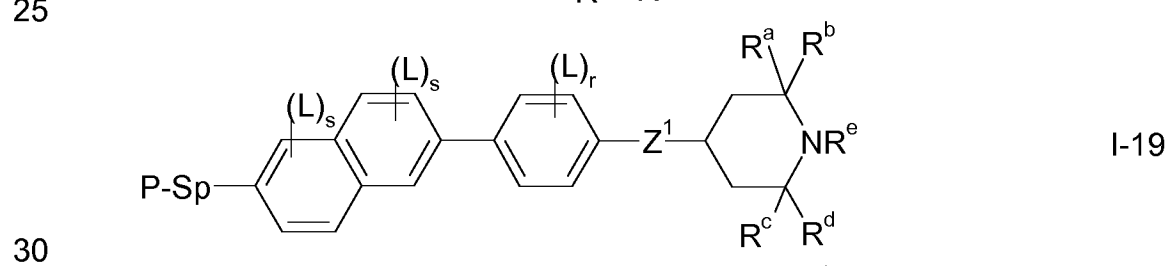
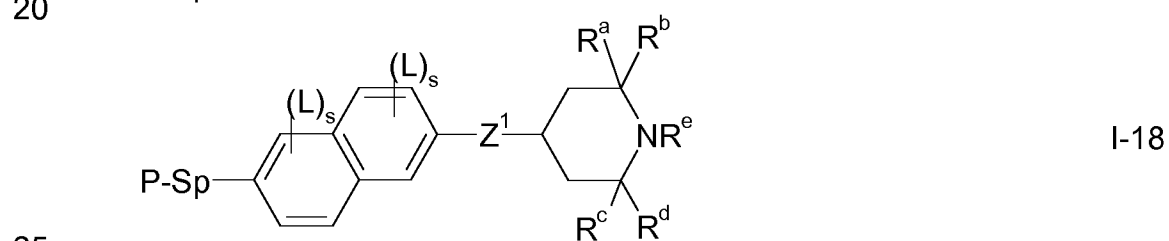
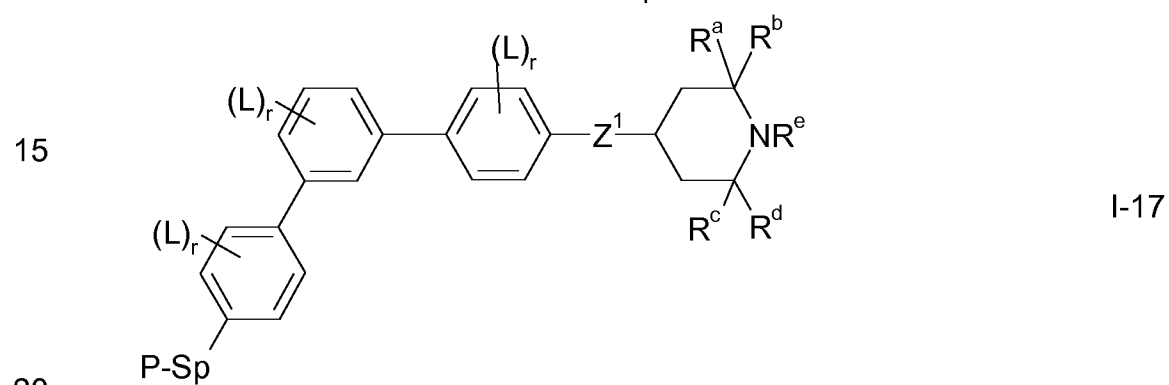
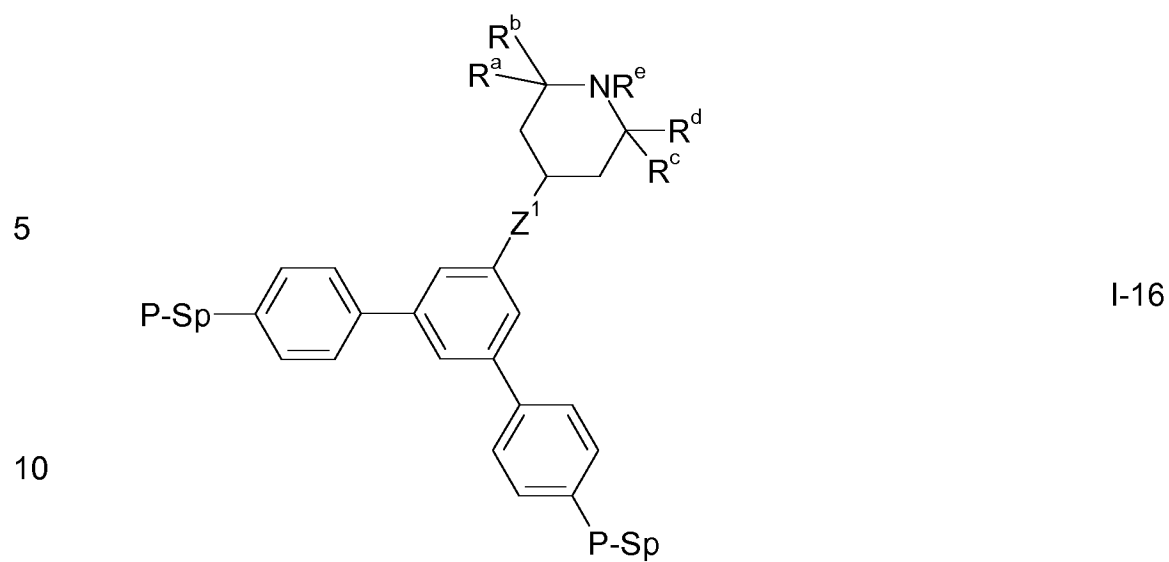


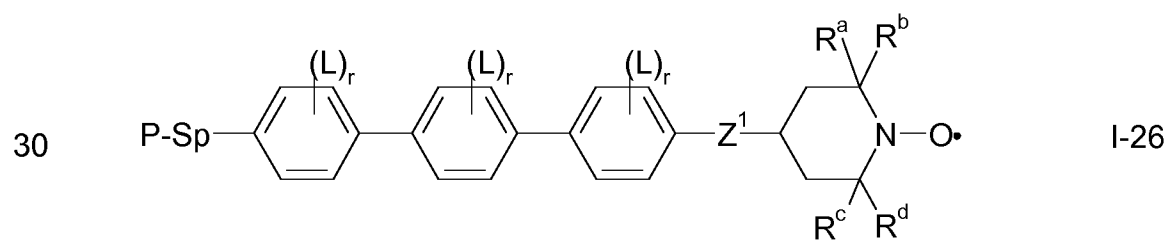
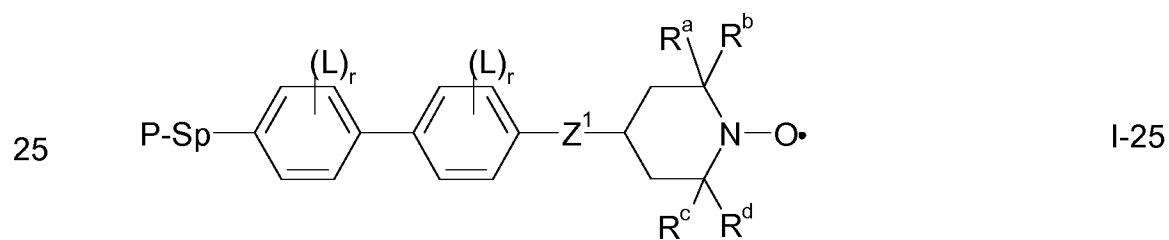
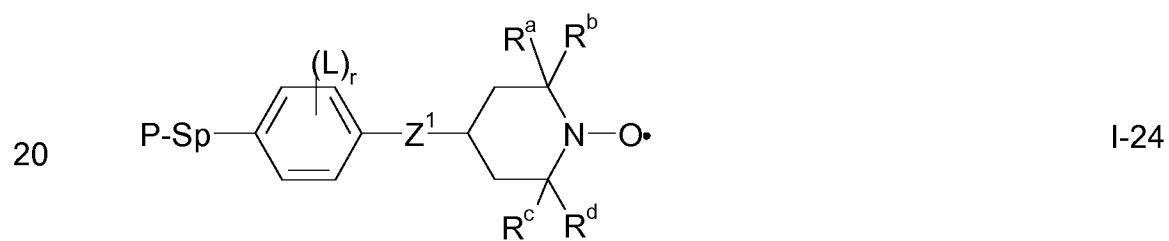
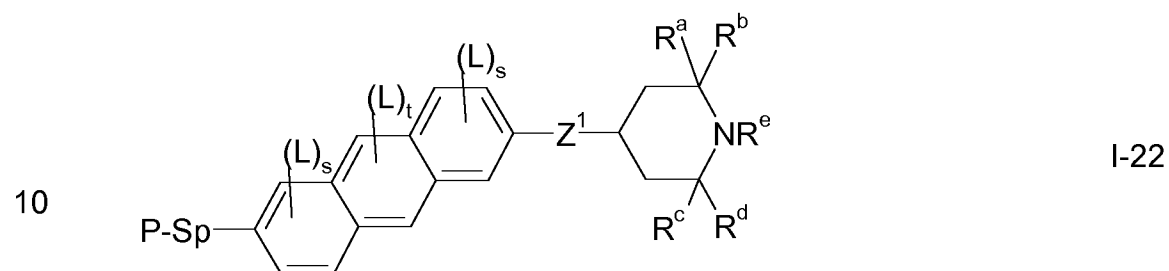
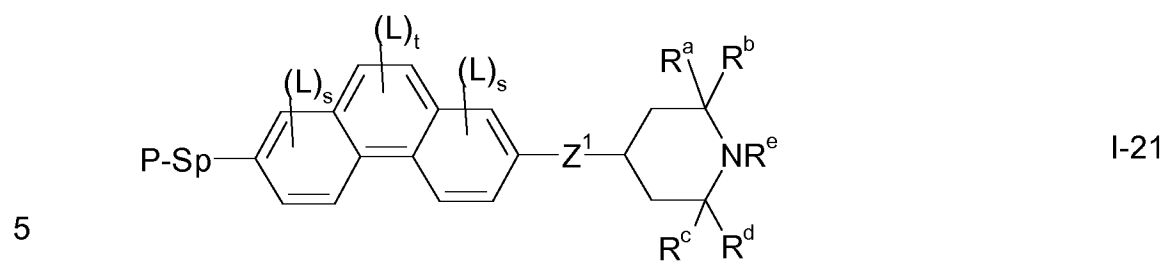
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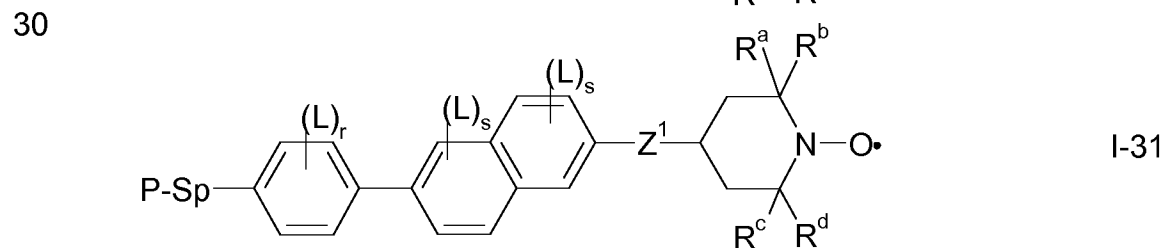
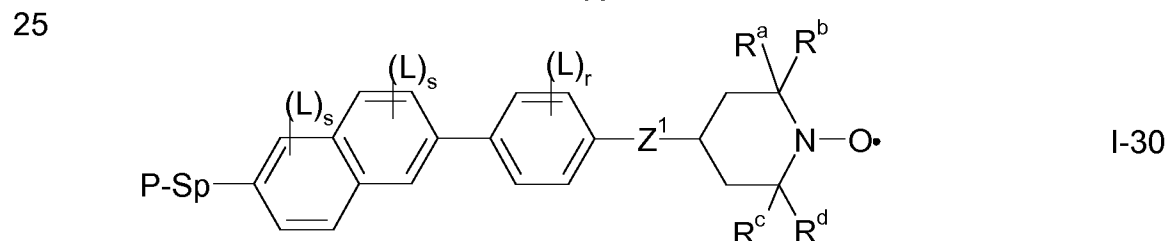
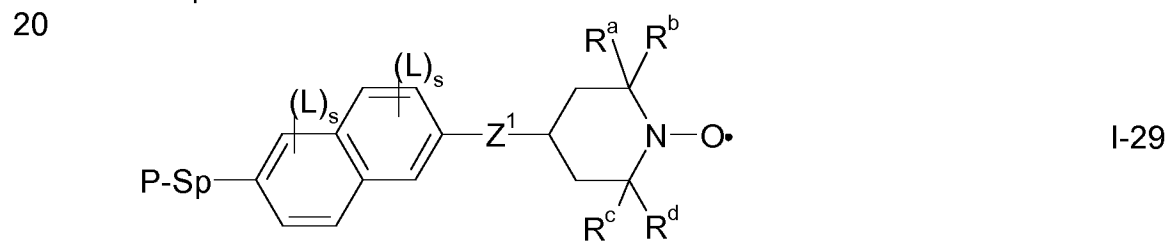
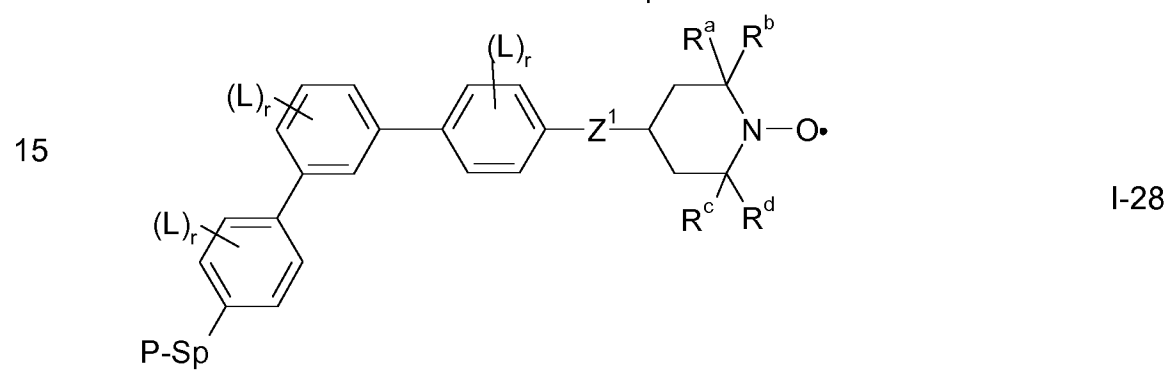
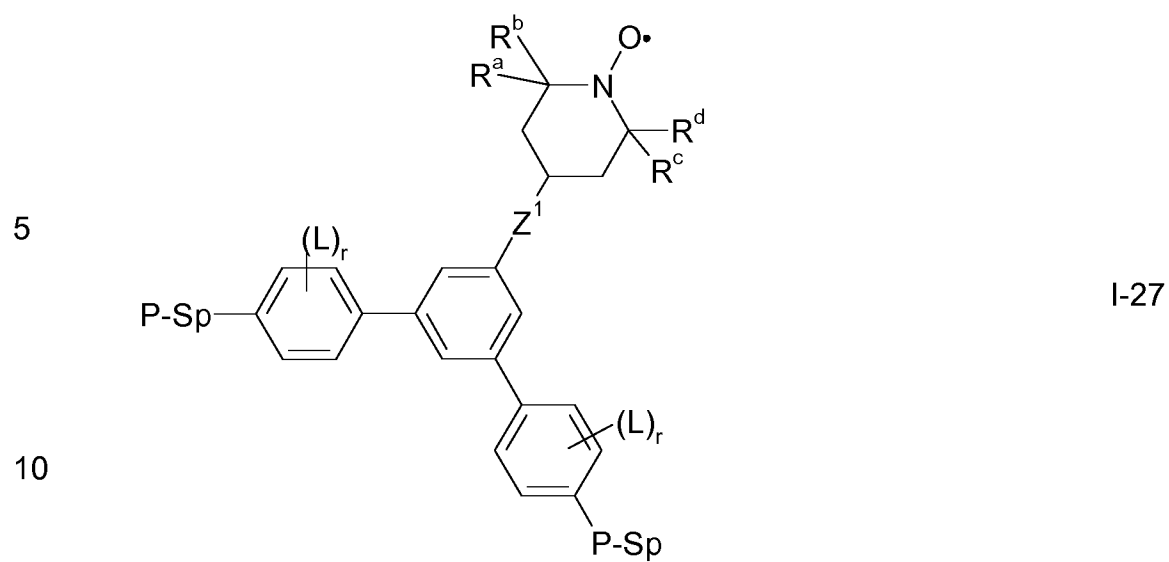


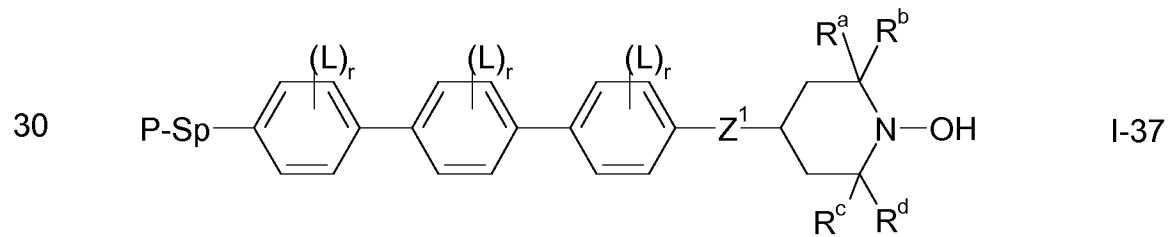
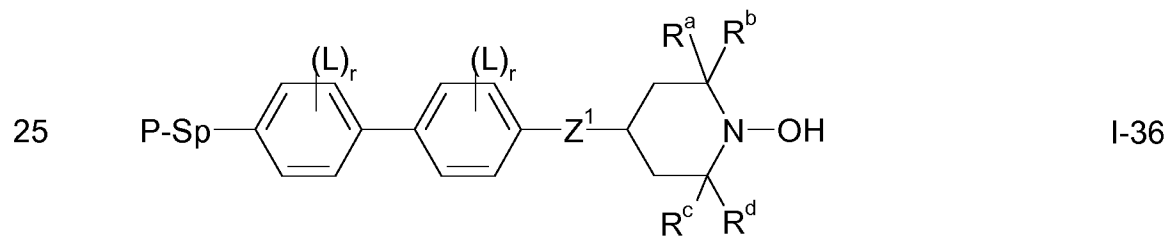
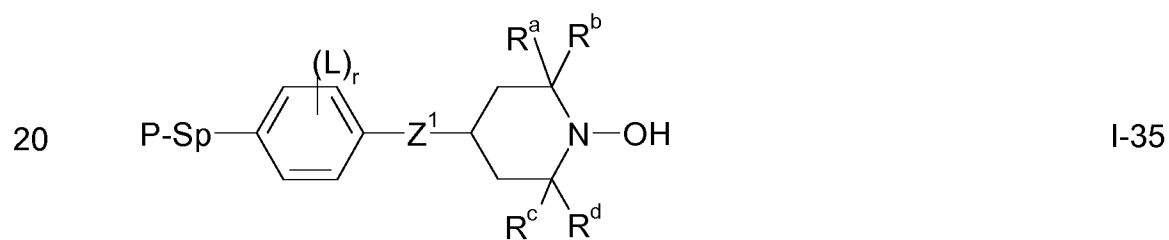
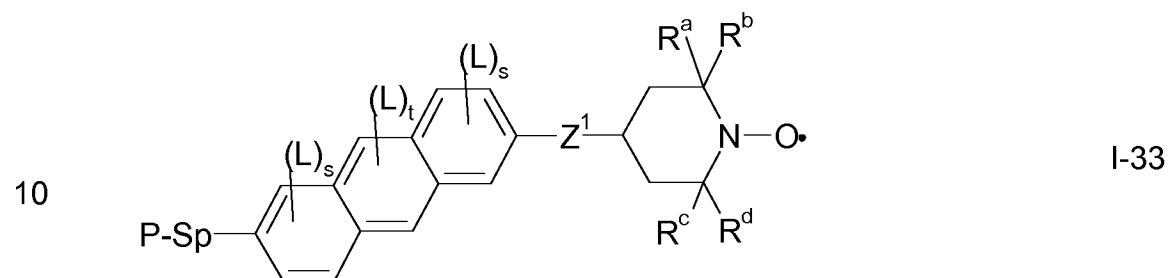
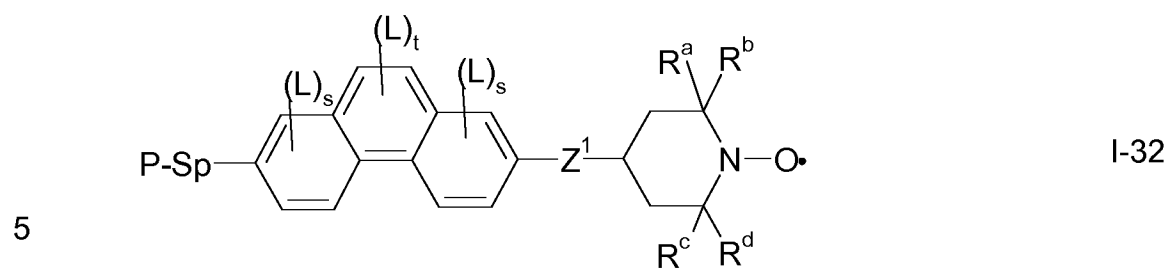
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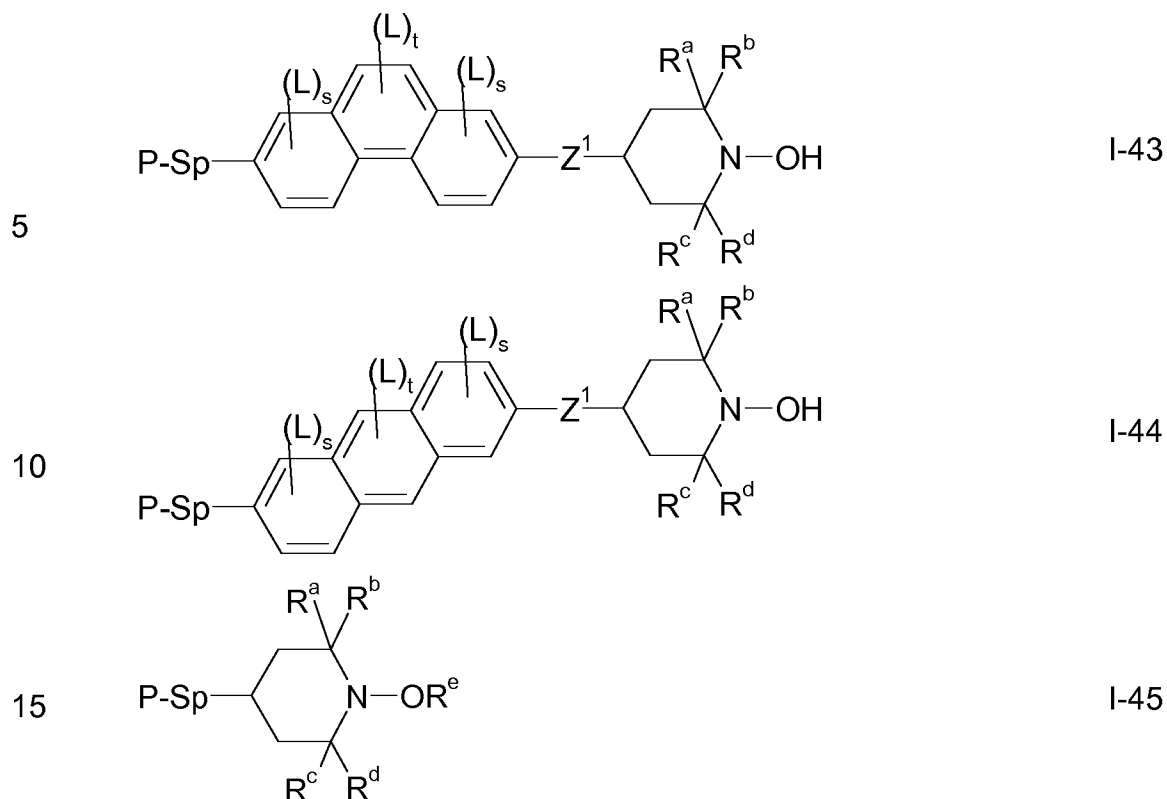
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20 wherein P, Sp, R^{a-d}, Z¹, L and R are as defined in formula I or have one of the preferred meanings as described above and below,
 R^e is alkyl having 1 to 12 C atoms,
 r is 0, 1, 2, 3 or 4 and
 s is 0, 1, 2 or 3.

25 Preferably Z¹ in formulae I and I-1 to I-45 is -CO-O-, -O-CO-, or a single bond, very preferably -CO-O- or a single bond.

Preferably P in formulae I and I-1 to I-45 is acrylate or methacrylate.

30 Preferably Sp in formulae I and I-1 to I-45 is a single bond.

Preferably R^a, R^b, R^c and R^d in formulae I and I-1 to I-45 are methyl.

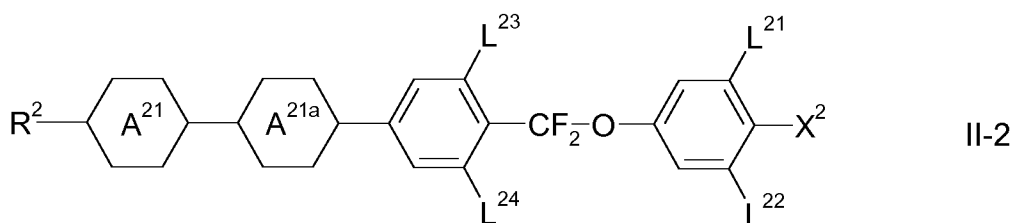
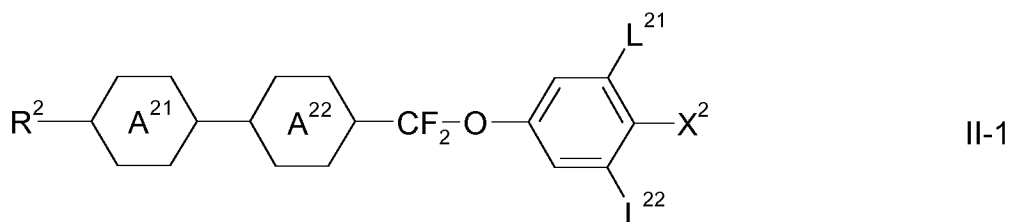
Preferably R^g in formula I is H.

Preferred structures among I-1 to I-45 are the structures I-1 and I-23, particularly structure I-23.

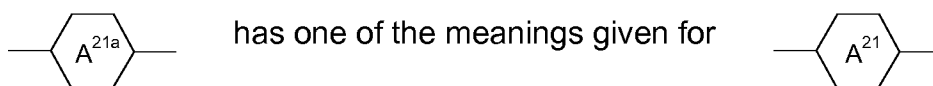
Further preferred compounds of formula I and its subformulae I-1 to I-45 are independently selected from the following preferred embodiments, including any combination thereof:

- The compounds contain exactly one polymerisable group (represented by the group P),
- P is acrylate or methacrylate,
- Sp is a single bond,
- Sp, when being different from a single bond, is selected from $-(CH_2)_a-O-$, $-(CH_2)_a-CO-O-$, $-(CH_2)_a-$ and $-(CH_2)_a-O-CO-$, wherein a is 2, 3, 4, 5 or 6, and the O-atom or the CO-group, respectively, is connected to the next ring A² or the group T, as applicable,
- R^a, R^b, R^c and R^d are methyl,
- R^e is methyl, ethyl, n-propyl, iso-propyl, tert-butyl, n-butyl or n-pentyl,
- R^g is H,
- m1 is 0, 1 or 2,
- m2 is 0, 1 or 2,
- Z¹ denotes $-CO-O-$, $-O-CO-$ or a single bond, preferably $-CO-O-$,
- Z² denotes $-CO-O-$, $-O-CO-$ or a single bond, preferably a single bond,
- L denotes F, Cl, CN, or alkyl or alkoxy with 1 to 6 C atoms that is optionally fluorinated, very preferably F, Cl, CN, CH₃, OCH₃, OCF₃, OCF₂H or OCFH₂, most preferably F,
- one or more of L denote a group T,
- r is 0 or 1,
- s is 0,
- t is 0
- u is 0, 1 or 2.

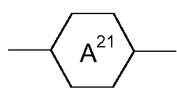
In a preferred embodiment of the present invention, the liquid-crystal medium comprises one or more dielectrically positive compounds having a dielectric anisotropy of greater than 3, selected from the group of the compounds of the formulae II-1 and II-2:



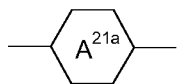
20 in which the parameters have the respective meanings indicated above under formula II, and L^{23} and L^{24} , independently of one another, denote H or F, preferably L^{23} denotes F, and



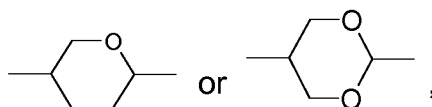
and, in the case of formulae II-1 and II-2, X^2 preferably denotes F or OCF_3 , particularly preferably F, and, in the case of formula II-2,



and

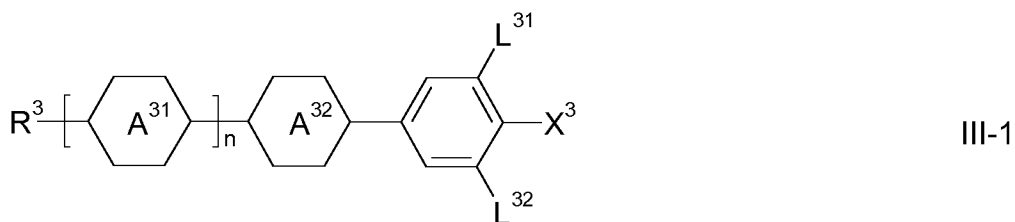


, independently of one another, preferably denote

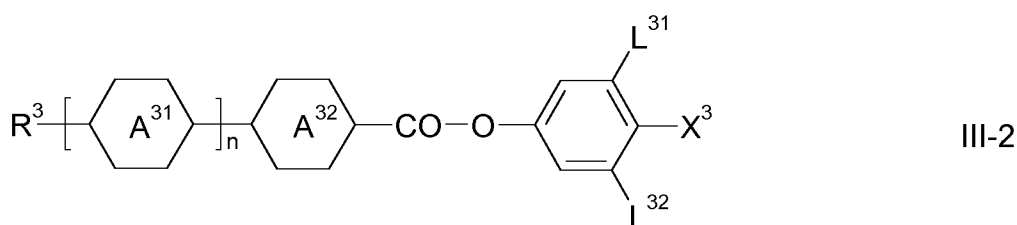


and/or selected from the group of the compounds of the formulae III-1 and III-2:

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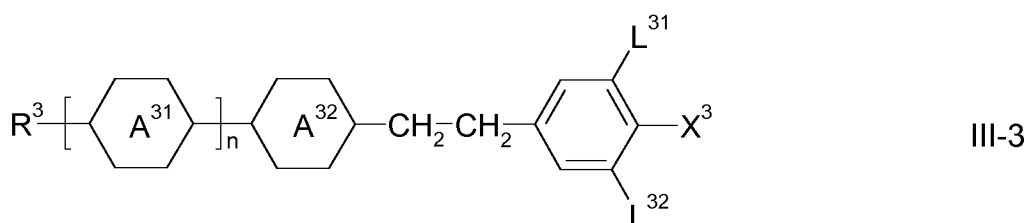
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in which the parameters have the meanings given under formula III,

20

and the media in accordance with the present invention may comprise, alternatively or in addition to the compounds of the formulae III-1 and/or III-2, one or more compounds of the formula III-3

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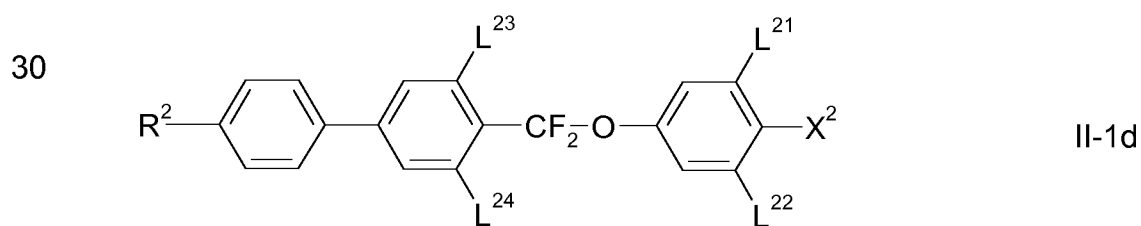
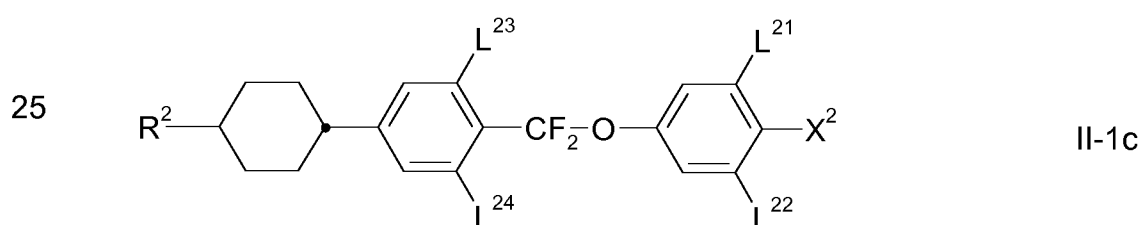
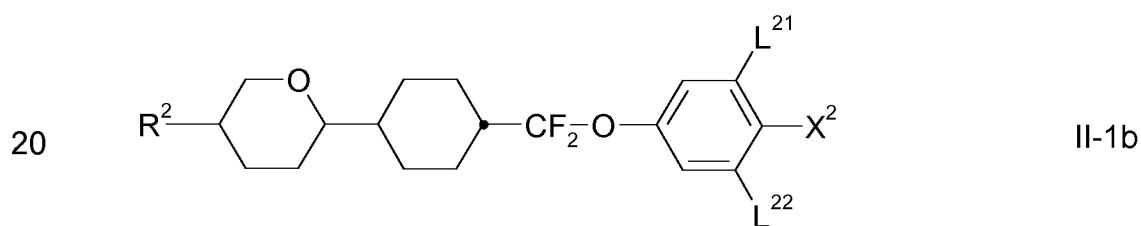
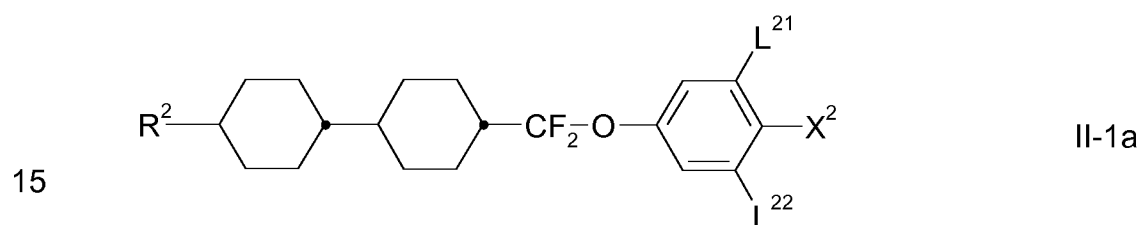
in which the parameters have the respective meanings indicated above, and the parameters L^{31} and L^{32} , independently of one another and of the other parameters, denote H or F.

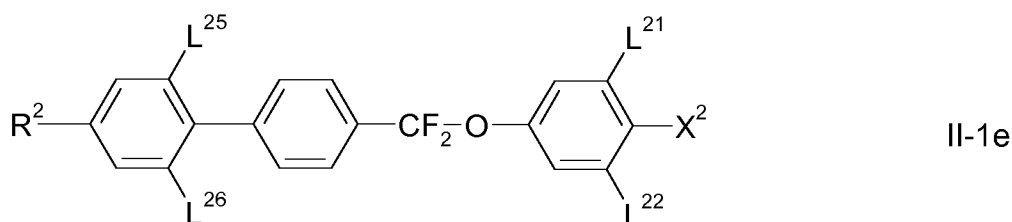
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The liquid-crystal medium preferably comprises compounds selected from the group of the compounds of the formulae II-1 and II-2 in which L^{21} and L^{22} and/or L^{23} and L^{24} both denote F.

In a preferred embodiment, the liquid-crystal medium comprises compounds selected from the group of the compounds of the formulae II-1 and II-2 in which L^{21} , L^{22} , L^{23} and L^{24} all denote F.

- 5 The liquid-crystal medium preferably comprises one or more compounds of the formula II-1. The compounds of the formula II-1 are preferably selected from the group of the compounds of the formulae II-1a to II-1e, preferably one or more compounds of formulae II-1a and/or II-1b and/or II-1d, preferably of formula II-1a and/or II-1d or II-1b and/or II-1d, most preferably of formula II-1d:
- 10





in which the parameters have the respective meanings indicated above,
and L^{25} and L^{26} , independently of one another and of the other parameters, denote H or F, and preferably

10 in the formulae II-1a and II-1b,

L^{21} and L^{22} both denote F,

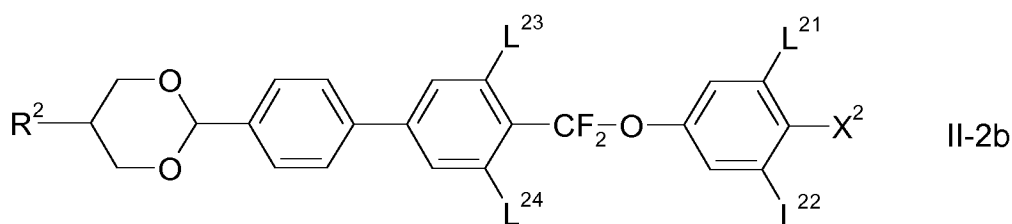
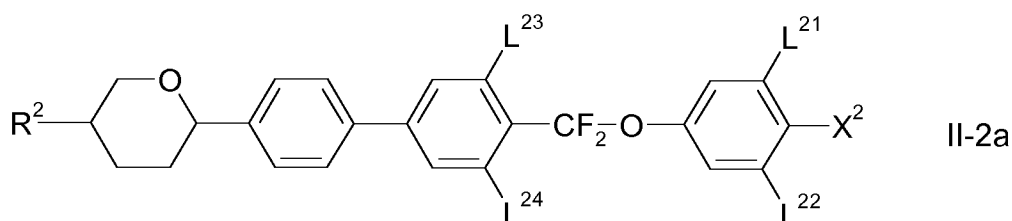
in the formulae II-1c and II-1d,

L^{21} and L^{22} both denote F and/or L^{23} and L^{24} both denote F, and

in formula II-1e,

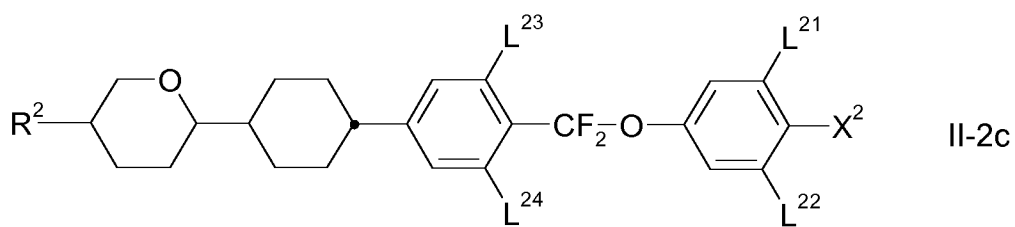
15 L^{21} , L^{22} and L^{23} denote F.

The liquid-crystal medium preferably comprises one or more compounds
of the formula II-2, which are preferably selected from the group of the
compounds of the formulae II-2a to II-2k, preferably one or more
20 compounds each of formulae II-2a, II-2h, II-2k and/or II-2j:

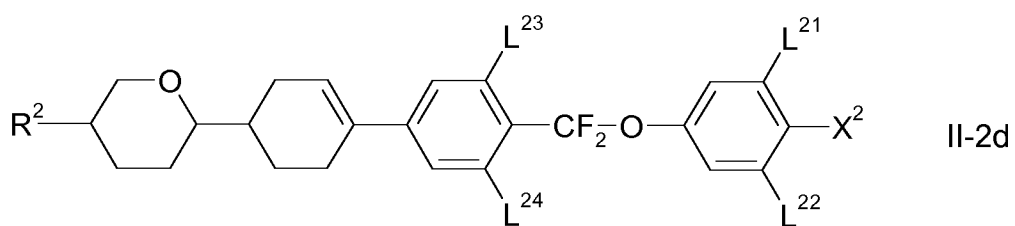


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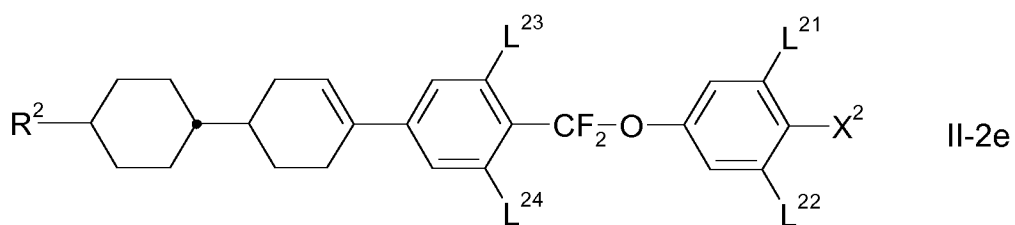
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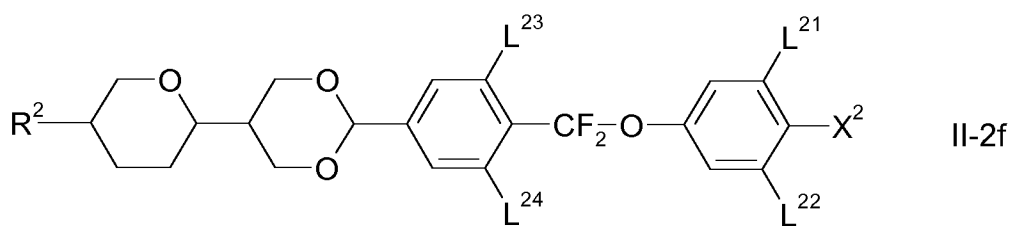
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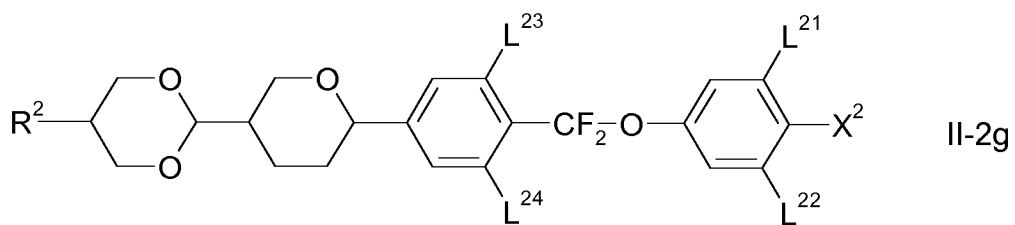
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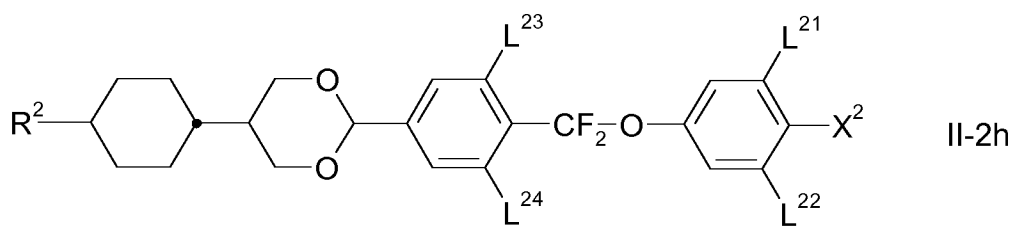
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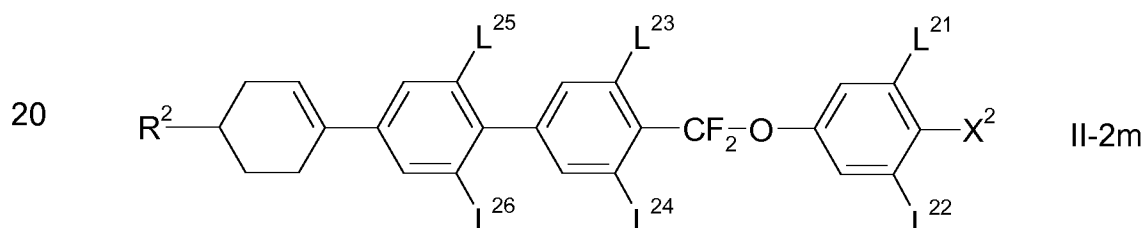
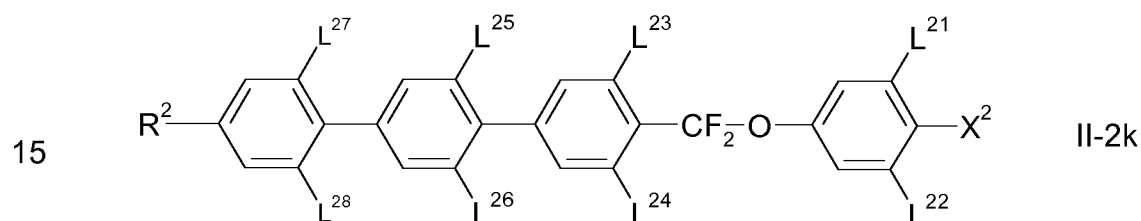
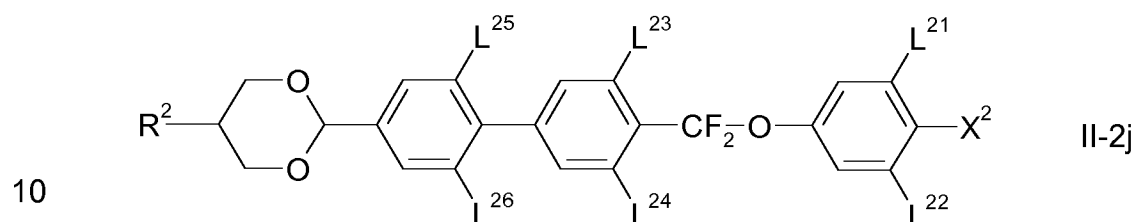
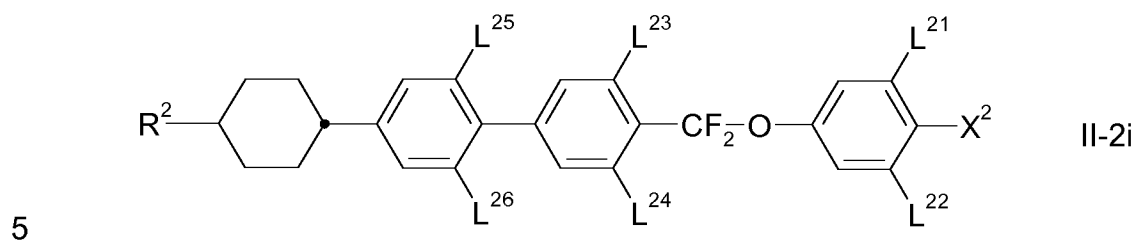
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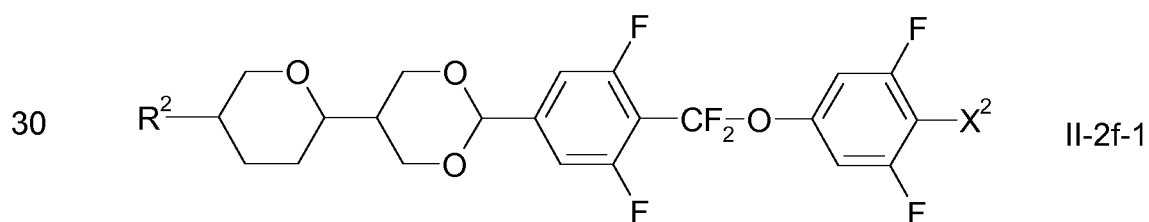
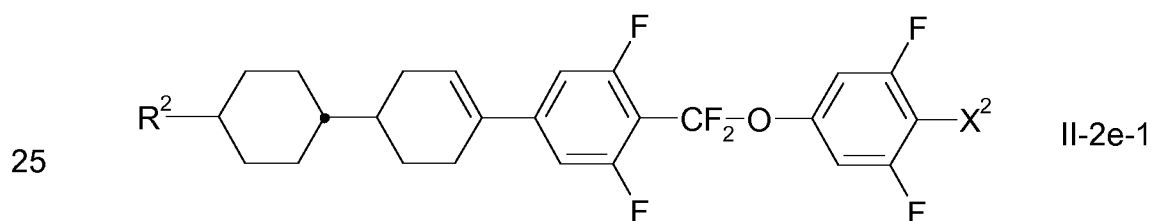
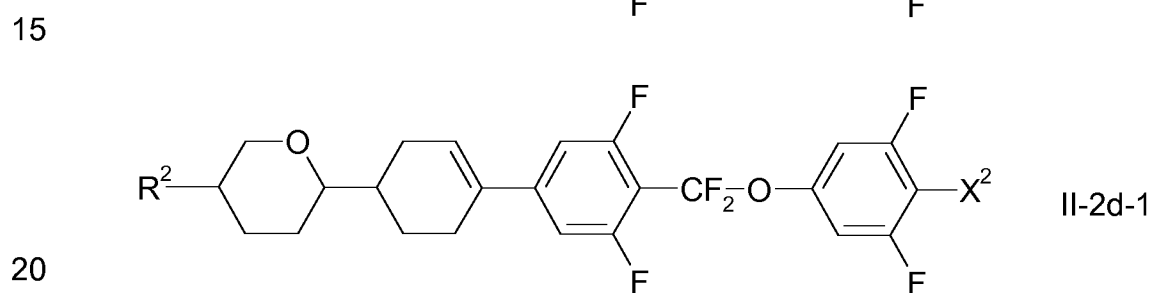
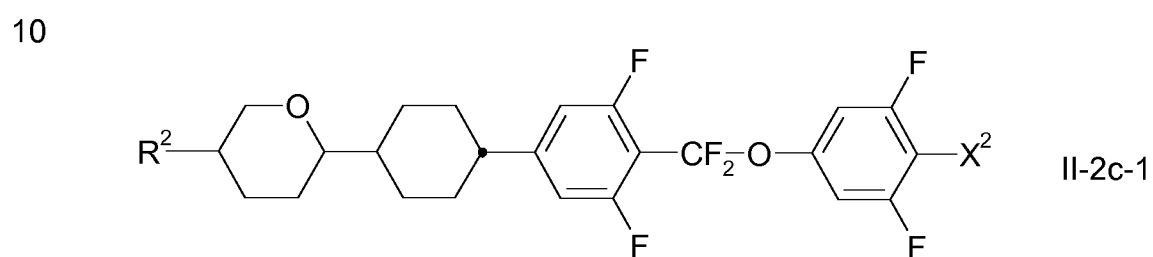
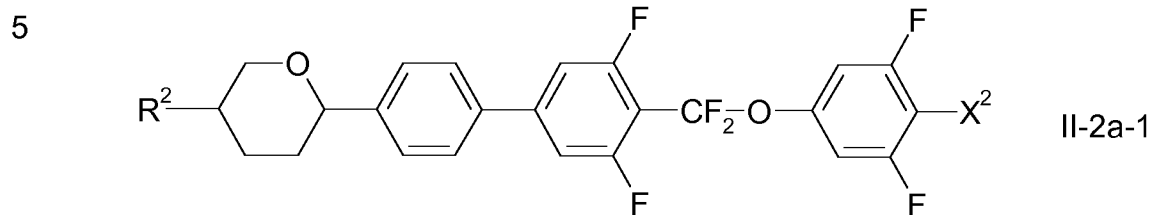


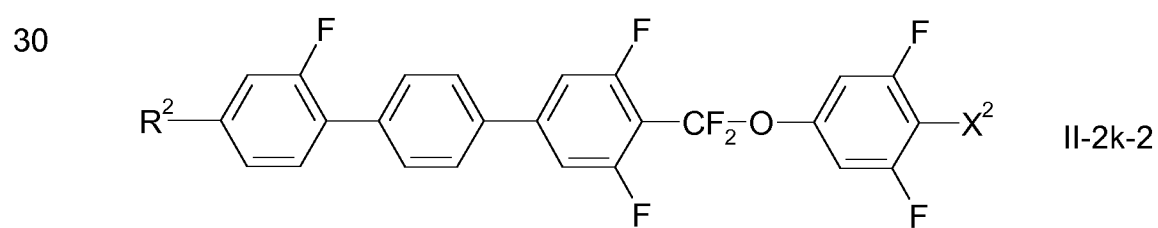
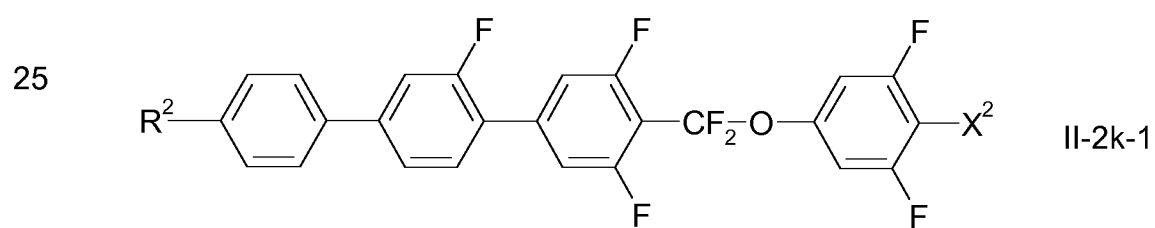
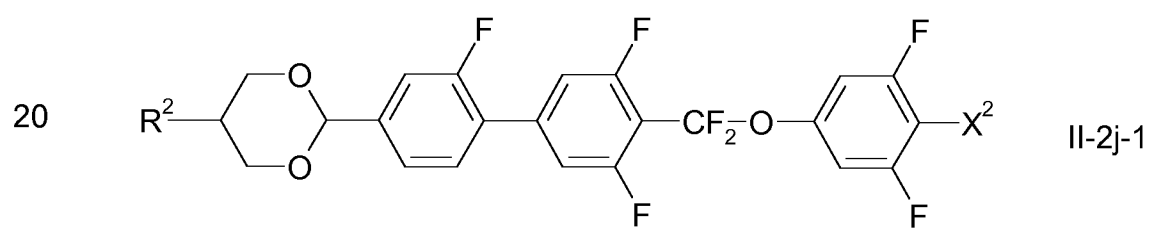
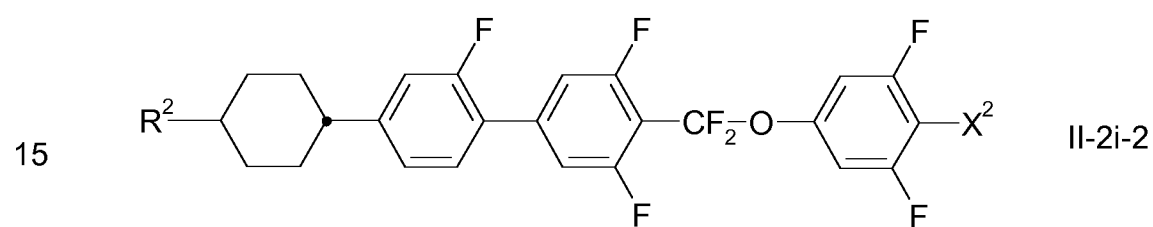
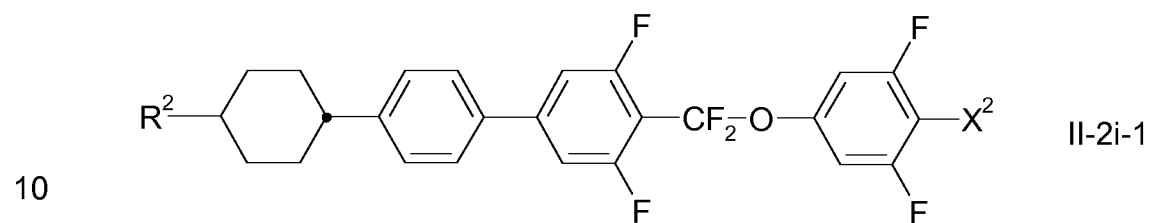
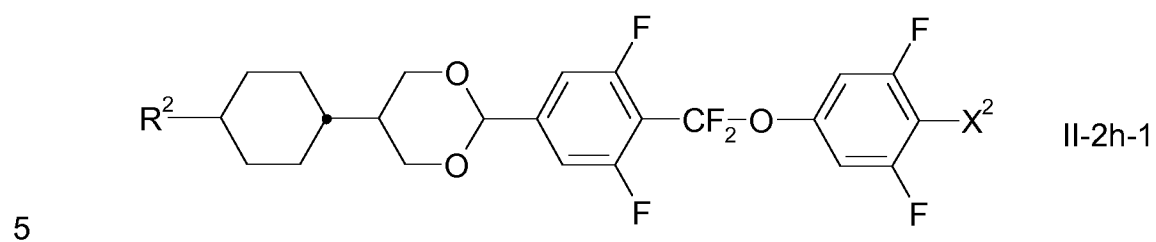
25 in which the parameters have the respective meanings indicated above,
and L^{25} to L^{28} , independently of one another, denote H or F, preferably L^{27}
and L^{28} both denote H, particularly preferably L^{26} denotes H.

30 The liquid-crystal medium preferably comprises compounds selected from
the group of the compounds of the formulae II-2a to II-2k in which L^{21} and
 L^{22} both denote F and/or L^{23} and L^{24} both denote F.

35 In a preferred embodiment, the liquid-crystal medium comprises com-
pounds selected from the group of the compounds of the formulae II-2a to
II-2k in which L^{21} , L^{22} , L^{23} and L^{24} all denote F.

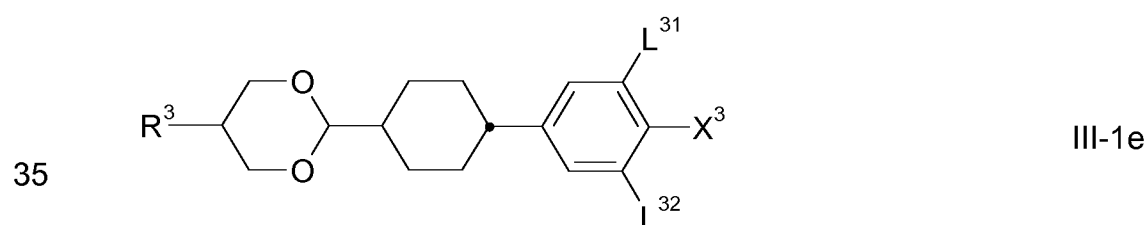
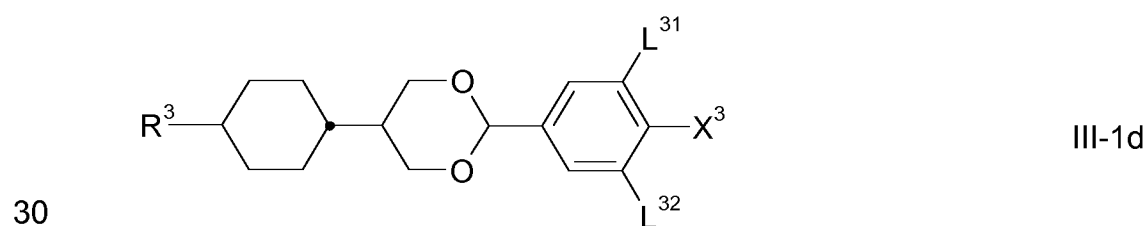
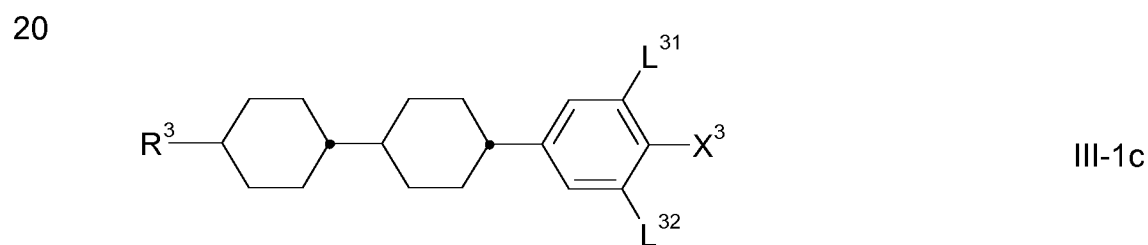
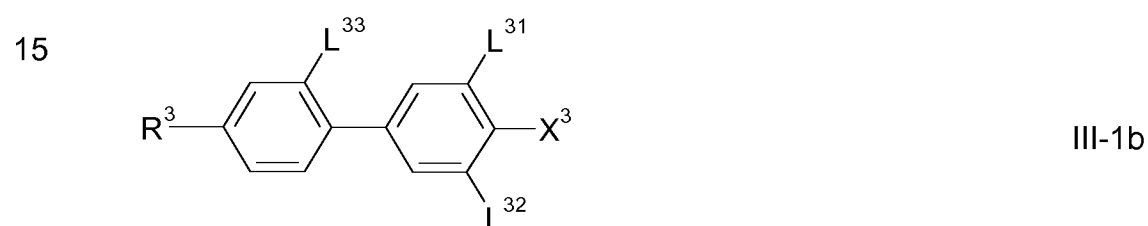
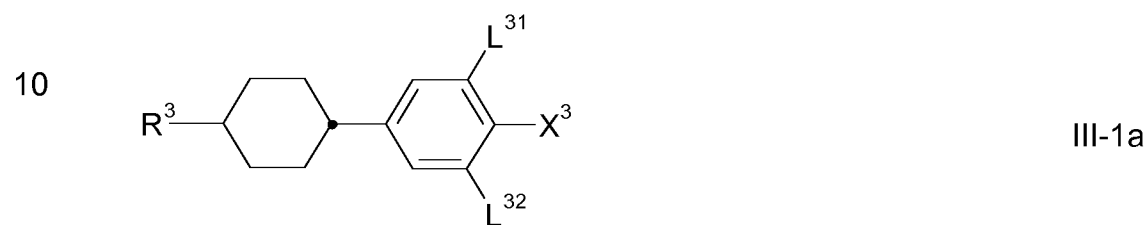
Especially preferred compounds of the formula II-2 are the compounds of the following formulae, particularly preferred of formulae II-2a-1, II-2h-1 and/or II-2k-1 and/or II-2j--1:

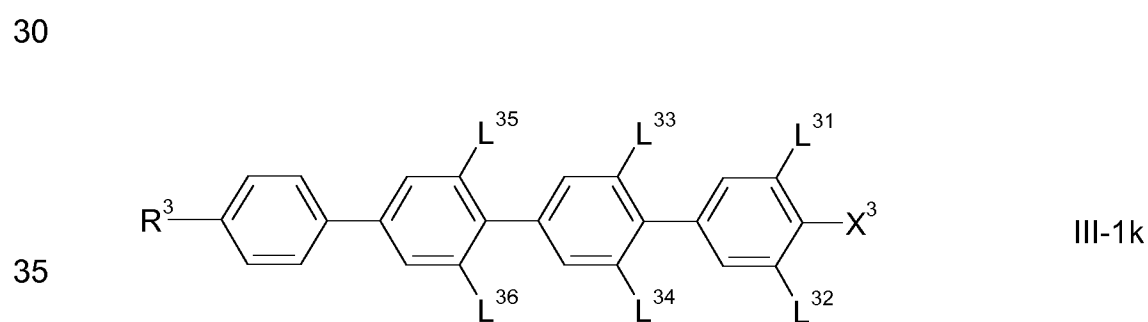
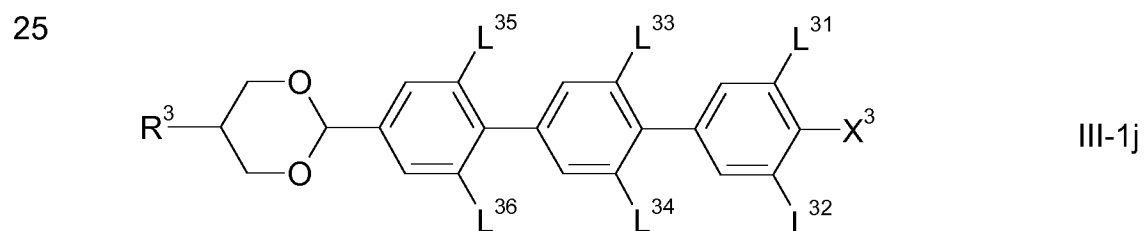
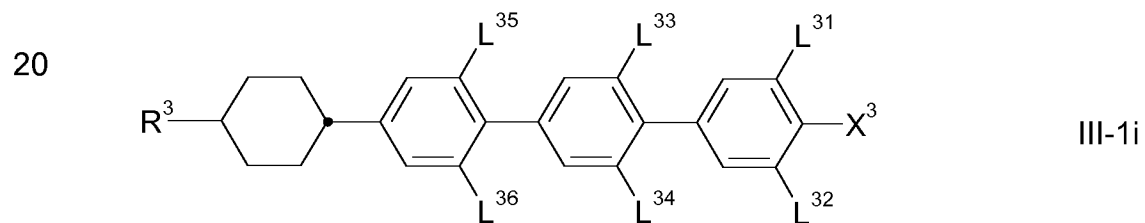
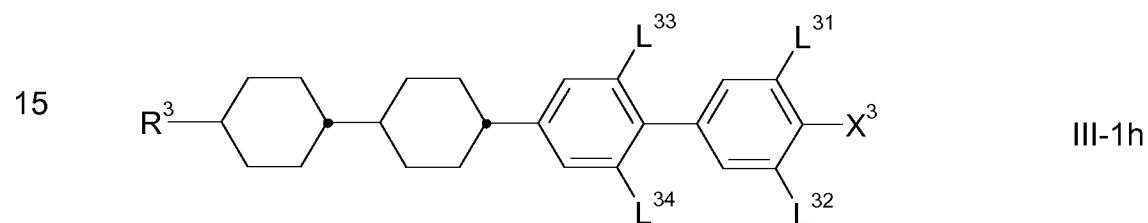
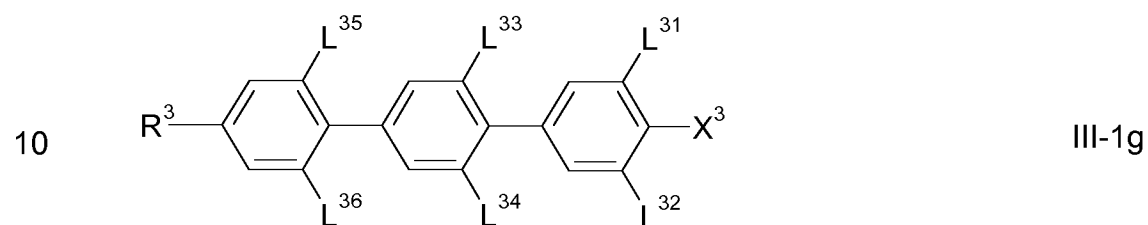
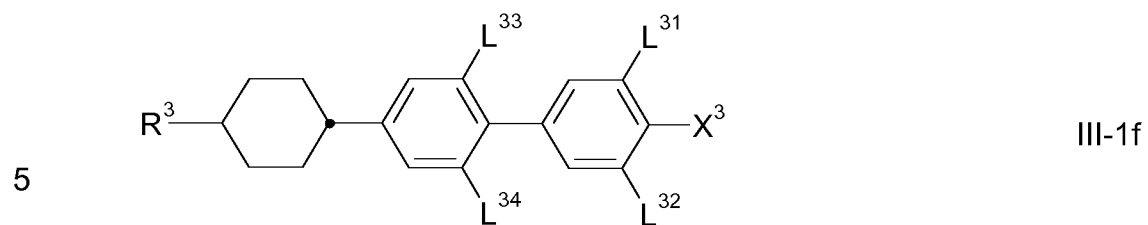




in which R^2 and X^2 have the meanings indicated above, and X^2 preferably denotes F.

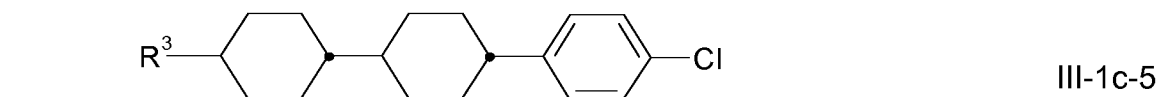
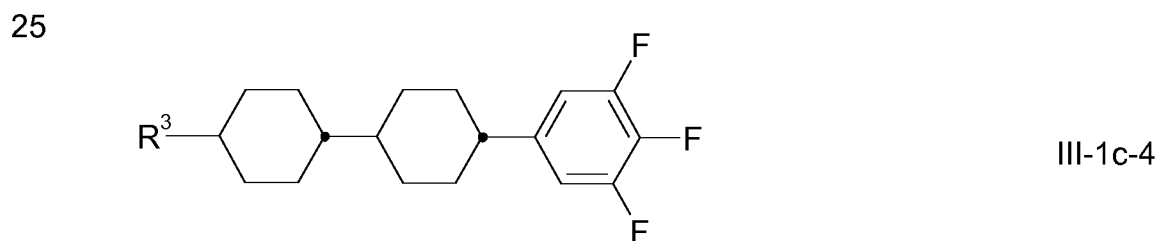
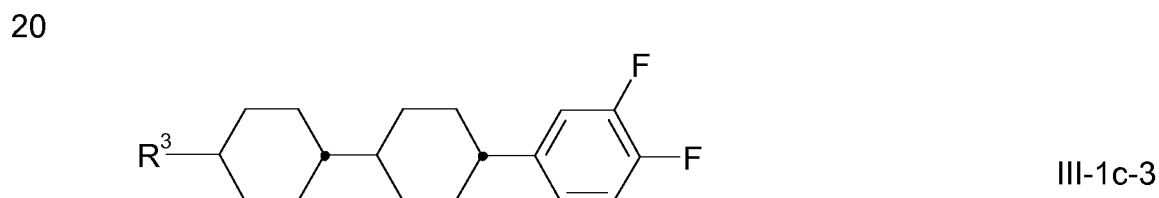
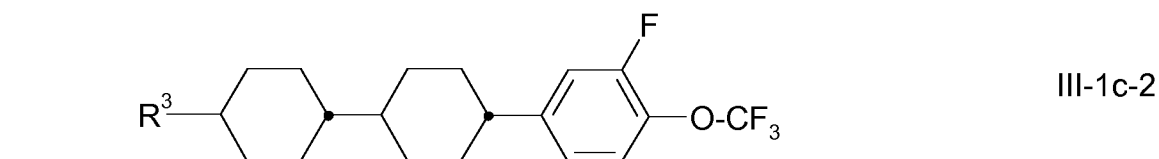
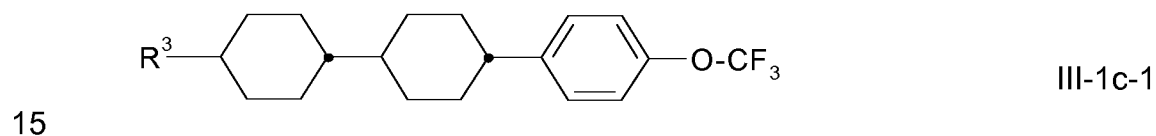
5 The liquid-crystal medium preferably comprises one or more compounds of the formula III-1. The compounds of the formula III-1 are preferably selected from the group of the compounds of the formulae III-1a to III-1j, preferably from formulae III-1c, III-1f, III-1g and III-1k:





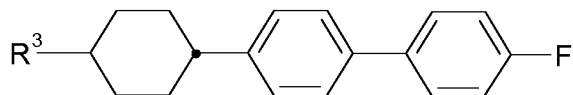
in which the parameters have the meanings given above and preferably in which the parameters have the respective meanings indicated above, the parameters L^{33} and L^{34} , independently of one another and of the other parameters, denote H or F and the parameters L^{35} and L^{36} , independently of one another and of the other parameters, denote H or F.

The liquid-crystal medium preferably comprises one or more compounds of the formula III-1c, which are preferably selected from the group of the compounds of the formulae III-1c-1 to III-1c-5, preferably of formulae III-1c-1 and/or III-1c-2, most preferably of formula III-1c-1:

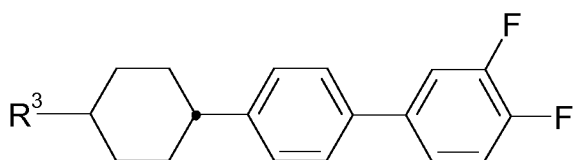


in which R^3 has the meaning indicated above.

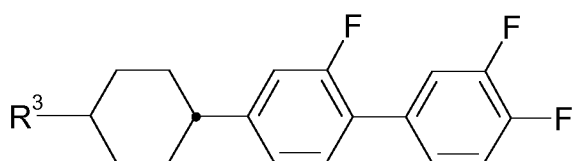
The liquid-crystal medium preferably comprises one or more compounds of the formula III-1f, which are preferably selected from the group of the compounds of the formulae III-1f-1 to III-1f-6, preferably of formulae III-1f-1 and/or III-1f-2 and/or III-1f-3 and /or III-1f-6, more preferably of formula III-1f-3 and/or III-1f-6, more preferably of formula III-1f-6:



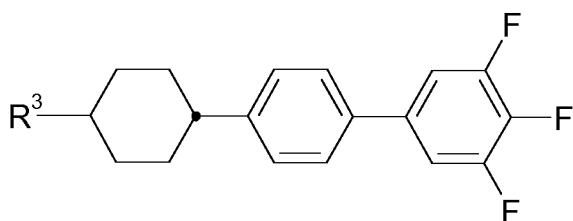
III-1f-1



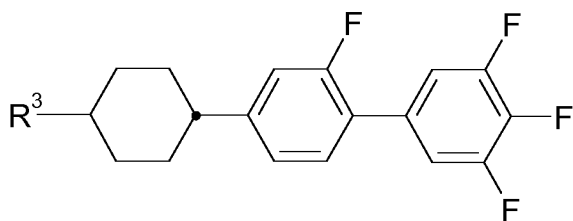
III-1f-2



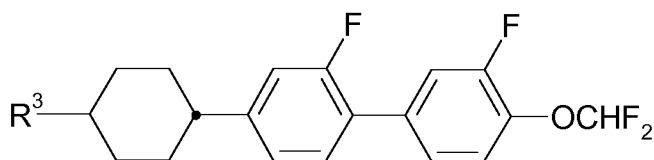
III-1f-3



III-1f-4



III-1f-5



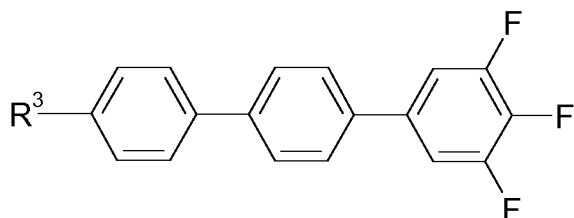
III-1f-6

in which R³ has the meaning indicated above.

The liquid-crystal medium preferably comprises one or more compounds of the formula III-1g, which are preferably selected from the group of the compounds of the formulae III-1g-1 to III-1g-5, preferably of formula III-1g-3:

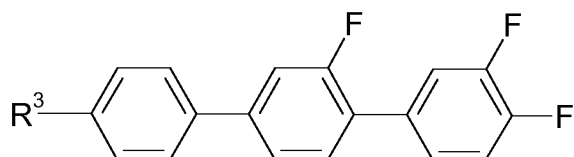
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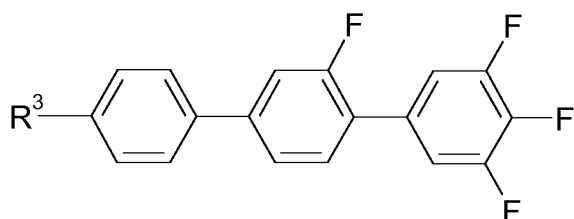
III-1g-1

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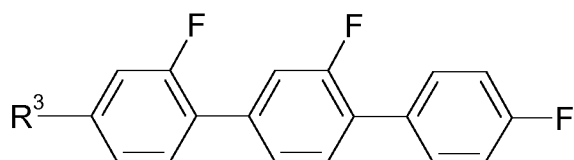
III-1g-2

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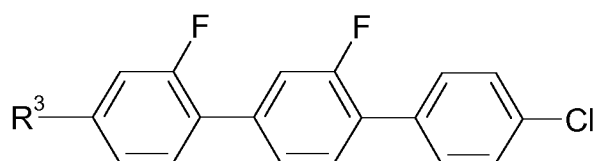
III-1g-3

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III-1g-4

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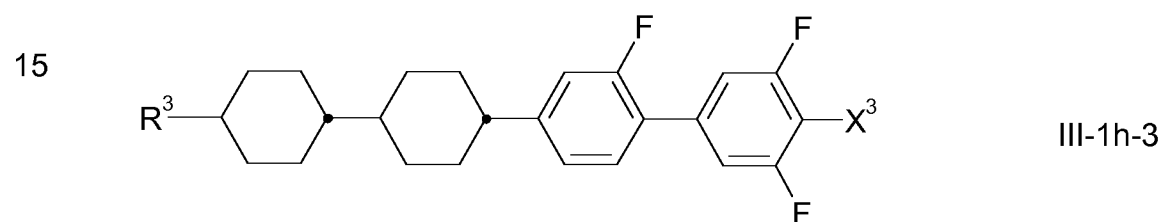
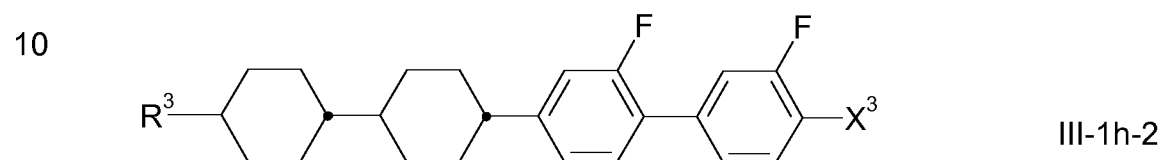
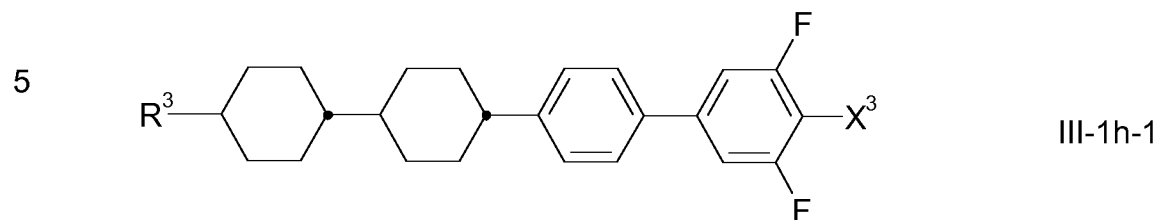
III-1g-5

in which R³ has the meaning indicated above.

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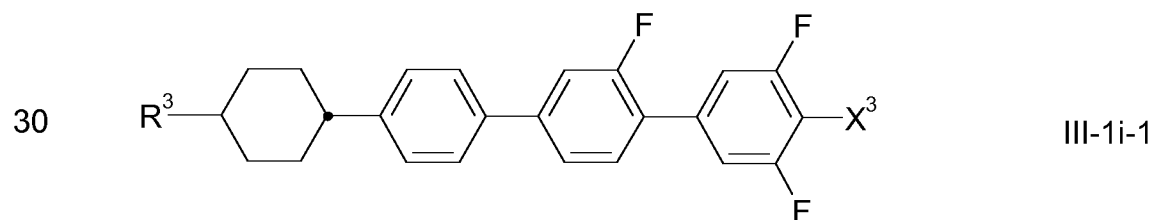
The liquid-crystal medium preferably comprises one or more compounds of the formula III-1h, which are preferably selected from the group of the

compounds of the formulae III-1h-1 to III-1h-3, preferably of the formula III-1h-3:

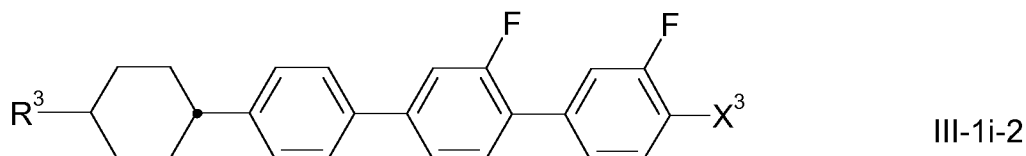


20 in which the parameters have the meanings given above, and X³ preferably denotes F.

The liquid-crystal medium preferably comprises one or more compounds of the formula III-1i, which are preferably selected from the group of the compounds of the formulae III-1i-1 and III-1i-2, preferably of the formula III-1i-1:



35



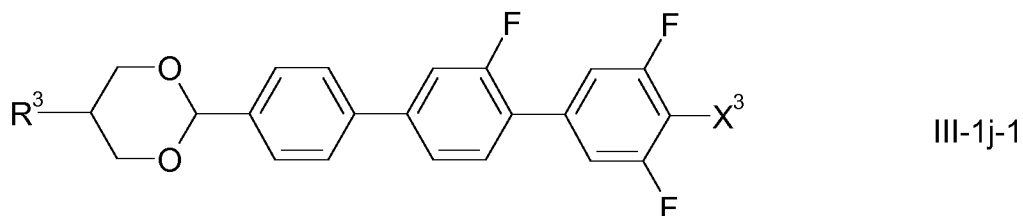
5

in which the parameters have the meanings given above, and X^3 preferably denotes F.

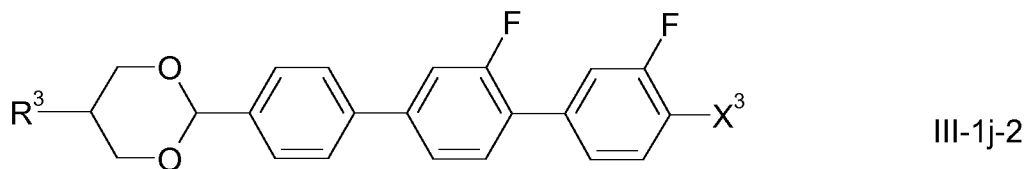
10

The liquid-crystal medium preferably comprises one or more compounds of the formula III-1j, which are preferably selected from the group of the compounds of the formulae III-1j-1 and III-1j-2, preferably of the formula III-1j-1:

15



20



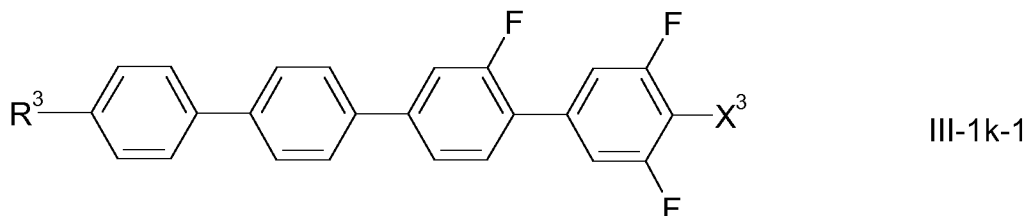
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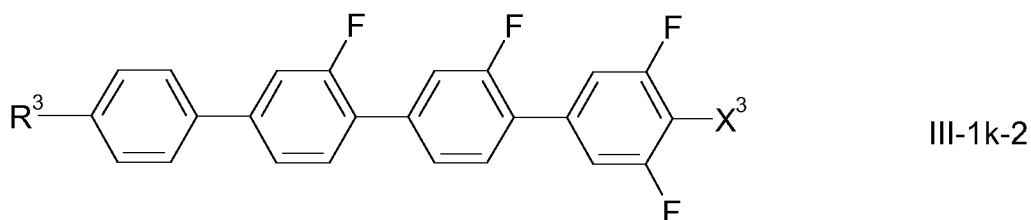
in which the parameters have the meanings given above.

30

The liquid-crystal medium preferably comprises one or more compounds of the formula III-1k, which are preferably selected from the group of the compounds of the formulae III-1k-1 and III-1k-2, preferably of the formula III-1k-1:

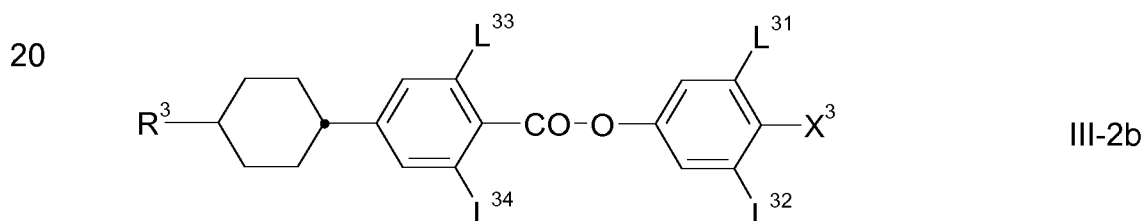
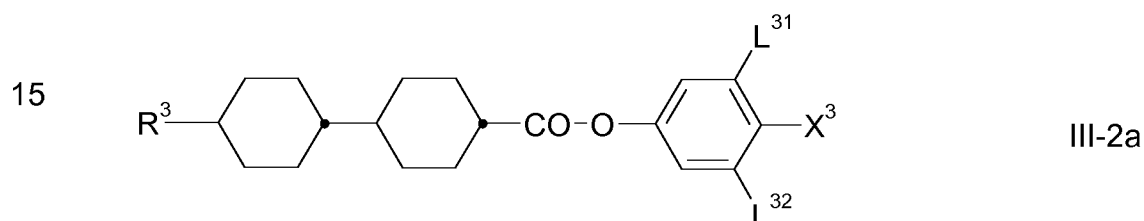
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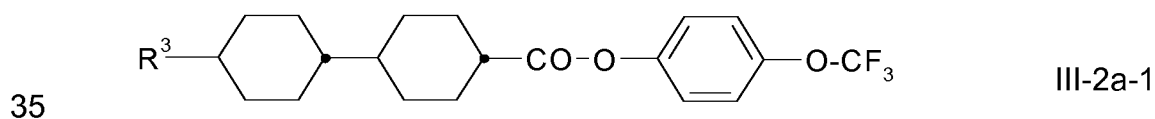
in which the parameters have the meanings given above.

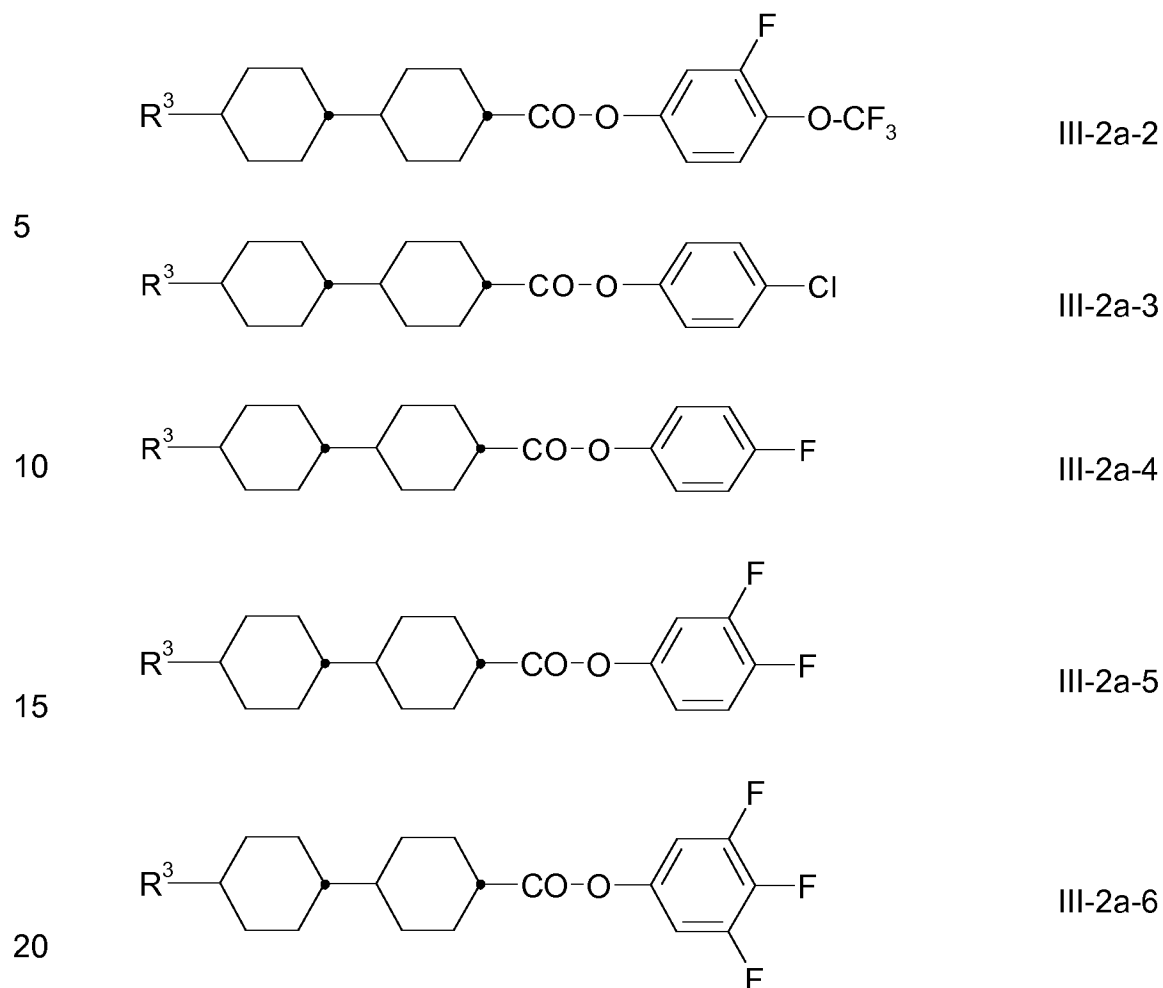
10 The liquid-crystal medium preferably comprises one or more compounds of the formula III-2. The compounds of the formula III-2 are preferably selected from the group of the compounds of the formulae III-2a and III-2b, preferably of formula III-2b:



25 in which the parameters have the respective meanings indicated above, and the parameters L^{33} and L^{34} , independently of one another and of the other parameters, denote H or F.

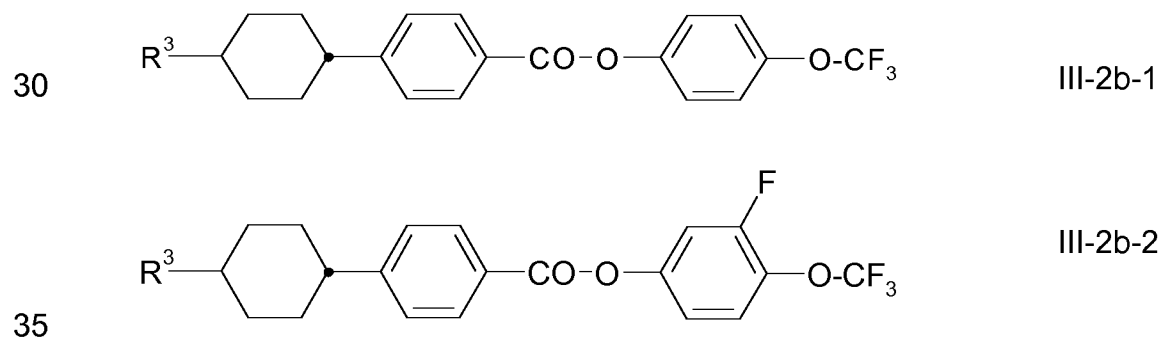
30 The liquid-crystal medium preferably comprises one or more compounds of the formula III-2a, which are preferably selected from the group of the compounds of the formulae III-2a-1 to III-2a-6:

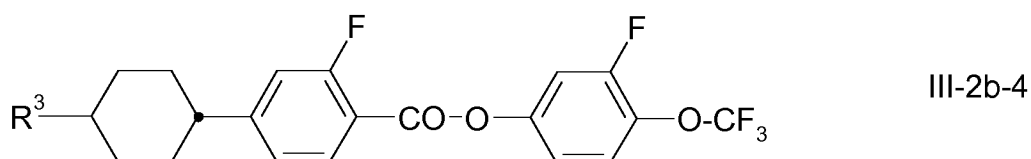
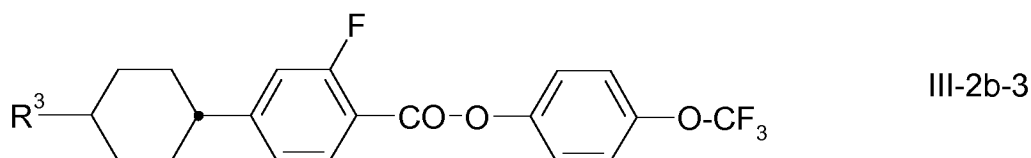




in which R³ has the meaning indicated above.

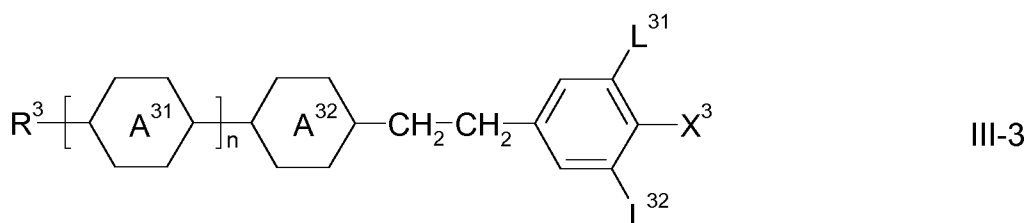
- 25 The liquid-crystal medium preferably comprises one or more compounds of the formula III-2b, which are preferably selected from the group of the compounds of the formulae III-2b-1 to III-2b-4, preferably III-2b-4:





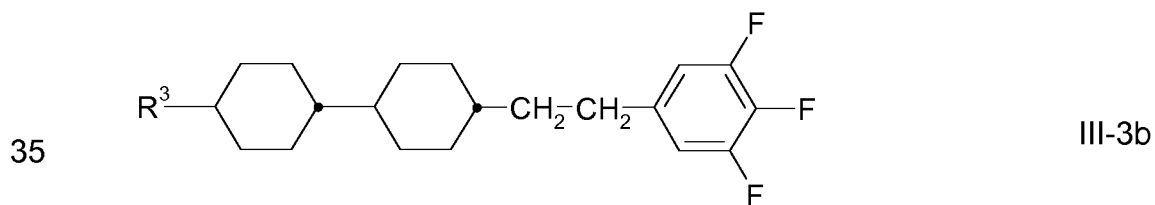
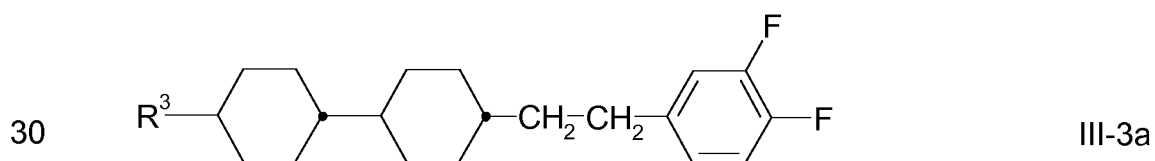
15 in which R³ has the meaning indicated above.

Alternatively or in addition to the compounds of the formulae III-1 and/or III-2, the media in accordance with the present invention may comprise one or more compounds of the formula III-3



25 in which the parameters have the respective meanings indicated above under formula III.

These compounds are preferably selected from the group of the formulae III-3a and III-3b:



in which R^3 has the meaning indicated above.

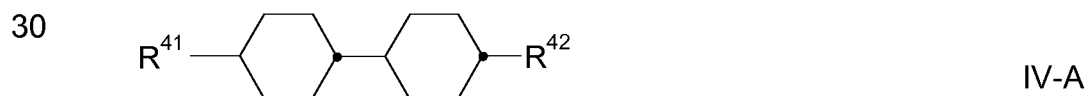
5 In a more preferred embodiment the liquid crystalline medium comprises additionally to the compounds of formula I and II one or more compounds of formula III-1h-3 and one or more compounds of formula III-1j-1.

10 The liquid-crystalline media in accordance with the present invention preferably comprise one or more dielectrically neutral compounds having a dielectric anisotropy in the range from -1.5 to 3.

15 In the present application, the elements all include their respective isotopes. In particular, one or more H in the compounds may be replaced by D, and this is also particularly preferred in some embodiments. A correspondingly high degree of deuteration of the corresponding compounds enables, for example, detection and recognition of the compounds. This is very helpful in some cases, in particular in the case of the compounds of formula I.

20 In the present application,
 alkyl particularly preferably denotes straight-chain alkyl, in particular CH_3- , C_2H_5- , $n-C_3H_7-$, $n-C_4H_9-$ or $n-C_5H_{11}-$, and
 alkenyl particularly preferably denotes $CH_2=CH-$, $E-CH_3-CH=CH-$, $CH_2=CH-CH_2-CH_2-$, $E-CH_3-CH=CH-CH_2-CH_2-$ or
 25 $E-(n-C_3H_7)-CH=CH-$.

In a further preferred embodiment, the medium comprises one or more compounds of formula IV-A



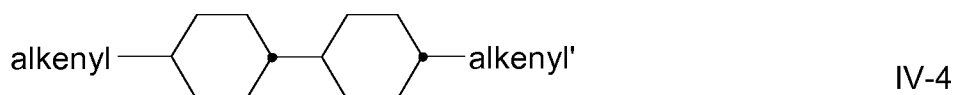
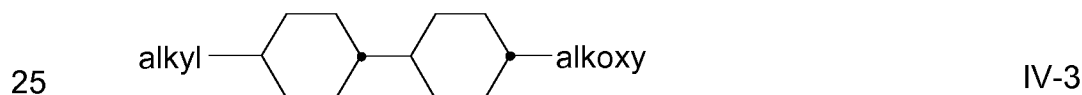
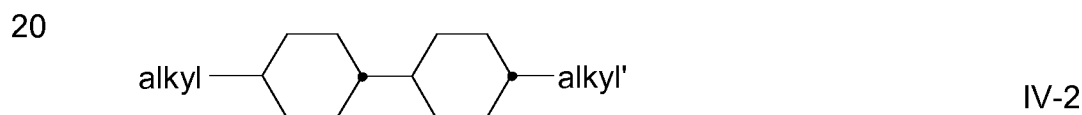
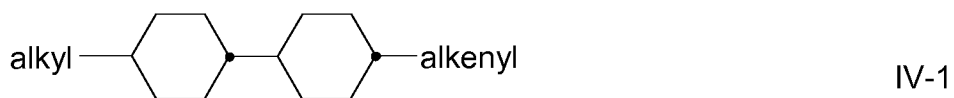
in which

35 R^{41} denotes an unsubstituted alkyl radical having 1 to 7 C atoms or an unsubstituted alkenyl radical having 2 to 7 C

atoms, preferably an *n*-alkyl radical, particularly preferably having 2, 3, 4 or 5 C atoms, and

5 R^{42} denotes an unsubstituted alkyl radical having 1 to 7 C atoms, an unsubstituted alkenyl radical having 2 to 7 C atoms, or an unsubstituted alkoxy radical having 1 to 6 C atoms, wherein the group preferably has 2 to 5 C atoms, and
10 preferably is an unsubstituted alkenyl radical having 2, 3 or 4 C atoms, more preferably a vinyl radical or 1-propenyl radical and in particular a vinyl radical.

In a particularly preferred embodiment, the medium comprises one or
15 more compounds of formula IV selected from the group of the compounds of the formulae IV-1 to IV-4, preferably of formula IV-1,



30 in which

alkyl and alkyl', independently of one another, denote alkyl having 1 to 7 C atoms, preferably having 2 to 5 C atoms,

35

alkenyl and alkenyl', independently of one another, denote alkenyl having 2 to 5 C atoms, preferably having 2 to 4 C atoms, particularly preferably 2 C atoms,

5 alkenyl' preferably denotes alkenyl having 2 to 5 C atoms, preferably having 2 to 4 C atoms, particularly preferably having 2 to 3 C atoms, and

10 alkoxy denotes alkoxy having 1 to 5 C atoms, preferably having 2 to 4 C atoms.

15 In a particularly preferred embodiment, the media according to the invention comprise one or more compounds of formula IV-1 and/or one or more compounds of formula IV-2.

In a further preferred embodiment, the medium comprises one or more compounds of formula V.

20 The media according to the invention preferably comprise the following compounds in the total concentrations indicated:

0.001 – 1 %by weight of one or more compounds of formula I,

25 5 – 60 % by weight of one or more compounds of formula II, preferably selected from the group of the compounds of the formulae II-1 and II-2 and/or

5 – 25 % by weight of one or more compounds of formula III, and/or

30 5 – 60 % by weight of one or more compounds of formula IV, and/or

3 – 25 % by weight of one or more compounds of formula V,

35

where the total content of all compounds of formula I and of formulae II to V, which are present in the medium, preferably is 95 % or more, more preferably 97 % or more and, most preferably, 100 %.

- 5 The condition on the total content holds for preferably for all media according to the present application.

- 10 In a further preferred embodiment, the media in accordance with the present invention in addition preferably comprise one or more dielectrically neutral compounds selected from the group of compounds of formulae IV and V, preferably in a total concentration in the range from 5 % or more to 90 % or less, more preferably from 10 % or more to 80 % or less, particularly preferably from 20 % or more to 70 % or less.

- 15 The medium according to the invention in a particularly preferred embodiment comprises:

- 20 one or more compounds of formula II in a total concentration in the range from 15 % by weight or more to 65 % or less, preferably in the range from 30 % or more to 55 % or less, and/or

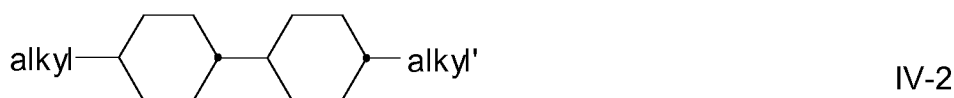
 one or more compounds of formula III in a total concentration in the range from 5 % or more to 30 % or less.

- 25 In a preferred embodiment of the present invention the concentration of the compounds of formula II in the media is in the range from 15 % by weight or more to 65 % or less, more preferably from 15 % or more to 60 % or less, more preferably from 20 % or more to 55 % or less and, most preferably, from 25 % or more to 40 % or less.

- 30 The present invention also relates to electro-optical displays or electro-optical components which contain liquid-crystalline media according to the invention. Preference is given to electro-optical displays which are based on the IPS or FFS effect, preferably on the IPS effect, and in particular
- 35 those which are addressed by means of an active-matrix addressing device.

Accordingly, the present invention likewise relates to the use of a liquid-crystalline medium according to the invention in an electro-optical display or in an electro-optical component, and to a process for the preparation of the liquid-crystalline media according to the invention, characterised in that one or more compounds of formula I are mixed with one or more compounds of formula II and optionally further compounds and additives.

In a further preferred embodiment, the medium comprises one or more compounds of formula IV, selected from the group of the compounds of the formulae IV-2 and IV-3,

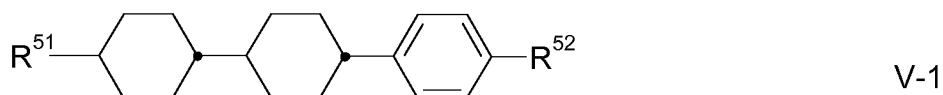


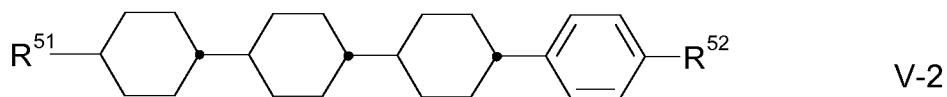
in which

alkyl and alkyl', independently of one another, denote alkyl having 1 to 7 C atoms, preferably having 2 to 5 C atoms,

alkoxy denotes alkoxy having 1 to 5 C atoms, preferably having 2 to 4 C atoms.

In a further preferred embodiment, the medium comprises one or more compounds of formula V selected from the group of the compounds of the formulae V-1 and V-2, preferably of formulae V-1,



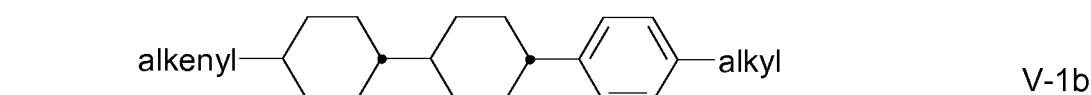
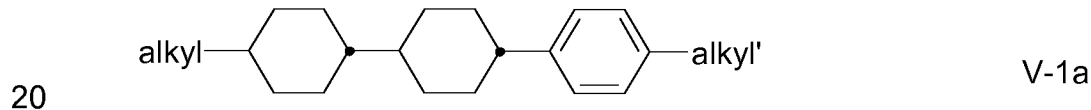


5 in which the parameters have the meanings given above under formula V, and preferably

R^{51} denotes alkyl having 1 to 7 C atoms or alkenyl having 2 to 7 C atoms, and

10 R^{52} denotes alkyl having 1 to 7 C atoms, alkenyl having 2 to 7 C atoms or alkoxy having 1 to 6 C atoms, preferably alkyl or alkenyl, particularly preferably alkyl.

15 In a further preferred embodiment, the medium comprises one or more compounds of formula V-1 selected from the group of the compounds of the formulae V-1a and V-1b,



25 in which

alkyl and alkyl', independently of one another, denote alkyl having 1 to 7 C atoms, preferably having 2 to 5 C atoms, and

30 alkenyl denotes alkenyl having 2 to 7 C atoms, preferably having 2 to 5 C atoms.

Besides compounds of the formulae I to V, other constituents may also be present, for example in an amount of up to 45 %, but preferably up to 35 %, in particular up to 10 %, of the mixture as a whole.

The media according to the invention may optionally also comprise a dielectrically negative component, whose total concentration is preferably 20 % or less, more preferably 10 % or less, based on the entire medium.

5 In a preferred embodiment, the liquid-crystal media according to the invention comprise in total, based on the mixture as a whole,

25 % or more to 65 % or less, preferably 30 % or more to 60 % or less, particularly preferably 35 % or more to 55 % or less, of compounds of
10 formulae II and/or III, and

5 % or more to 60 % or less, preferably 25 % or more to 55 % or less, particularly preferably 35 % or more to 55 % or less, of compounds of
15 formulae IV and/ or V.

The liquid-crystal media in accordance with the present invention may comprise one or more chiral compounds.

20 Particularly preferred embodiments of the present invention meet one or more of the following conditions,

where the acronyms (abbreviations) are explained in Tables A to C and illustrated by examples in Table D.

25 Preferably the media according to the present invention fulfil one or more of the following conditions.

i. The liquid-crystalline medium has a birefringence of 0.060 or more, particularly preferably 0.070 or more.
30

ii. The liquid-crystalline medium has a birefringence of 0.200 or less, particularly preferably 0.180 or less.

iii. The liquid-crystalline medium has a birefringence in the range from
35 0.090 or more to 0.160 or less.

- iv. The liquid-crystalline medium comprises one or more particularly preferred compounds of formula I, preferably selected from the (sub-) formulae I-1 and I-23, most preferably of (sub-)formula I-23.
- 5 v. The total concentration of the compounds of formula II in the mixture as a whole is 25 % or more, preferably 30 % or more, and is preferably in the range from 25 % or more to 49 % or less, particularly preferably in the range from 29 % or more to 47 % or less, and very particularly preferably in the range from 37 % or more to 44 % or less.
- 10
- vi. The liquid-crystalline medium comprises one or more compounds of formula IV selected from the group of the compounds of the following formulae: CC-n-V and/or CC-n-V_m and/or CC-V-V and/or CC-V-V_n and/or CC-nV-V_n, particularly preferably CC-3-V, preferably in a concentration of up to 60 % or less, particularly preferably up to 50 % or less, and optionally additionally CC-3-V₁, preferably in a concentration of up to 15 % or less, and/or CC-4-V, preferably in a concentration of up to 40 % or less, particularly preferably up to 30% or less.
- 15
- 20
- vii. The media comprise the compound of formula CC-n-V, preferably CC-3-V, preferably in a concentration of 1 % or more to 60 % or less, more preferably in a concentration of 3 % or more to 38 % or less.
- 25
- viii. The total concentration of the compounds of formula CC-3-V in the mixture as a whole preferably either is 15 % or less, preferably 10 % or less or 20 % or more, preferably 25 % or more.

30

The invention furthermore relates to an electro-optical display having active-matrix addressing based on the IPS or FFS effect, characterised in that it contains, as dielectric, a liquid-crystalline medium in accordance with the present invention.

35

The liquid-crystal mixture preferably has a nematic phase range having a width of at least 70 degrees.

5 The rotational viscosity γ_1 is preferably 350 mPa·s or less, preferably 250 mPa·s or less and, in particular, 150 mPa·s or less.

The mixtures according to the invention are suitable for all IPS and FFS-TFT applications using dielectrically positive liquid crystalline media, such as, e.g. SG-FFS.

10

The liquid-crystalline media according to the invention preferably virtually completely consist of 4 to 15, in particular 5 to 12, and particularly preferably 10 or less, compounds. These are preferably selected from the group of the compounds of the formulae I, II, III, IV, V, VI, VII, VIII and IX.

15

The liquid-crystalline media according to the invention may optionally also comprise more than 18 compounds. In this case, they preferably comprise 18 to 25 compounds.

20

In a preferred embodiment, the liquid-crystal media according to the invention predominantly comprise, preferably essentially consist of and, most preferably, virtually completely consist of compounds, which do not comprise a cyano group.

25

In a preferred embodiment, the liquid-crystal media according to the invention comprise compounds selected from the group of the compounds of the formulae I, II, and III, IV and V, preferably selected from the group of the compounds of the formulae I, II-1, II-2, IV and V, they preferably consist predominantly, particularly preferably essentially and very particularly preferably virtually completely of the compounds of the said formulae.

30

The liquid-crystal media according to the invention preferably have a nematic phase from in each case at least -10°C or less to 70°C or more, particularly preferably from -20°C or less to 80°C or more, very particularly preferably from -30°C or less to 85°C or more and most preferably from -40°C or less to 90°C or more.

35

5 The expression "have a nematic phase" here means on the one hand that no smectic phase and no crystallisation are observed at low temperatures at the corresponding temperature and on the other hand that no clearing occurs on heating out of the nematic phase. The investigation at low temperatures is carried out in a flow viscometer at the corresponding temperature and checked by storage in test cells having a cell thickness corresponding to the electro-optical application for at least 100 hours. If the storage stability at a temperature of -20°C in a corresponding test cell is 10 1000 h or more, the medium is regarded as stable at this temperature. At temperatures of -30°C and -40°C, the corresponding times are 500 h and 250 h respectively. At high temperatures, the clearing point is measured in capillaries by conventional methods.

15 In a preferred embodiment, the liquid-crystal media according to the invention are characterised by optical anisotropy values in the moderate to low range. The birefringence values are preferably in the range from 0.075 or more to 0.130 or less, particularly preferably in the range from 0.085 or more to 0.120 or less and very particularly preferably in the range from 20 0.090 or more to 0.115 or less.

In this embodiment, the liquid-crystal media according to the invention have a positive dielectric anisotropy and relatively high absolute values of the dielectric anisotropy $\Delta\epsilon$, which preferably is in the range from 9.0 or 25 more to 22 or less, more preferably to 18 or less, more preferably from 10 or more to 15 or less, particularly preferably from 4.0 or more to 9.0 or less and very particularly preferably from 4.5 or more to 8.0 or less.

30 The liquid-crystal media according to the invention preferably have relatively low values for the threshold voltage (V_0) in the range from 1.0 V or more to 5.0 V or less, preferably to 2.5 V or less, preferably from 1.2 V or more to 2.2 V or less, particularly preferably from 1.3 V or more to 2.0 V or less.

35 In addition, the liquid-crystal media according to the invention have high values for the VHR in liquid-crystal cells.

5 In freshly filled cells at 20°C in the cells, the values of the VHR of these media are greater than or equal to 95 %, preferably greater than or equal to 97%, particularly preferably greater than or equal to 98 % and very particularly preferably greater than or equal to 99 %, and after 5 minutes in the oven at 100°C in the cells, these are greater than or equal to 90 %, preferably greater than or equal to 93 %, particularly preferably greater than or equal to 96 % and very particularly preferably greater than or equal to 98 %.

10

In general, liquid-crystal media having a low addressing voltage or threshold voltage here have a lower VHR than those having a higher addressing voltage or threshold voltage, and vice versa.

15 These preferred values for the individual physical properties are preferably also in each case maintained by the media according to the invention in combination with one another.

20 In the present application, the term "compounds", also written as "compound(s)", means both one and also a plurality of compounds, unless explicitly indicated otherwise.

In a preferred embodiment, the liquid-crystalline media according to the invention comprise

25

one or more compounds of formula I, preferably selected from the group of the formulae I-1 and/or I-23, and/or

30 one or more compounds of formula II, preferably selected from the group of formulae PUQU-n-F, CDUQU-n-F, APUQU-n-F and PGUQU-n-F, and/or CPUQU-n-F, and/or

one or more compounds of formula III, preferably selected from the group of formulae CCP-n-OT, CGG-n-F, and CGG-n-OD, and/or

35

one or more compounds of formulae IV and/or V, preferably selected from the group of formulae CC-n-V, CCP-n-m, CCP-V-n, CCP-V2-n and CGP-n-n, and/or

- 5 optionally, preferably obligatorily, one or more compounds of formula IV, preferably selected from the group of the compounds of the formulae CC-n-V, CC-n-Vm, CC-n-mVI and CC-nV-Vm, preferably CC-3-V, CC-3-V1, CC-4-V, CC-5-V, CC-3-2V1 and CC-V-V, particularly preferably selected from the group of the compounds CC-3-V, CC-3-V1, CC-4-V, CC-3-2V1
10 and CC-V-V, very particularly preferably the compound CC-3-V, and optionally additionally the compound(s) CC-4-V and/or CC-3-V1 and/or CC-3-2V1 and/or CC-V-V, and/or

- optionally, preferably obligatorily, one or more compounds of formula V,
15 preferably selected from the group of formulae CCP-V-1 and/or CCP-V2-1.

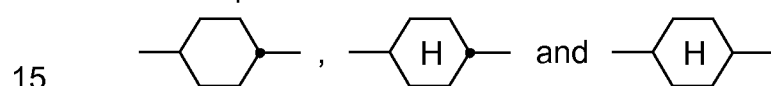
For the present invention, the following definitions apply in connection with the specification of the constituents of the compositions, unless indicated otherwise in individual cases:

- 20
- "comprise": the concentration of the constituents in question in the composition is preferably 5% or more, particularly preferably 10% or more, very particularly preferably 20% or more,
 - 25 - "predominantly consist of": the concentration of the constituents in question in the composition is preferably 50% or more, particularly preferably 55% or more and very particularly preferably 60% or more,
 - 30 - "essentially consist of": the concentration of the constituents in question in the composition is preferably 80% or more, particularly preferably 90% or more and very particularly preferably 95% or more, and
 - 35 - "virtually completely consist of": the concentration of the constituents in question in the composition is preferably 98% or more, particularly preferably 99% or more and very particularly preferably 100.0%.

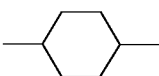
This applies both to the media as compositions with their constituents, which can be components and compounds, and also to the components with their constituents, the compounds. Only in relation to the concentration of an individual compound relative to the medium as a whole does the term comprise mean: the concentration of the compound in question is preferably 1% or more, particularly preferably 2% or more, very particularly preferably 4% or more.

For the present invention, " $\leq$ " means less than or equal to, preferably less than, and " $\geq$ " means greater than or equal to, preferably greater than.

For the present invention

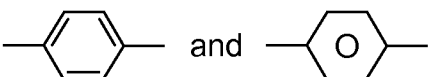


denote *trans*-1,4-cyclohexylene,



denotes a mixture of both *cis*- and *trans*-1,4-cyclohexylene,

and



denote 1,4-phenylene.

For the present invention, the expression "dielectrically positive compounds" means compounds having a $\Delta\epsilon$ of > 1.5 , the expression "dielectrically neutral compounds" means those where $-1.5 \leq \Delta\epsilon \leq 1.5$ and the expression "dielectrically negative compounds" means those where $\Delta\epsilon < -1.5$.

The host mixture used for measuring $\Delta\epsilon$ of dielectrically positive and dielectrically neutral compounds is ZLI-4792 and that used for dielectrically negative compounds is ZLI-2857, both from Merck KGaA, Germany. The values for the respective compounds to be investigated are obtained from

the change in the dielectric constant of the host mixture after addition of the compound to be investigated and extrapolation to 100% of the compound employed. The compound to be investigated is dissolved in the host mixture in an amount of 10%. If the solubility of the substance is too
5 low for this purpose, the concentration is halved in steps until the investigation can be carried out at the desired temperature.

The liquid-crystal media according to the invention may, if necessary, also comprise further additives, such as, for example, stabilisers and/or pleo-
10 chroitic, e.g. dichroitic, dyes and/or chiral dopants in the usual amounts. The amount of these additives employed is preferably in total 0 % or more to 10 % or less, based on the amount of the entire mixture, particularly preferably 0.1 % or more to 6 % or less. The concentration of the
15 individual compounds employed is preferably 0.1 % or more to 3 % or less. The concentration of these and similar additives is generally not taken into account when specifying the concentrations and concentration ranges of the liquid-crystal compounds in the liquid-crystal media.

In a special embodiment, the liquid-crystal media according to the inven-
20 tion may comprise a polymer precursor which comprises one or more reactive compounds, preferably reactive mesogens, and, if necessary, also further additives, such as, for example, polymerisation initiators and/or polymerisation moderators, in the usual amounts. The amount of
25 these additives employed is in total 0 % or more to 10 % or less, based on the amount of the entire mixture, preferably 0.1 % or more to 2 % or less. The concentration of these and similar additives is not taken into account when specifying the concentrations and concentration ranges of the liquid-crystal compounds in the liquid-crystal media.

30 The compositions consist of a plurality of compounds, preferably 3 or more to 30 or fewer, particularly preferably 6 or more to 20 or fewer and very particularly preferably 10 or more to 16 or fewer compounds, which are mixed in a conventional manner. In general, the desired amount of the components used in lesser amount is dissolved in the components making
35 up the principal constituent of the mixture. This is advantageously carried out at elevated temperature. If the selected temperature is above the

clearing point of the principal constituent, completion of the dissolution operation is particularly easy to observe. However, it is also possible to prepare the liquid-crystal mixtures in other conventional ways, for example using pre-mixes or from a so-called "multi-bottle system".

5

The mixtures according to the invention exhibit very broad nematic phase ranges having clearing points of 65°C or more, very favourable values for the capacitive threshold, relatively high values for the holding ratio and at the same time very good low-temperature stabilities at -30°C and -40°C.

10

Furthermore, the mixtures according to the invention are distinguished by low rotational viscosities γ_1 .

It goes without saying to the person skilled in the art that the media according to the invention may also comprise compounds in which, for example, H, N, O, Cl, F have been replaced by the corresponding isotopes.

15

The structure of the IPS liquid-crystal displays according to the invention corresponds to the usual geometry, as described, for example, in US 2001022569 A or US 2002030782 A.

20

The liquid-crystal phases according to the invention can be modified by means of suitable additives in such a way that they can be employed in any type of, for example, IPS and FFS LCD display that has been disclosed to date.

25

Table E below indicates possible dopants which can be added to the mixtures according to the invention. If the mixtures comprise one or more dopants, the amount is 0.01 % to 4 %, preferably 0.1 % to 1.0 %.

30

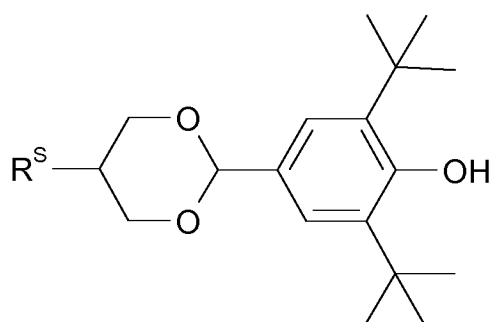
Additional stabilisers which can be added, for example, to the mixtures according to the invention, preferably in amounts of 0.001 % to 6 %, in particular 0.1 % to 3 %, are shown below in Table F.

35

In a preferred embodiment of the invention the liquid crystalline medium comprises additionally a stabiliser selected from the class of phenols,

more preferably from the derivatives of 2,6-ditert-butyl phenols, which are preferably those phenols listed in Table F below, and most preferably selected from the the group of formulae S-1 and S-2:

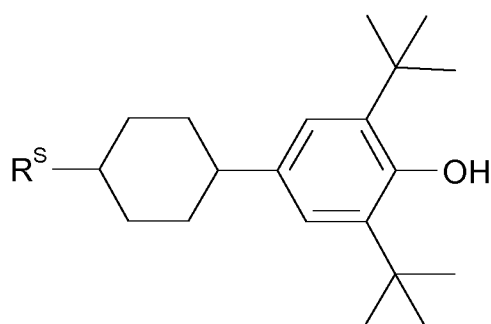
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S-1

10

15



S-2

20

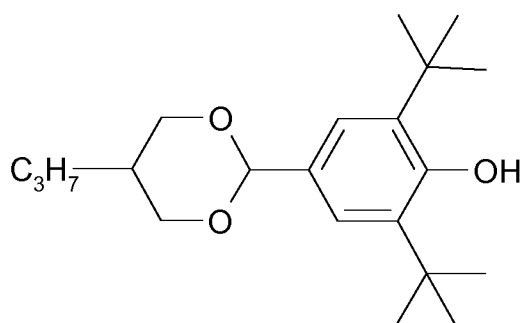
wherein

R^S denotes alkyl, alkoxy, fluorinated alkyl or fluorinated alkoxy having 1 to 9 C atoms, alkenyl, alkenyloxy or alkoxyalkyl having 2 to 9 C atoms.

25

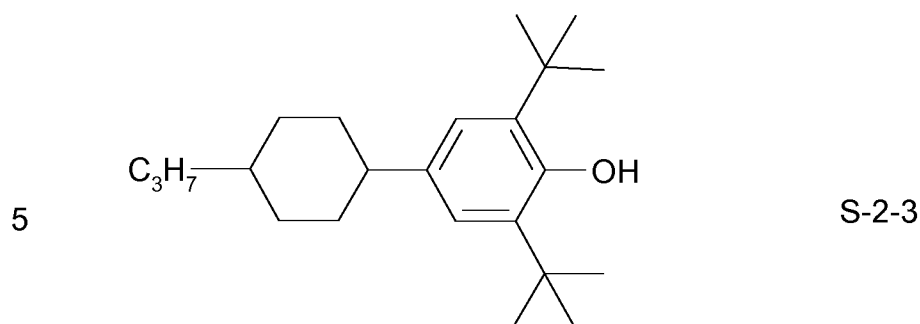
Particularly preferred structures of formula S-1 or S-2 are the compounds of formula S-1-3 and S-2-3:

30



S-1-3

35



10 For the purposes of the present invention, all concentrations are, unless explicitly noted otherwise, indicated in per cent by weight and relate to the corresponding mixture as a whole or mixture component, again a whole, unless explicitly indicated otherwise. In this context the term "the mixture" describes the liquid crystalline medium.

15 All temperature values indicated in the present application, such as, for example, the melting point $T(C,N)$, the smectic (S) to nematic (N) phase transition $T(S,N)$ and the clearing point $T(N,I)$, are indicated in degrees Celsius ($^{\circ}C$) and all temperature differences are correspondingly indicated in differential degrees ($^{\circ}$ or degrees), unless explicitly indicated otherwise.

20 For the present invention, the term "threshold voltage" relates to the capacitive threshold (V_0), also known as the Freedericks threshold, unless explicitly indicated otherwise.

25 All physical properties are and have been determined in accordance with "Merck Liquid Crystals, Physical Properties of Liquid Crystals", status Nov. 1997, Merck KGaA, Germany, and apply for a temperature of $20^{\circ}C$, and Δn is determined at 436 nm, 589 nm and at 633 nm, and $\Delta \epsilon$ at 1 kHz, unless explicitly indicated otherwise in each case.

30 The dielectric anisotropy of the compounds is determined here by dissolving 10% of the compounds in a liquid-crystalline host and determining the capacitance of the resultant mixture in each case in at least one test cell having a cell thickness of 20 μm with homeotropic and with homogeneous surface alignment at 1 kHz. The measurement voltage is typically 0.3 V to

35

1.0 V, but is always lower than the capacitive threshold of the respective liquid-crystal mixture investigated.

5 The threshold voltages, as well as all other electro-optical properties, are determined using test cells produced at Merck. The test cells for the determination of $\Delta\epsilon$ have a cell thickness of approximately 20 μm . The electrode is a circular ITO electrode having an area of 1.13 cm^2 and a guard ring. The orientation layers are SE-1211 from Nissan Chemicals, Japan, for homeotropic orientation ($\epsilon_{||}$) and polyimide AL-1054 from JSR, 10 Japan, for homogeneous orientation ($\epsilon_{\perp}$). The capacitances are determined using a Solatron 1260 frequency response analyser using a sine wave with a voltage of 0.3 V_{rms} . The light used in the electro-optical measurements is white light. A set-up using a commercially available DMS instrument from Autronic-Melchers, Germany, is used here. The character- 15 istic voltages have been determined under perpendicular observation. The threshold (V_{10}), mid-grey (V_{50}) and saturation (V_{90}) voltages have been determined for 10%, 50% and 90% relative contrast, respectively.

20 Unless indicated otherwise, a chiral dopant is not added to the liquid-crystal mixtures used, but the latter are also particularly suitable for applications in which doping of this type is necessary.

The rotational viscosity is determined using the rotating permanent magnet method and the flow viscosity in a modified Ubbelohde 25 viscometer. For liquid-crystal mixtures ZLI-2293, ZLI-4792 and MLC-6608, all products from Merck KGaA, Darmstadt, Germany, the rotational viscosity values determined at 20°C are 161 $\text{mPa}\cdot\text{s}$, 133 $\text{mPa}\cdot\text{s}$ and 186 $\text{mPa}\cdot\text{s}$ respectively, and the flow viscosity values (ν) are 21 $\text{mm}^2\cdot\text{s}^{-1}$, 14 $\text{mm}^2\cdot\text{s}^{-1}$ and 27 $\text{mm}^2\cdot\text{s}^{-1}$, respectively. 30

The dispersion of the materials may for practical purposes be conveniently characterized in the following way, which is used throughout this application unless explicitly stated otherwise. The values of the birefringence are determined at a temperature of 20°C at several fixed 35 wavelengths using a modified Abbé refractometer with homeotropically aligning surfaces on the sides of the prisms in contact with the material.

The birefringence values are determined at the specific wavelength values of 436 nm (respective selected spectral line of a low pressure mercury lamp), 589 nm (sodium "D" line) and 633 nm (wavelength of a HE-Ne laser (used in combination with an attenuator/diffusor in order to prevent damage to the eyes of the observers. In the following table Δn is given at 589 nm and $\Delta(\Delta n)$ is given as $\Delta(\Delta n) = \Delta n(436 \text{ nm}) - \Delta n(633 \text{ nm})$).

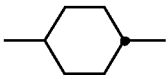
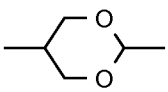
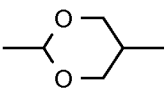
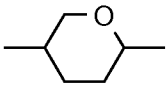
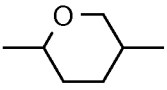
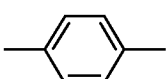
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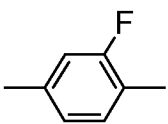
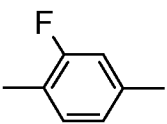
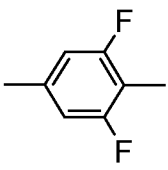
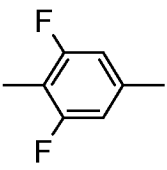
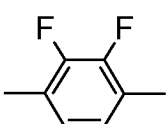
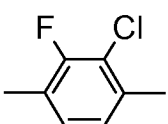
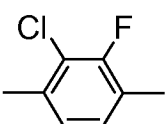
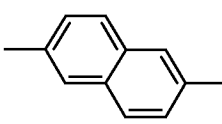
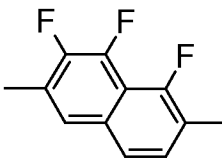
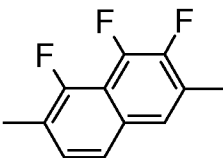
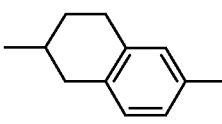
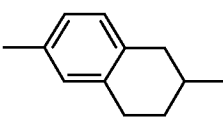
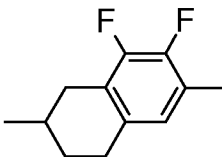
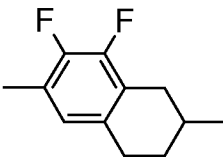
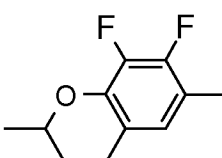
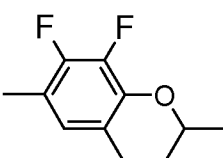
10	V_0	threshold voltage, capacitive [V] at 20°C,
	n_e	extraordinary refractive index measured at 20°C and 589 nm,
	n_o	ordinary refractive index measured at 20°C and 589 nm,
	Δn	optical anisotropy measured at 20°C and 589 nm,
	λ	wavelength λ [nm],
15	$\Delta n(\lambda)$	optical anisotropy measured at 20°C and wavelength λ ,
	$\Delta(\Delta n)$	change in optical anisotropy defined as: $\Delta n(20^\circ\text{C}, 436 \text{ nm}) - \Delta n(20^\circ\text{C}, 633 \text{ nm})$,
	$\Delta(\Delta n^*)$	"relative change in optical anisotropy" defined as: $\Delta(\Delta n)/\Delta n(20^\circ\text{C}, 589 \text{ nm})$,
20	$\varepsilon_\perp$	dielectric susceptibility perpendicular to the director at 20°C and 1 kHz,
	$\varepsilon_\parallel$	dielectric susceptibility parallel to the director at 20°C and 1 kHz,
	$\Delta\varepsilon$	dielectric anisotropy at 20°C and 1 kHz,
25	$T(N, I)$ or clp.	clearing point [°C],
	ν	flow viscosity measured at 20°C [mm ² ·s ⁻¹],
	γ_1	rotational viscosity measured at 20°C [mPa·s],
	k_{11}	elastic constant, "splay" deformation at 20°C [pN],
	k_{22}	elastic constant, "twist" deformation at 20°C [pN],
30	k_{33}	elastic constant, "bend" deformation at 20°C [pN],
	LTS	low-temperature stability of the phase, determined in test cells,
	VHR	voltage holding ratio,
	ΔVHR	decrease in the voltage holding ratio, and
35	S_{rel}	relative stability of the VHR,

The following examples explain the present invention without limiting it. However, they show the person skilled in the art preferred mixture concepts with compounds preferably to be employed and the respective concentrations thereof and combinations thereof with one another. In addition, the examples illustrate the properties and property combinations that are accessible.

For the present invention and in the following examples, the structures of the liquid-crystal compounds are indicated by means of acronyms, with the transformation into chemical formulae taking place in accordance with Tables A to C below. All radicals C_nH_{2n+1} , C_mH_{2m+1} and C_lH_{2l+1} or C_nH_{2n} , C_mH_{2m} and C_lH_{2l} are straight-chain alkyl radicals or alkylene radicals, in each case having n , m and l C atoms respectively. Preferably n , m and l are independently of each other 1, 2, 3, 4, 5, 6, or 7. Table A shows the codes for the ring elements of the nuclei of the compound, Table B lists the bridging units, and Table C lists the meanings of the symbols for the left- and right-hand end groups of the molecules. The acronyms are composed of the codes for the ring elements with optional linking groups, followed by a first hyphen and the codes for the left-hand end group, and a second hyphen and the codes for the right-hand end group. Table D shows illustrative structures of compounds together with their respective abbreviations.

Table A: Ring elements

C			
D		DI	
A		AI	
P			

	G		GI	
5	U		UI	
10	Y			
	P(F, Cl)Y		P(Cl,F)Y	
15	np			
20	n3f		nN3fl	
25	th		thl	
	tH2f		tH2fl	
30	o2f		o2fl	
35				

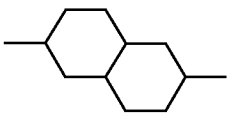
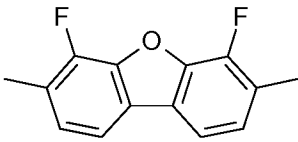
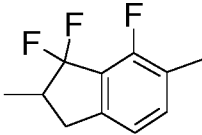
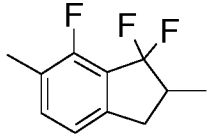
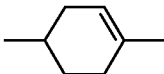
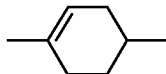
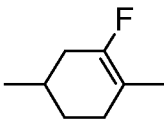
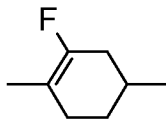
5	dh			
	B			
	K		KI	
	L		LI	
	F		FI	

Table B: Bridging units

20	E	-CH ₂ -CH ₂ -		
	V	-CH=CH-		
	T	-C≡C-		
	W	-CF ₂ -CF ₂ -		
	B	-CF=CF-		
	Z	-CO-O-	ZI	-O-CO-
	X	-CF=CH-	XI	-CH=CF-
	O	-CH ₂ -O-	OI	-O-CH ₂ -
	Q	-CF ₂ -O-	QI	-O-CF ₂ -

Table C: End groups

30	On the left individually or in combination		On the right individually or in combination	
	-n-	C _n H _{2n+1} -	-n	-C _n H _{2n+1}
	-nO-	C _n H _{2n+1} -O-	-nO	-O-C _n H _{2n+1}
	-V-	CH ₂ =CH-	-V	-CH=CH ₂
	-nV-	C _n H _{2n+1} -CH=CH-	-nV	-C _n H _{2n} -CH=CH ₂
	-Vn-	CH ₂ =CH-C _n H _{2n} -	-Vn	-CH=CH-C _n H _{2n+1}
	-nVm-	C _n H _{2n+1} -CH=CH-C _m H _{2m} -	-nVm	-C _n H _{2n} -CH=CH-C _m H _{2m+1}

5	-N-	N $\equiv$ C-	-N	-C $\equiv$ N
	-S-	S=C=N-	-S	-N=C=S
	-F-	F-	-F	-F
	-CL-	Cl-	-CL	-Cl
	-M-	CFH ₂ -	-M	-CFH ₂
	-D-	CF ₂ H-	-D	-CF ₂ H
	-T-	CF ₃ -	-T	-CF ₃
	-MO-	CFH ₂ O -	-OM	-OCFH ₂
	-DO-	CF ₂ HO -	-OD	-OCF ₂ H
	-TO-	CF ₃ O -	-OT	-OCF ₃
10	-A-	H-C $\equiv$ C-	-A	-C $\equiv$ C-H
	-nA-	C _n H _{2n+1} -C $\equiv$ C-	-An	-C $\equiv$ C-C _n H _{2n+1}
	-NA-	N $\equiv$ C-C $\equiv$ C-	-AN	-C $\equiv$ C-C $\equiv$ N

	On the left only in combination		On the right only in combination	
15	-...n...-	-C _n H _{2n} -	-...n...	-C _n H _{2n} -
	-...M...-	-CFH-	-...M...	-CFH-
	-...D...-	-CF ₂ -	-...D...	-CF ₂ -
	-...V...-	-CH=CH-	-...V...	-CH=CH-
	-...Z...-	-CO-O-	-...Z...	-CO-O-
	-...ZI...-	-O-CO-	-...ZI...	-O-CO-
	-...K...-	-CO-	-...K...	-CO-
	-...W...-	-CF=CF-	-...W...	-CF=CF-

in which n and m are each integers, and the three dots "..." are placeholders for other abbreviations from this table.

Besides the compounds of formula B, the mixtures according to the invention preferably comprise one or more compounds of the compounds mentioned below.

25

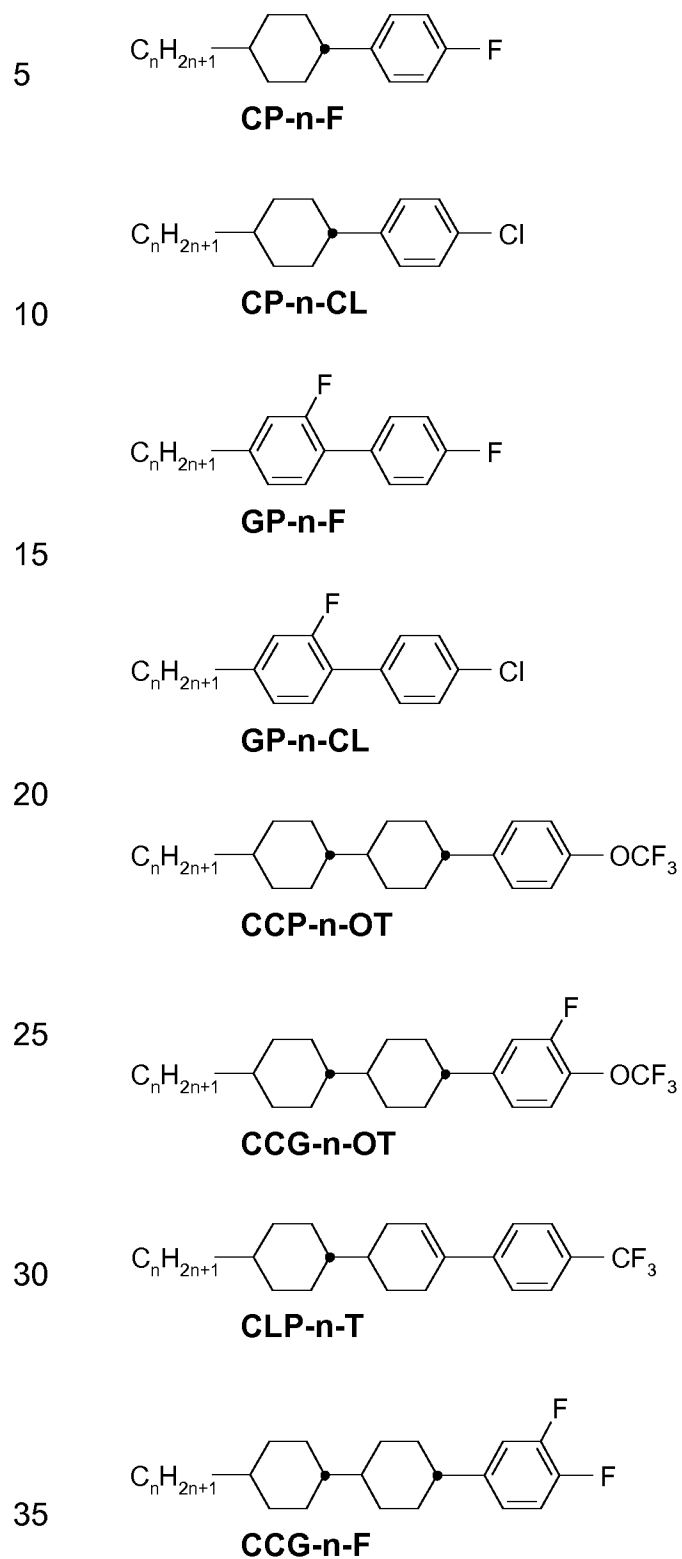
The following abbreviations are used:

(n, m, k and l are, independently of one another, each an integer, preferably 1 to 9 preferably 1 to 7, k and l possibly may be also 0 and preferably are 0 to 4, more preferably 0 or 2 and most preferably 2, n preferably is 1, 2, 3, 4 or 5, in the combination "-nO-" it preferably is 1, 2, 3 or 4, preferably 2 or 4, m preferably is 1, 2, 3, 4 or 5, in the combination "-Om" it preferably is 1, 2, 3 or 4, more preferably 2 or 4. The combination "-IVm" preferably is "2V1".)

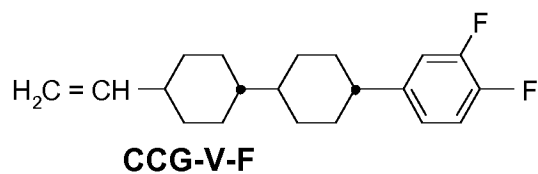
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Table D

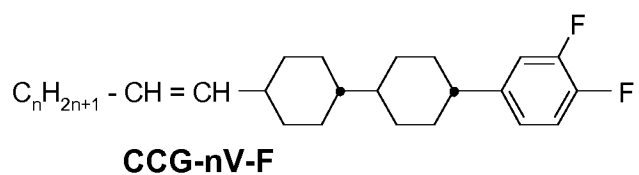
Exemplary, preferred dielectrically positive compounds



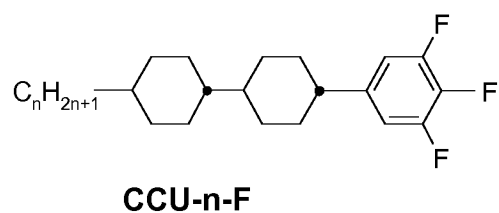
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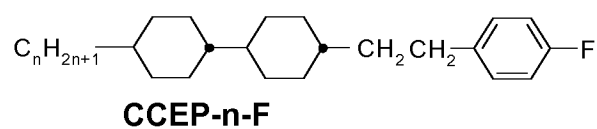
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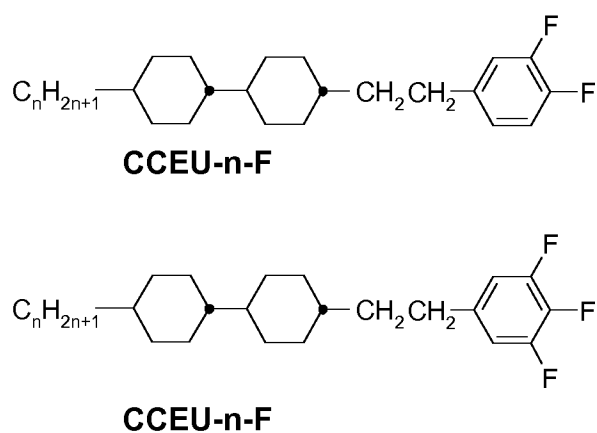
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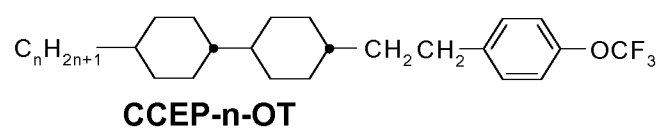
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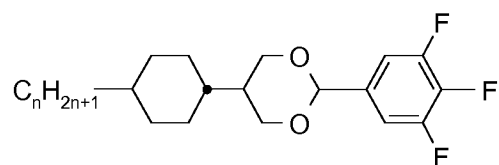
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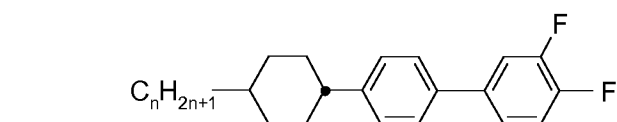
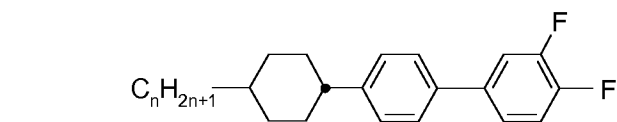
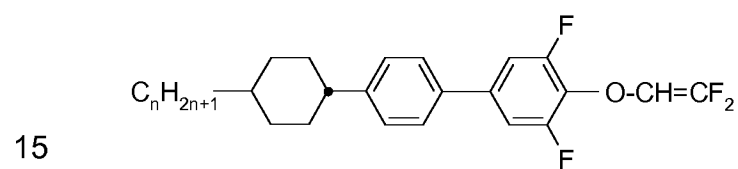
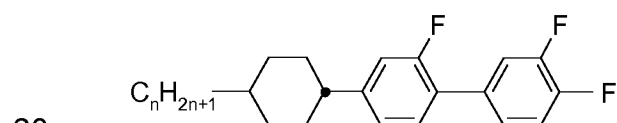
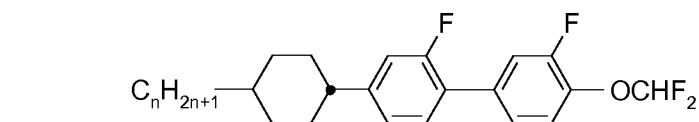
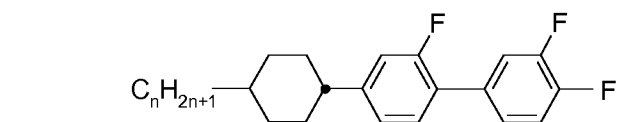
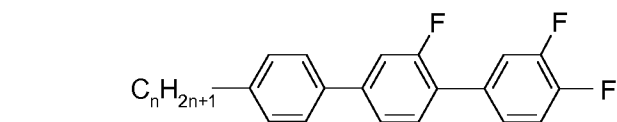


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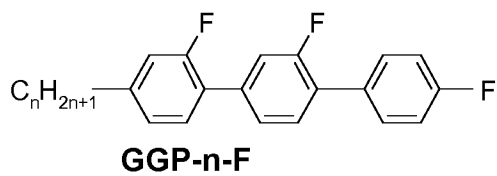


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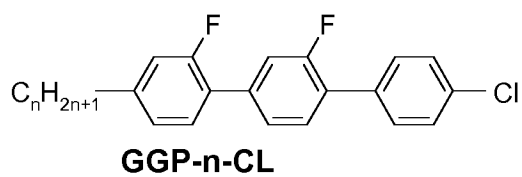


CDU-n-F**CPG-n-F****CPU-n-F****CPU-n-OXF****CGG-n-F****CGG-n-OD****CGU-n-F****PGU-n-F**

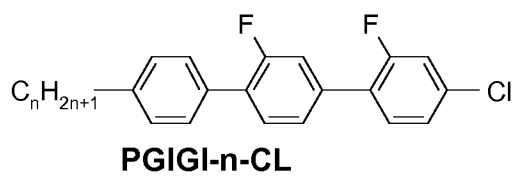
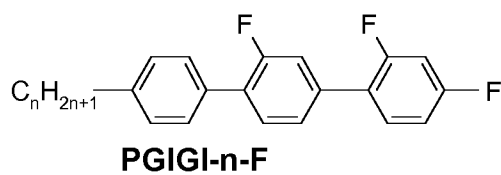
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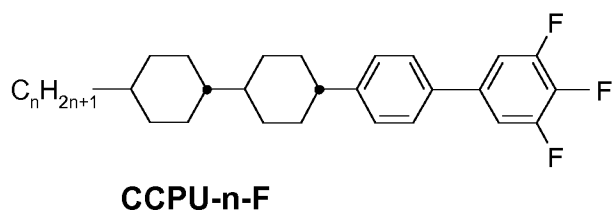
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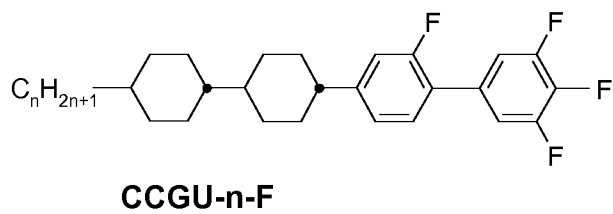
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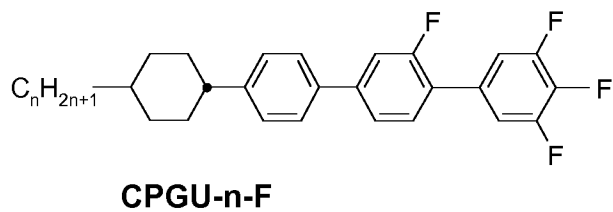
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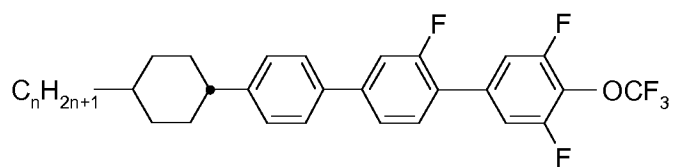
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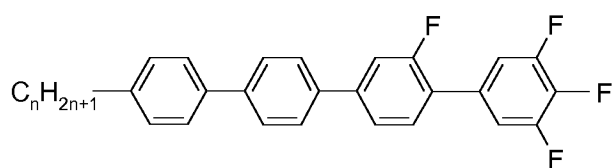
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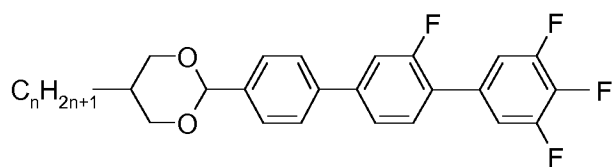
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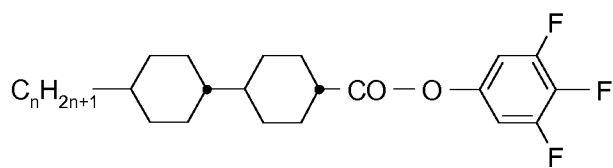
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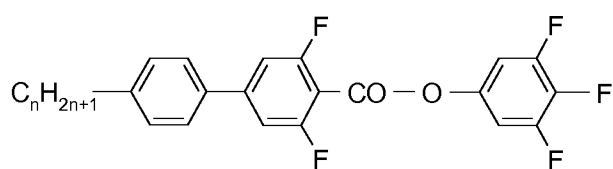
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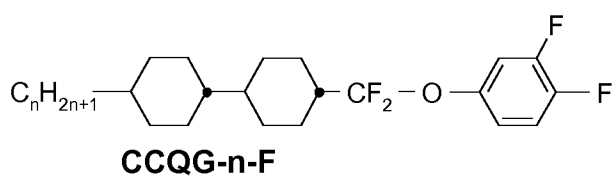
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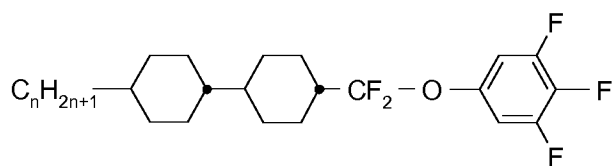
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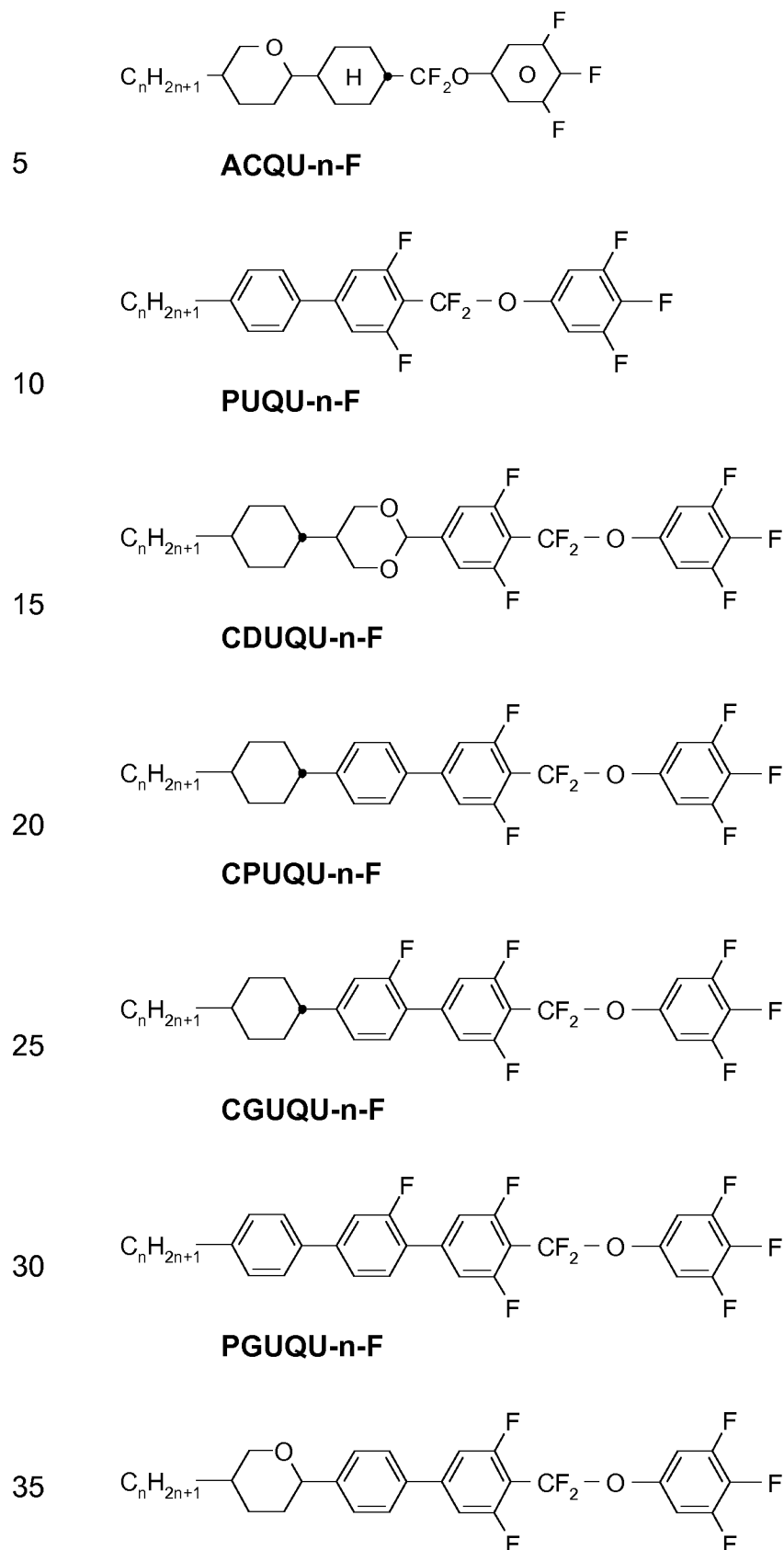
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**CCQG-n-F**

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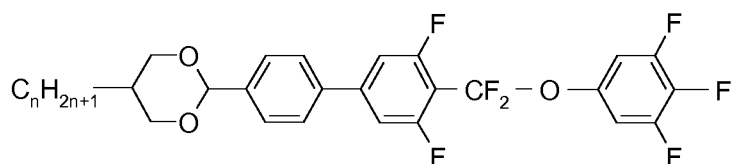
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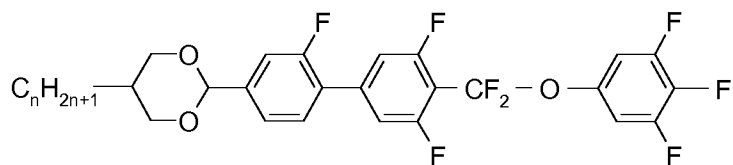


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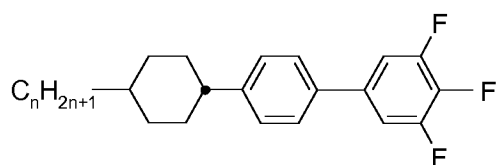
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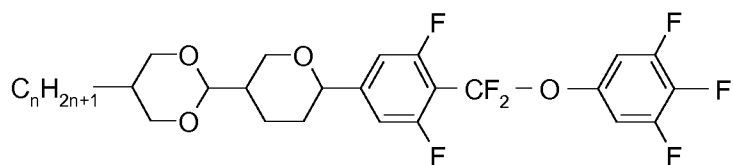
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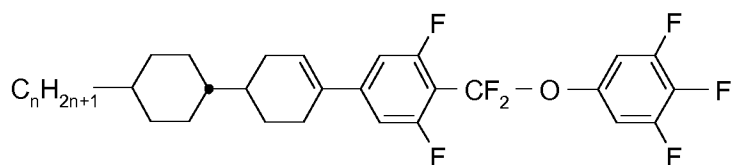
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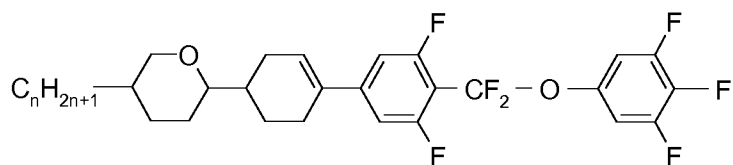
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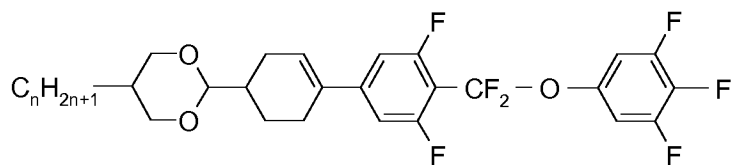
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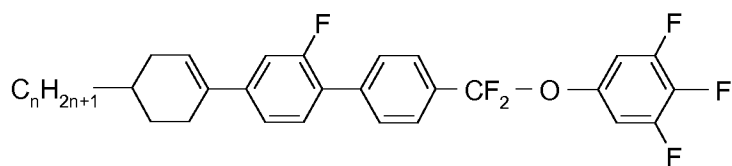
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**ALUQU-n-F**

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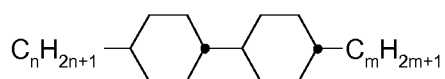
**DLUQU-n-F**

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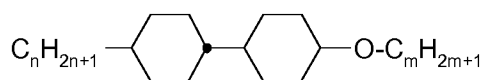
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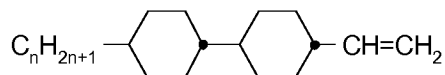
Exemplary, preferred dielectrically neutral compounds

**CC-n-m**

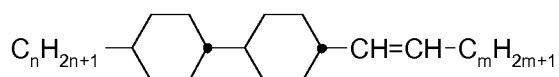
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**CC-n-Om**

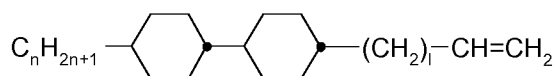
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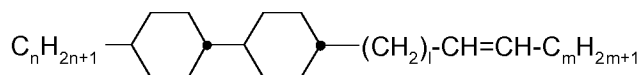
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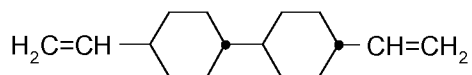
**CC-n-Vm**

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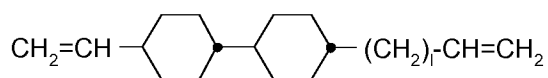
**CC-n-IV**

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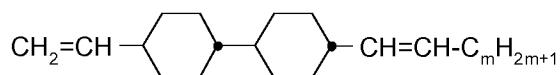
**CC-n-IVm**

**CC-V-V**

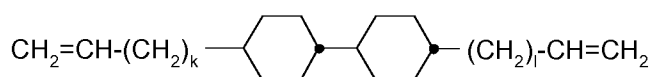
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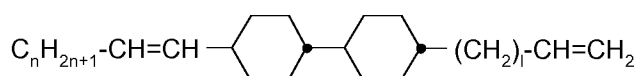
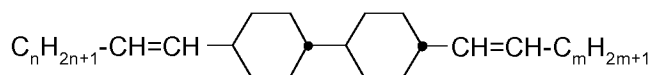
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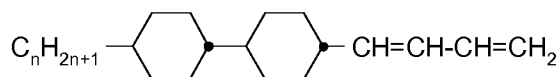
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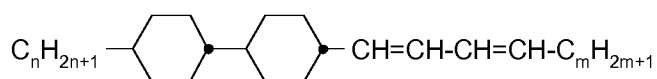
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**CC-nV-IV****CC-nV-Vm**

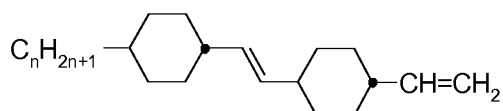
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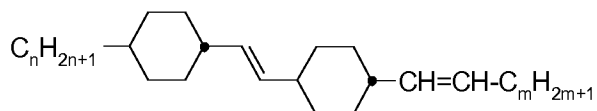
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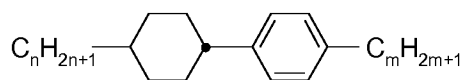
**CC-n-VVm**

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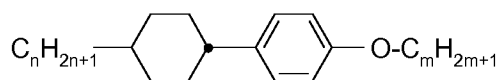
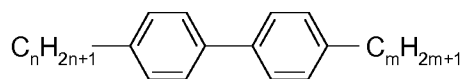
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**CVC-n-Vm**

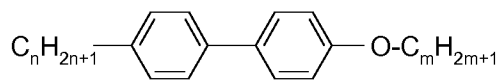
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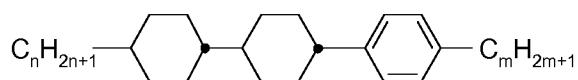
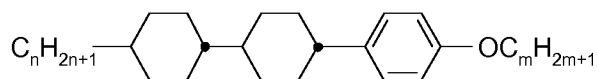
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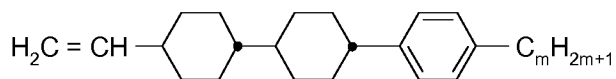
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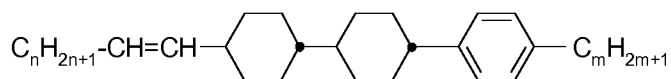
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**CCP-n-m****CCP-n-Om**

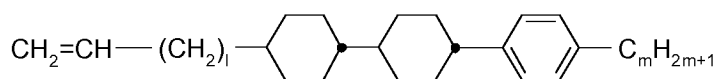
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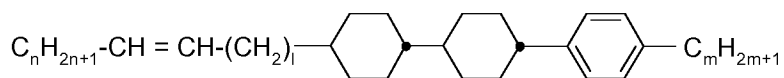
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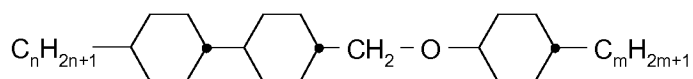
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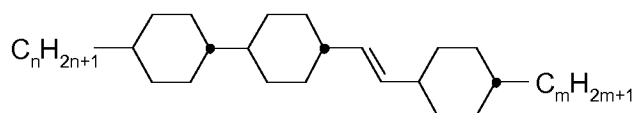
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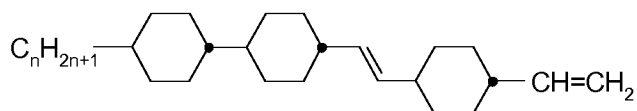
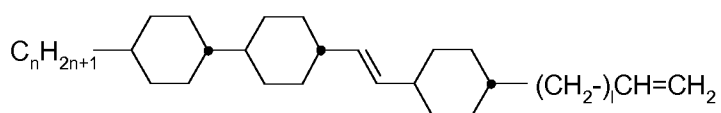
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**CCOC-n-m**

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**CCVC-n-m**

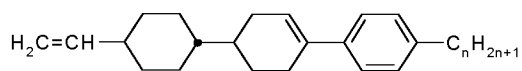
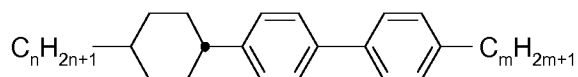
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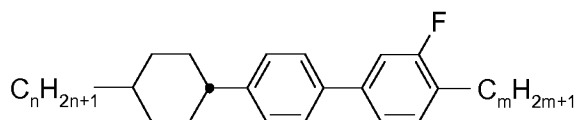
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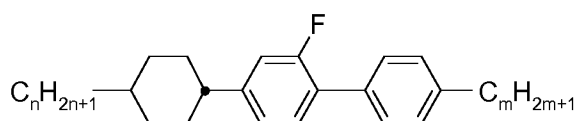
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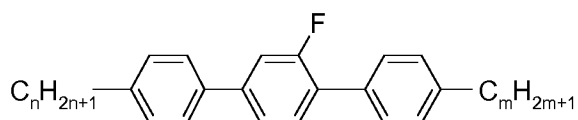
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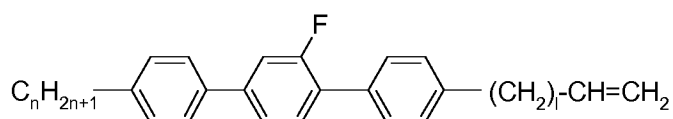
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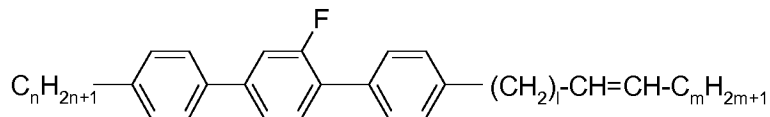
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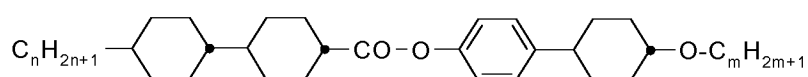
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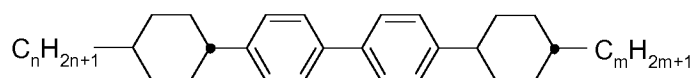
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**PGP-n-IVm**

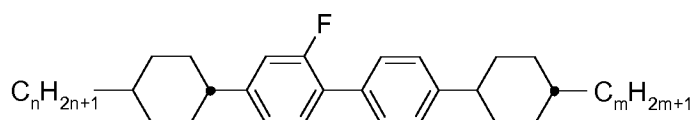
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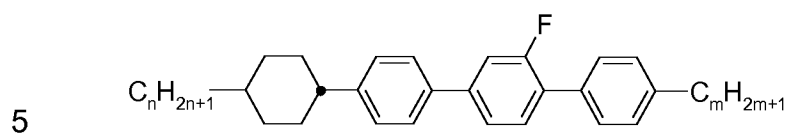
**CCZPC-n-m**

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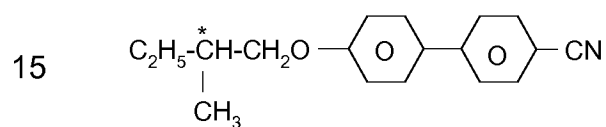
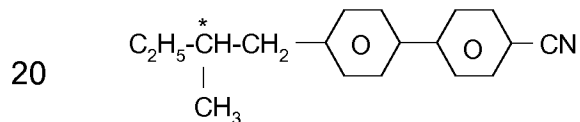
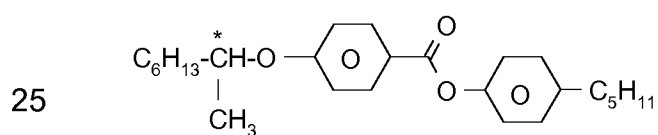
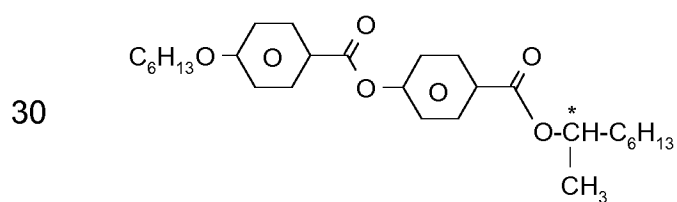
**CPPC-n-m**

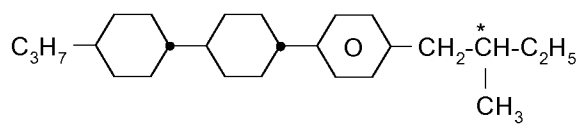
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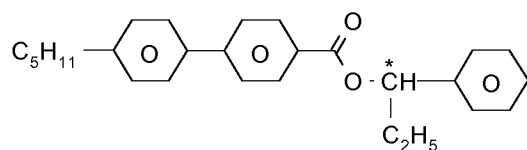
CGPC-n-m**CPGP-n-m**

10 Table E shows chiral dopants which are preferably employed in the mixtures according to the invention.

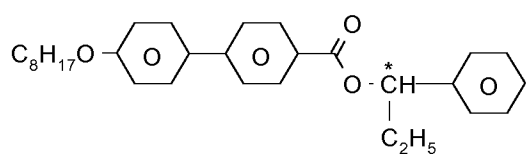
Table E**C 15****CB 15****CM 21****R S-811 / S-811**

**CM 44**

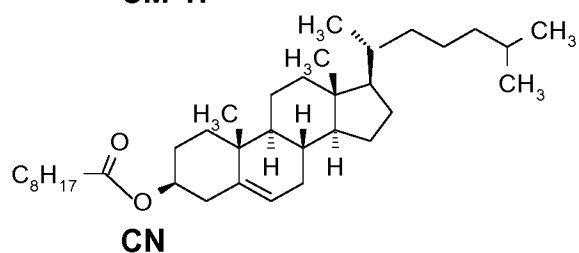
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**CM 45**

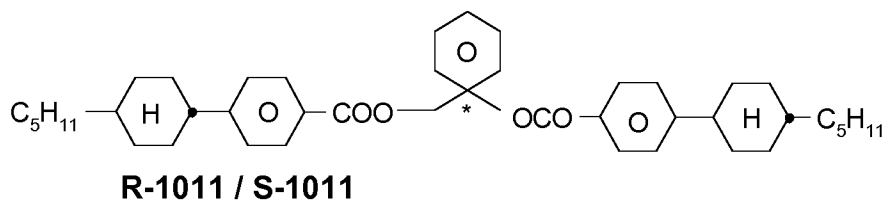
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**CM 47**

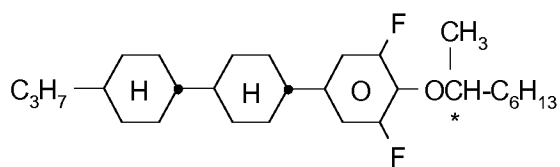
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**CN**

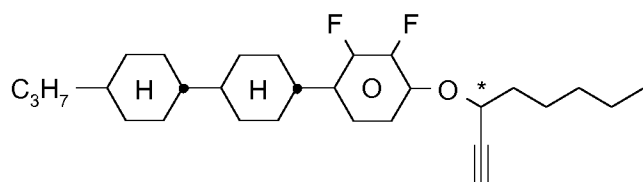
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**R-1011 / S-1011**

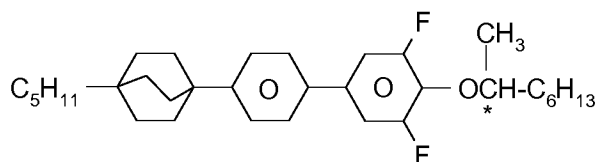
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**R-2011 / S-2011**

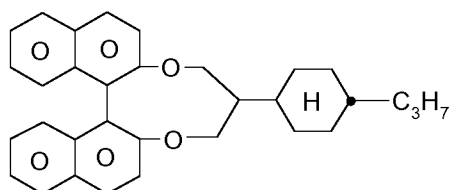
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**R-3011 / S-3011**

35

**R-4011 / S-4011**

5

**R-5011 / S-5011**

10

In a preferred embodiment of the present invention, the media according to the invention comprise one or more compounds selected from the group of the compounds from Table E.

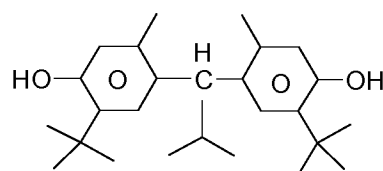
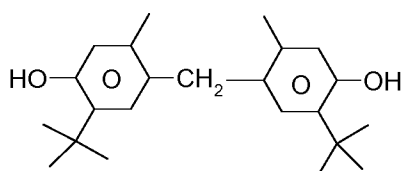
15

Table F shows stabilisers which can preferably be employed in the mixtures according to the invention in addition to the compounds of formula I. The parameter n here denotes an integer in the range from 1 to 12. In particular, the phenol derivatives shown can be employed as additional stabilisers since they act as antioxidants.

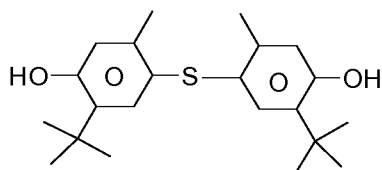
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Table F

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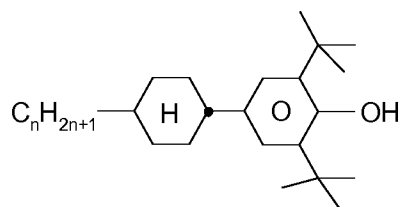
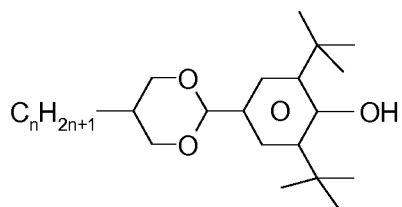


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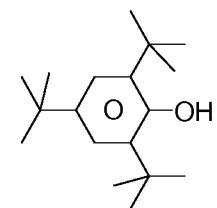
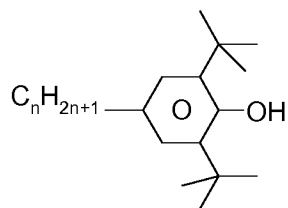


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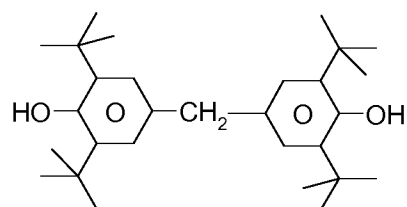
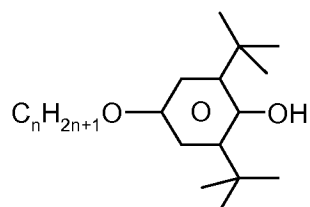
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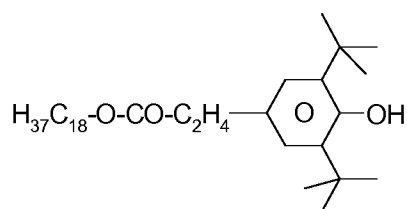
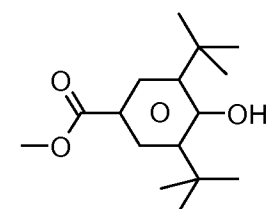
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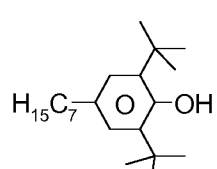
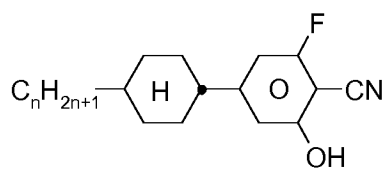
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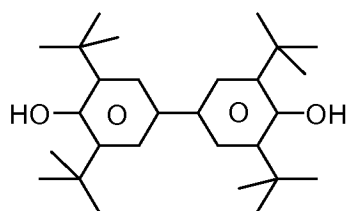
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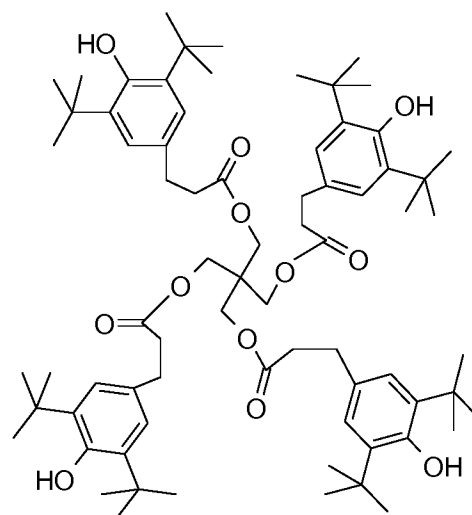
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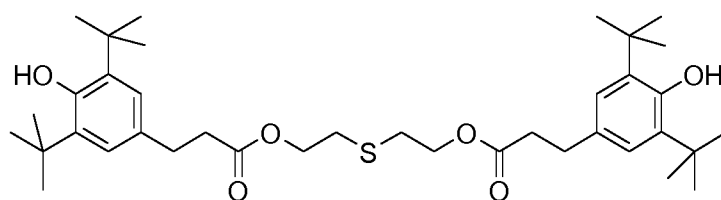
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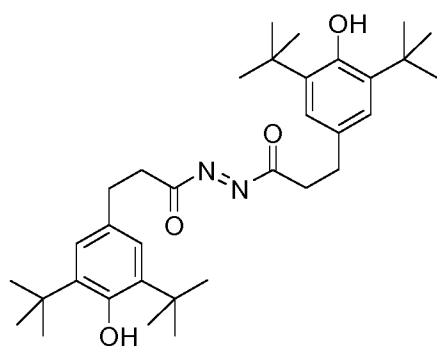
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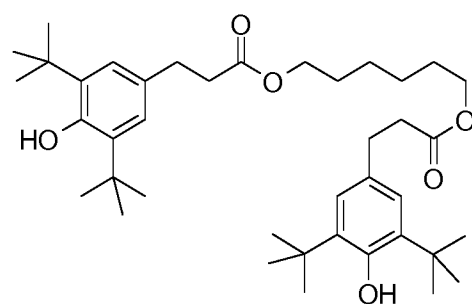
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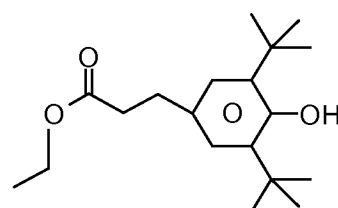
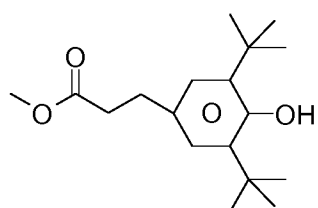
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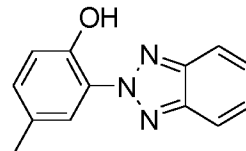
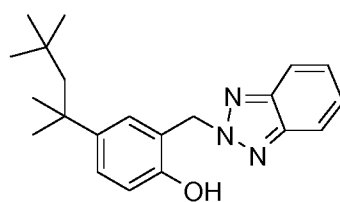
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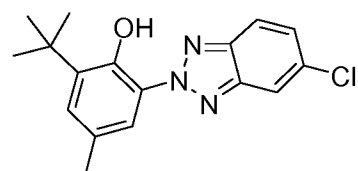
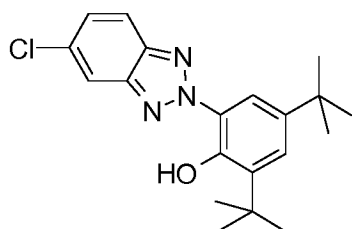
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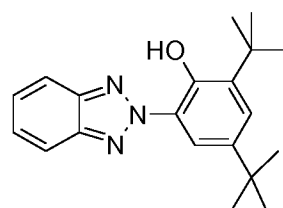
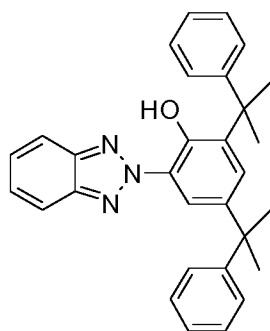
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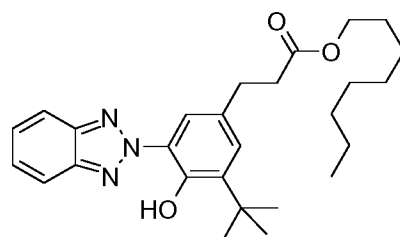
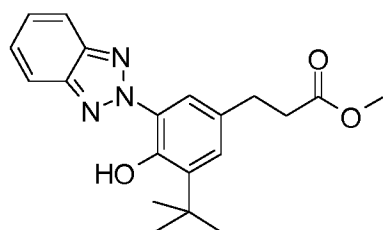
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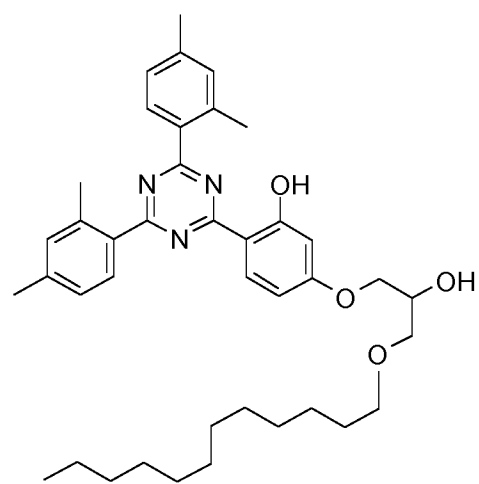
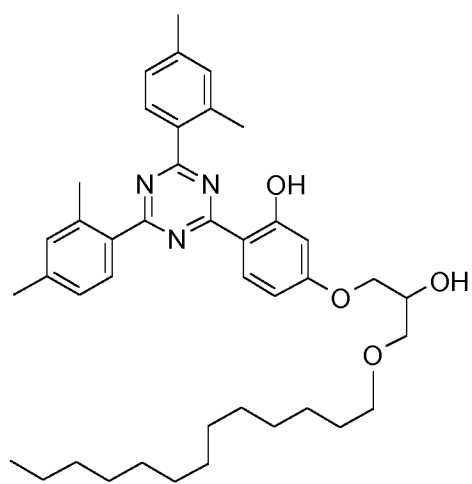


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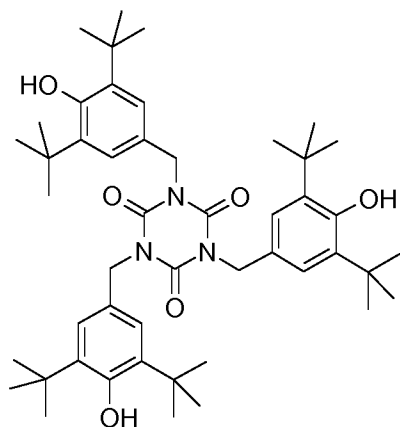
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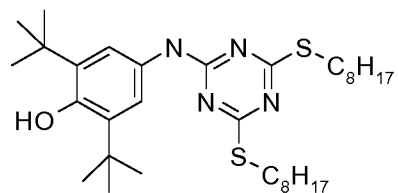
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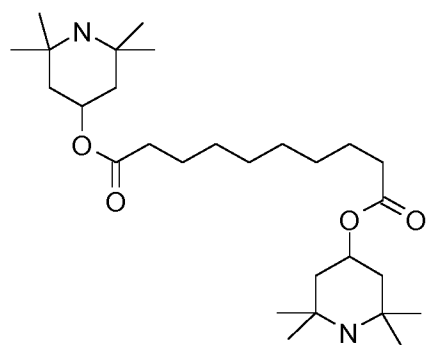
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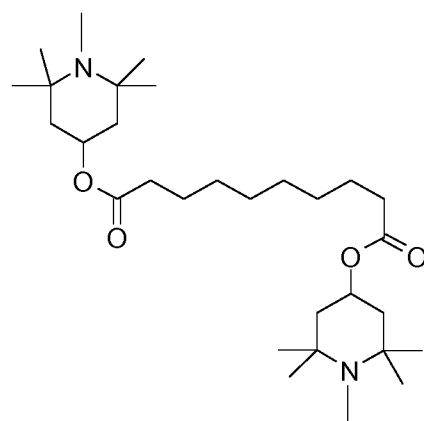
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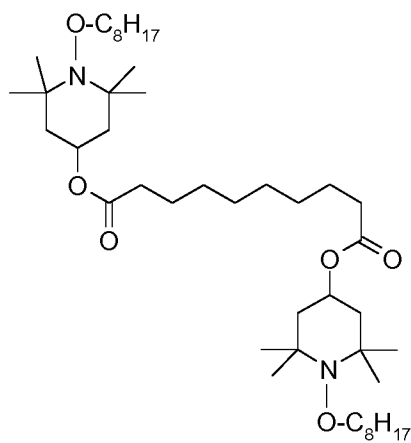
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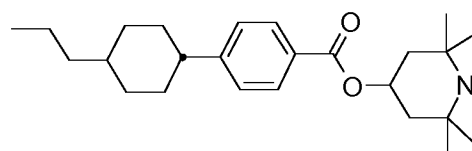
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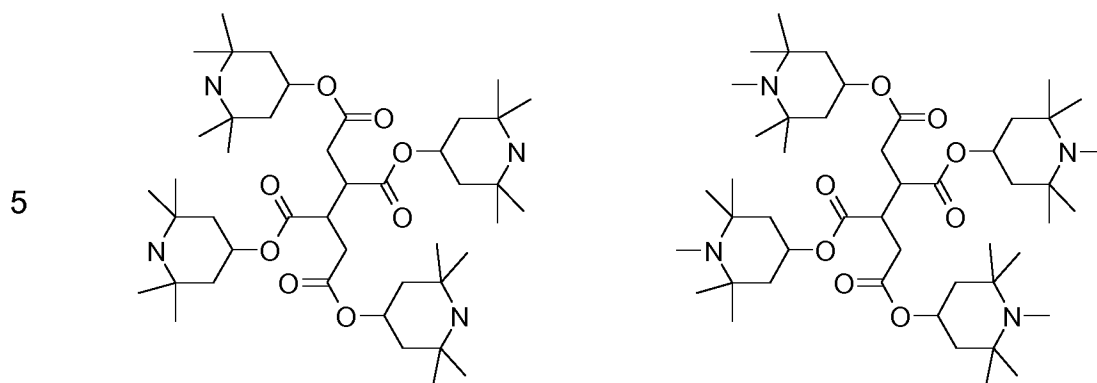
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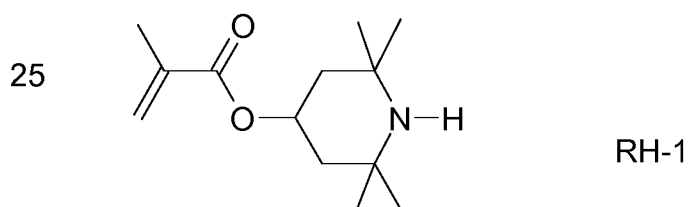


wherein n independently of each other is 1, 2, 3, 4, 5, 6, or 7.

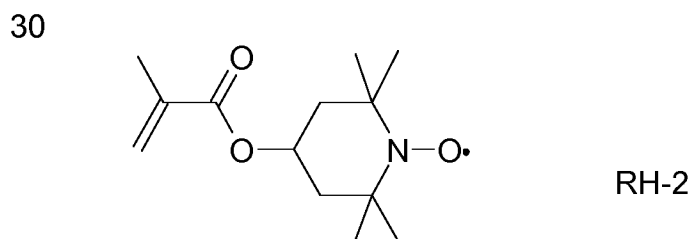
Examples

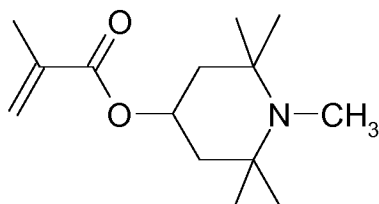
The following examples explain the present invention without restricting it in any way. However, the physical properties make it clear to the person skilled in the art what properties can be achieved and in what ranges they can be modified. In particular, the combination of the various properties which can preferably be achieved is thus well defined for the person skilled in the art.

The following polymerizable stabilizers (polymerizable piperidine derivatives) are used:



Source: Santa Cruz Biotechnology Inc. (CAS 31582-45-3)





RH-3

5

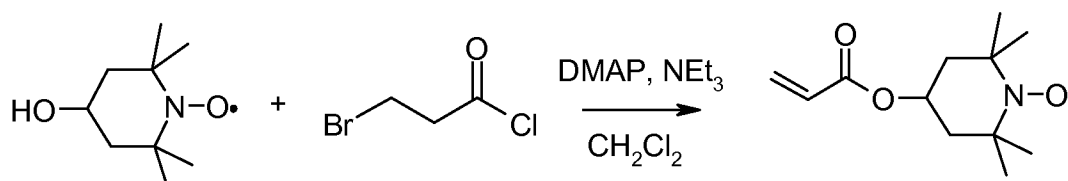
Synthesis example for additives

Exemplary compounds of formula I are synthesized as follows or according to WO 2016/116119 A1 (examples).

10

Synthesis Example

Compound **RH-2** is prepared as follows.



RH-2

20

4-hydroxyl TEMPO (8.00 g, 45.5 mmol) and 4-(dimethylamino)pyridine (0.30 g, 2.46 mmol) is added into 100 ml DCM. After cooled down to 2°C, triethylamine (25.00 ml, 180.35 mmol) is added to the above solution, followed by dropwise addition of 3-bromo-propionyl chloride (6.00 ml, 50.6 mmol) in 50 ml DCM. After complete addition, the reaction mixture is allowed to warm up to room temperature. After complete conversion indicated by TLC, aqueous ammonium chloride solution is added. The aqueous phase is extracted with DCM. The organic phase is combined and dried over anhydrous sodium sulfate, and filtrated. After removing solvent in vacuo, the solid residue is purified by column chromatography on silica gel with DCM/methyl t-butyl ether (MTBE) 95:5 as eluent, and further recrystallization from heptane/MTBE to afford **3** as red crystal (4.2 g, m.p. 102 °C).

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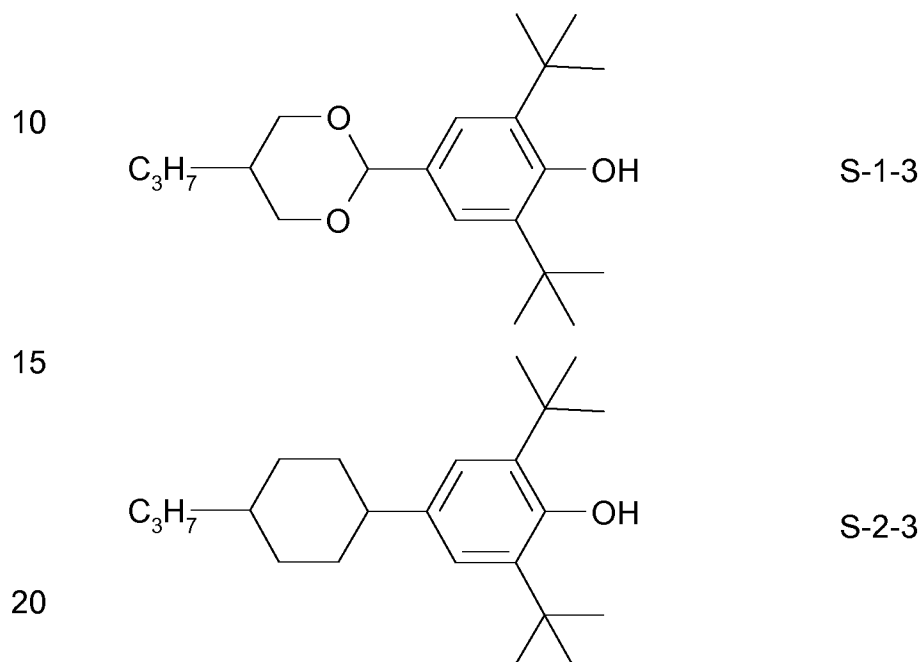
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$^1\text{H-NMR}$ (CDCl_3 , 500 MHz): δ (ppm): 6.54 (br. m., 1 H, H_{olefin}), 6.24 (br. m., 1 H, H_{olefin}), 6.00 (br. m., 1 H, H_{olefin}), MS (EI^+) m/z : $[\text{M}]^+$ Calcd. for $\text{C}_{12}\text{H}_{20}\text{NO}_3$: 226.3; Found 226.1.

5 Additional stabilizers

As an additional stabilizer a compound selected from structures S-1-3 or S-2-3 can advantageously be used, which have the following structures:



Mixture examples

25 For the production of the examples according to the present invention the following host mixtures **H1** to **H4** are used:

H1: Nematic host-mixture

30	APUQU-2-F	6.0 %	Clearing point [$^{\circ}\text{C}$]:	94
	APUQU-3-F	8.0 %	Δn (589 nm, 20°C):	0.1038
	CC-3-2V1	10.0 %	$\Delta \varepsilon$ (1 kHz, 20°C):	17.3
	CC-3-V	24.5 %	$\varepsilon_{\parallel}$ (1 kHz, 20°C):	21.1
	CC-3-V1	9.5 %	$\varepsilon_{\perp}$ (1 kHz, 20°C):	3.8
	CCP-30CF3	4.0 %	K_1 (20°C) [pN]:	15.9
35	CCQU-3-F	9.0 %	K_3 (20°C) [pN]:	16.1
	CDUQU-3-F	10 %	γ_1 (20°C) [mPa·s]:	111

	DGUQU-4-F	4.0 %		
	DPGU-4-F	5.0 %		
	PGUQU-3-F	3.0 %		
	PGUQU-4-F	7.0 %		
5	<u>H2: Nematic host-mixture</u>			
	CC-3-V	32.0 %	Clearing point [°C]:	93
	CC-3-V1	12.5 %	Δn (589 nm, 20°C):	0.1094
10	CCP-V2-1	6.0 %	$\Delta \epsilon$ (1 kHz, 20°C):	13.4
	CCP-30CF3	8.5 %	$\epsilon_{ }$ (1 kHz, 20°C):	16.9
	CCQU-3-F	2.0 %	$\epsilon_{\perp}$ (1 kHz, 20°C):	3.5
	PUQU-3-F	2.0 %	K_1 (20°C) [pN]:	14.7
	APUQU-2-F	9.0 %	K_3 (20°C) [pN]:	15.9
15	APUQU-3-F	9.0 %	γ_1 (20°C) [mPa·s]:	91
	PGUQU-3-F	5.0 %		
	PGUQU-4-F	8.0 %		
	DPGU-4-F	6.0 %		
20	<u>H3: Nematic host-mixture</u>			
	CC-3-V	36.0 %	Clearing point [°C]:	82.5
	CC-3-V1	9.0 %	Δn (589 nm, 20°C):	0.0968
	CCP-V2-1	5.0 %	$\Delta \epsilon$ (1 kHz, 20°C):	9.8
25	CCP-3F.F.F	9.0 %	$\epsilon_{ }$ (1 kHz, 20°C):	13.1
	CCP-30CF3	6.0 %	$\epsilon_{\perp}$ (1 kHz, 20°C):	3.3
	CCQU-5-F	5.0 %	K_1 (20°C) [pN]:	13.0
	CCGU-3-F	3.0 %	K_3 (20°C) [pN]:	15.0
	PUQU-3-F	6.0 %	γ_1 (20°C) [mPa·s]:	77
30	APUQU-3-F	6.0 %		
	PGUQU-3-F	3.0 %		
	PGUQU-4-F	9.0 %		
	PGUQU-5-F	3.0 %		

H4: Nematic host-mixture

	CC-3-V	36.0 %	Clearing point [°C]:	78
	CC-3-V1	5.0 %	Δn (589 nm, 20°C):	0.1095
5	CCP-V-1	8.0 %	$\Delta \epsilon$ (1 kHz, 20°C):	12.9
	PGP-2-2V	3.0 %	$\epsilon_{ }$ (1 kHz, 20°C):	16.6
	CCQU-3-F	9.5 %	$\epsilon_{\perp}$ (1 kHz, 20°C):	3.7
	PUQU-3-F	8.5 %	K_1 (20°C) [pN]:	12.1
	APUQU-2-F	5.0 %	K_3 (20°C) [pN]:	13.4
10	APUQU-3-F	8.0 %	γ_1 (20°C) [mPa·s]:	78
	PGUQU-3-F	4.0 %		
	PGUQU-4-F	8.0 %		
	PGUQU-5-F	5.0 %		

15 Comparative Example A

Mixture (A) is prepared by mixing the host mixture H1 with 0.05 % by weight of non-polymerizable stabilizer S-1-3. The mixture is investigated with regard to voltage holding ratio before and after backlight load test.

20 Mixture Example 1

To mixture (A) of the comparative example (A) the polymerizable additive RH-1 is added in a concentration of 0.01 % by weight.

Mixture Example 2

25 To mixture (A) of the comparative example (A) the polymerizable additive RH-2 is added in a concentration of 0.01 % by weight.

VHR measurement: Effect of polymerizable piperidine derivatives under backlight load

30 Test cells with (a) rubbed polyimide and (b) with photo-aligned polyimide are filled with the media of the preceding Examples. The voltage-holding ratio (VHR) of the test cells is measured before and after intensive light load (120 min) for (a) and (b) (Table 1 and 2). The irradiated light is equivalent to 500 h of a typical white CCFL backlight for displays.

35

Table 1: VHR Results, with rubbed polyimide (OPTMER® AL16301, JSR Corp.):

5	Mixture:	Ex. A (comparative)	Ex. 1	Ex. 2
	Backlight Load time / h	VHR / % at 60°C		
	0 (BL*)	98.0	97.4	97.4
	120 (BL)	75.4	94.1	96.0

*BL = Backlight Load test; 120 h accelerated LED-based backlight

Table 2: Results, with photo-aligned polyimide:

10	Mixture:	Ex. A (comparative)	Ex. 1	Ex. 2
	Backlight Load time / h	VHR / % at 60°C		
	0 (BL*)	99.6	99.6	99.7
	120 (BL)	96.9	97.8	99.8

15

*BL = Backlight Load test; 120 h accelerated LED-based backlight

Comparative Example B

20 Mixture (B) is prepared by mixing the host mixture H1 with 0.05 % by weight of non-polymerizable stabilizer S-2-3. The mixture is investigated with regard to voltage holding ratio before and after backlight load test.

Mixture Example 3

25 To mixture (B) of the comparative example (B) the polymerizable additive RH-1 is added in a concentration of 0.01 % by weight.

Mixture Example 4

30 To mixture (B) of the comparative example (B) the polymerizable additive RH-2 is added in a concentration of 0.01 % by weight.

VHR measurement: Effect of polymerizable piperidine derivatives under backlight load

35 Test cells with (a) rubbed polyimide and (b) with photo-aligned polyimide are filled with the media of the preceding Examples and VHR is measured as above (Table 3 and 4).

Table 3: VHR Results, with rubbed polyimide (OPTMER® AL16301, JSR Corp.):

Mixture:	Ex. B (comparative)	Ex. 3	Ex. 4
Backlight Load time / h	VHR / % at 60°C		
0 (BL*)	98.1	96.5	96.9
144 (BL)	82.7	96.6	97.0

*BL = Backlight Load test; 144 h accelerated LED-based backlight

Table 4: Results, with photo-aligned polyimide:

Mixture:	Ex. B (comparative)	Ex. 3	Ex. 4
Backlight Load time / h	VHR / % at 60°C		
0 (BL*)	99.8	99.5	99.7
120 (BL)	98.2	99.3	99.6

*BL = Backlight Load test; 120 h accelerated LED-based backlight

By using the polymerizable additives like the compound of the formula RH-1 or RH-2, the VHR drop after backlight load is avoided. The test cells filled with mixtures of Example 1 to 4 show little decrease of VHR after backlight load, while the comparative examples (Examples A and B) without any polymerizable additive show a considerable VHR drop.

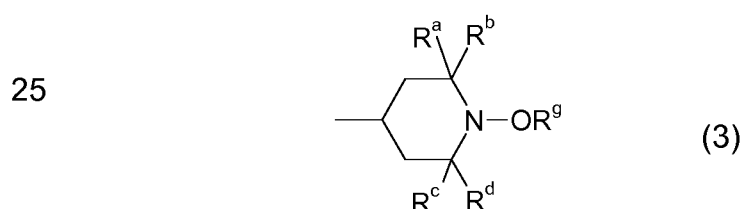
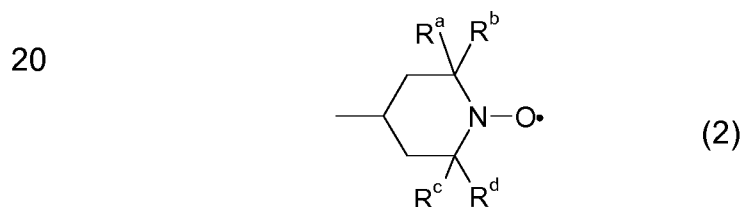
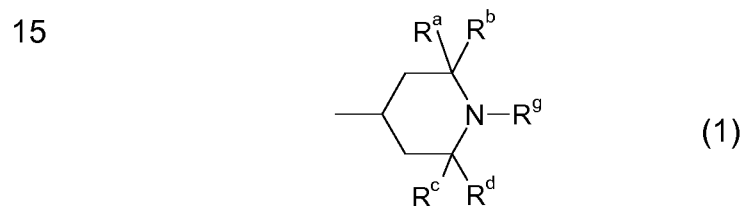
Patent Claims

1. Liquid-crystalline medium having a nematic phase and a dielectric anisotropy ($\Delta\epsilon$) of 1.5 or more characterized in that it comprises at least one polymerizable compound of the formula I or a polymer comprising its polymerized form,



- wherein the groups, independently of each other, and on each occurrence identically or differently, have the following meanings

T a group selected from the following formulae



- 30 R^g H or straight chain or branched alkyl or alkoxyalkyl with 1 to 10 C atoms, or benzyl,

R^a, R^b, R^c, R^d straight chain or branched alkyl with 1 to 10 C atoms,

- 35 P vinyloxy, acrylate, methacrylate, fluoroacrylate, chloroacrylate, oxetane or epoxy,

	Sp	a spacer group or a single bond,
5	A ¹ , A ²	an alicyclic, heterocyclic, aromatic or heteroaromatic group with 4 to 30 ring atoms, which may also contain fused rings, and is optionally substituted by one or more groups L or R-(A ³ -Z ³) _{m2} -, and one of A ¹ and A ² may also denote a single bond,
10	A ³	an alicyclic, heterocyclic, aromatic or heteroaromatic group with 4 to 30 ring atoms, which may also contain fused rings, and is optionally substituted by one or more groups L,
15	Z ¹	-O-, -S-, -CO-, -CO-O-, -O-CO-, -O-CO-O-, -OCH ₂ -, -CH ₂ O-, -SCH ₂ -, -CH ₂ S-, -CF ₂ O-, -OCF ₂ -, -CF ₂ S-, -SCF ₂ -, -(CH ₂) _n -, -CF ₂ CH ₂ -, -CH ₂ CF ₂ -, -(CF ₂) _n -, -CH=CH-, -CF=CF-, -CH=CF-, -CF=CH-, -C≡C-, -CH=CH-CO-O-, -O-CO-CH=CH-, -CH ₂ -CH ₂ -CO-O-, -O-CO-CH ₂ -CH ₂ -, -CR ⁰⁰ R ⁰⁰⁰ -, or a single bond, with the proviso that, if m1 is
20		0 and Sp is a single bond, Z ¹ is a single bond,
25	Z ² , Z ³	-O-, -S-, -CO-, -CO-O-, -O-CO-, -O-CO-O-, -OCH ₂ -, -CH ₂ O-, -SCH ₂ -, -CH ₂ S-, -CF ₂ O-, -OCF ₂ -, -CF ₂ S-, -SCF ₂ -, -(CH ₂) _n -, -CF ₂ CH ₂ -, -CH ₂ CF ₂ -, -(CF ₂) _n -, -CH=CH-, -CF=CF-, -CH=CF-, -CF=CH-, -C≡C-, -CH=CH-CO-O-, -O-CO-CH=CH-, -CH ₂ -CH ₂ -CO-O-, -O-CO-CH ₂ -CH ₂ -, -CR ⁰⁰ R ⁰⁰⁰ -, or a single bond,
30	R ⁰⁰ , R ⁰⁰⁰	H or alkyl having 1 to 12 C atoms,
35	R	P-Sp-, H, F, Cl, CN, or straight chain, branched or cyclic alkyl having 1 to 25 C atoms, wherein one or more non-adjacent CH ₂ -groups are optionally replaced by -O-, -S-, -CO-, -CO-O-, -O-CO-, -O-CO-O- in such a manner that O- and/or S-atoms are not directly connected with each other, and wherein one or more H atoms are each

optionally replaced by F, Cl or P-Sp-, or R is a group selected from formula 1, 2, 3 and 4,

5 L P-Sp-, F, Cl, CN, or straight chain, branched or cyclic alkyl having 1 to 25 C atoms, wherein one or more non-adjacent CH₂-groups are optionally replaced by -O-, -S-, -CO-, -CO-O-, -O-CO-, -O-CO-O- in such a manner that O- and/or S-atoms are not directly connected with each other, and wherein one or more H atoms are each
10 optionally replaced by F, Cl or P-Sp-, or L is a group selected from formula 1, 2, 3 and 4,

m1 0, 1, 2, 3 or 4,

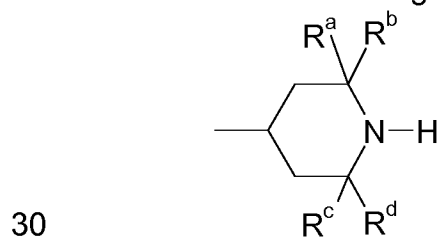
15 m2 0, 1, 2, 3 or 4, and

n 1, 2, 3 or 4.

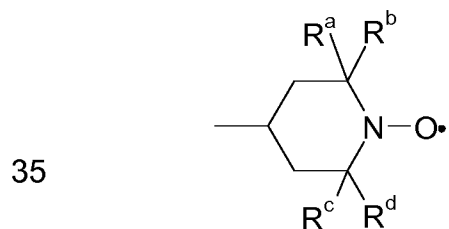
20 2. Medium according to Claim 1, characterized in that in formula I
m1 is 0 or 1.

3. Medium according to Claim 1 or 2, characterized in that the compounds of formula I are selected from the group of compounds of formulae, wherein

25 T is a group selected from



or



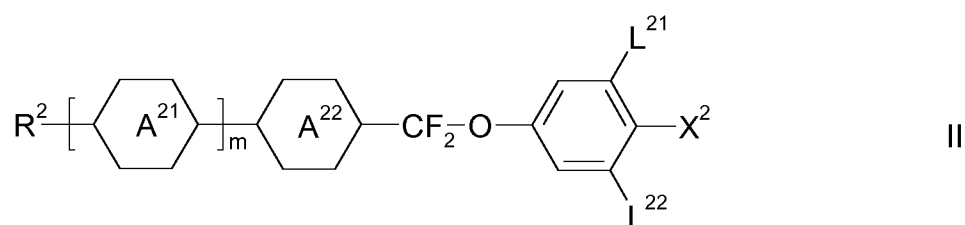
in which

R^a , R^b , R^c , R^d are independently straight chain or branched alkyl with 1 to 10 C atoms.

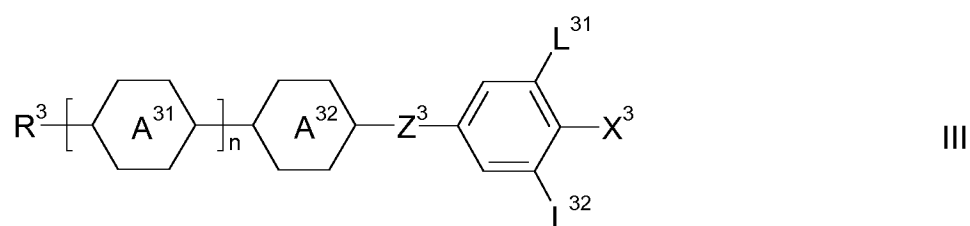
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4. Medium according to at least one of Claims 1 to 3, characterized in that it comprises one or more compounds selected from the group of compounds of formulae II and III.

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in which

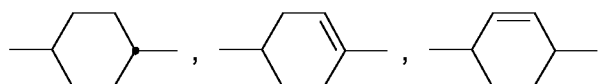
R^2 denotes alkyl, alkoxy, fluorinated alkyl or fluorinated alkoxy having 1 to 7 C atoms, alkenyl, alkenyloxy, alkoxyalkyl or fluorinated alkenyl having 2 to 7 C atoms,

25



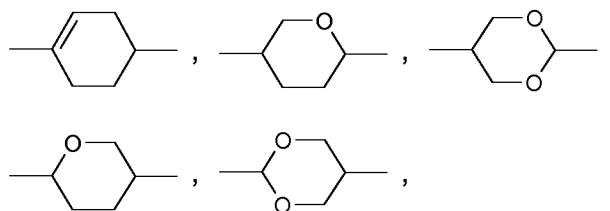
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on each appearance, independently of one another, denote

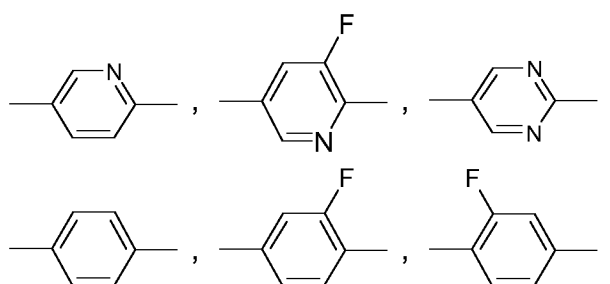


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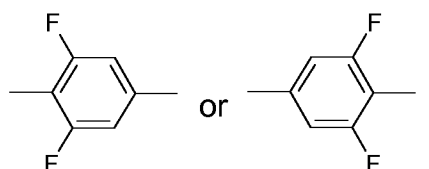
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L^{21} and L^{22} denote H or F,

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X^2 denotes halogen, halogenated alkyl or alkoxy having 1 to 3 C atoms or halogenated alkenyl or alkenyloxy having 2 or 3 C atoms,

m denotes 0, 1, 2 or 3,

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R^3 denotes alkyl, alkoxy, fluorinated alkyl or fluorinated alkoxy having 1 to 7 C atoms, alkenyl, alkenyloxy, alkoxyalkyl or fluorinated alkenyl having 2 to 7 C atoms

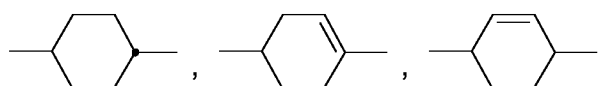
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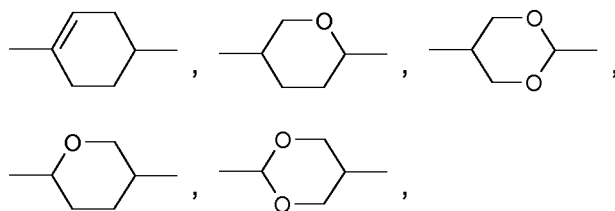
and

on each appearance, independently of one another, are

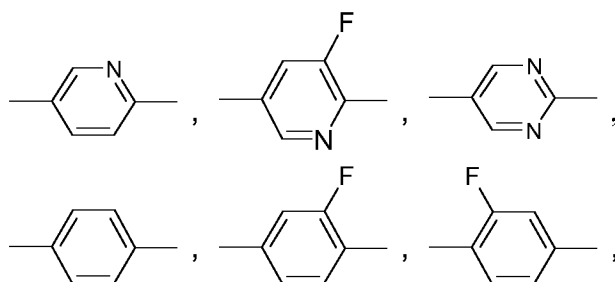
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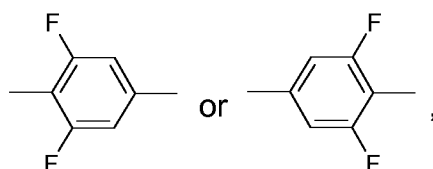
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L^{31} and L^{32} , independently of one another, denote H or F,

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X^3 denotes halogen, halogenated alkyl or alkoxy having 1 to 3 C atoms or halogenated alkenyl or alkenyloxy having 2 or 3 C atoms, F, Cl, $-OCF_3$, $-OCHF_2$, $-O-CH_2CF_3$, $-O-CH=CF_2$, $-O-CH=CH_2$ or $-CF_3$,

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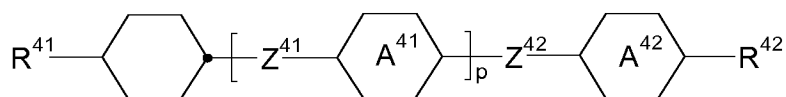
Z^3 denotes $-CH_2CH_2-$, $-CF_2CF_2-$, $-COO-$, *trans*- $CH=CH-$, *trans*- $CF=CF-$, $-CH_2O-$ or a single bond, and

n denotes 0, 1, 2 or 3.

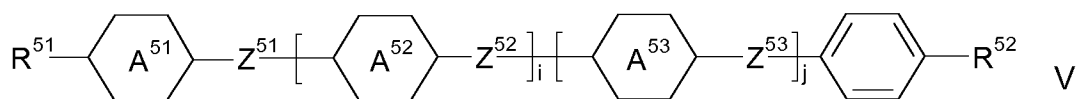
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5. Liquid-crystalline medium according to at least one of Claims 1 to 4, characterized in that it comprises one or more dielectrically neutral compounds selected from the group of formulae IV and V:

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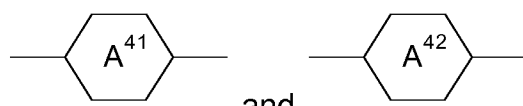


IV

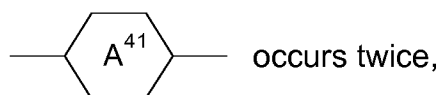


in which

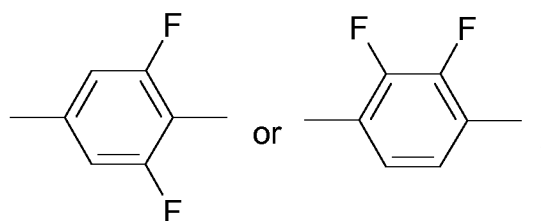
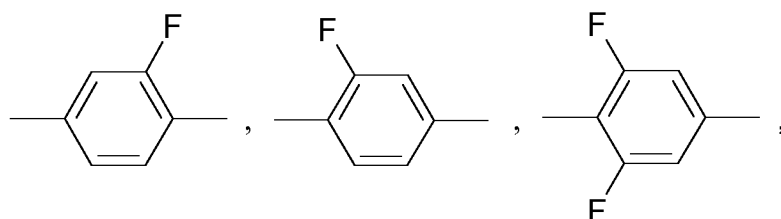
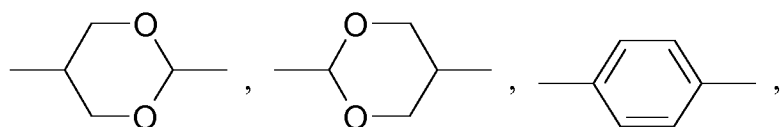
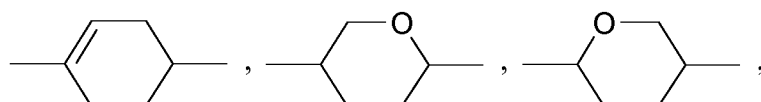
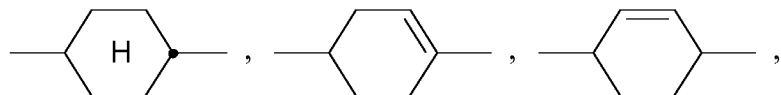
R^{41} and R^{42} , independently of one another, denote alkyl, alkoxy, fluorinated alkyl or fluorinated alkoxy having 1 to 7 C atoms, alkenyl, alkenyloxy, alkoxyalkyl or fluorinated alkenyl having 2 to 7 C atoms,



independently of one another and, if



also these independently of one another, denote



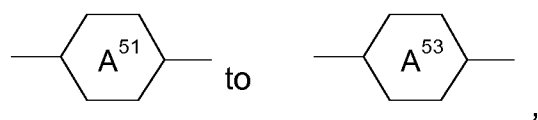
Z^{41} and Z^{42} , independently of one another and, if Z^{41} occurs twice, also these independently of one another, denote $-\text{CH}_2\text{CH}_2-$, $-\text{COO}-$, *trans*- $\text{CH}=\text{CH}-$, *trans*- $\text{CF}=\text{CF}-$, $-\text{CH}_2\text{O}-$, $-\text{CF}_2\text{O}-$, $-\text{C}\equiv\text{C}-$ or a single bond,

5

p denotes 0, 1 or 2,

R^{51} and R^{52} , independently of one another, denote alkyl, alkoxy, fluorinated alkyl or fluorinated alkoxy having 1 to 7 C atoms, alkenyl, alkenyloxy, alkoxyalkyl or fluorinated alkenyl having 2 to 7 C atoms,

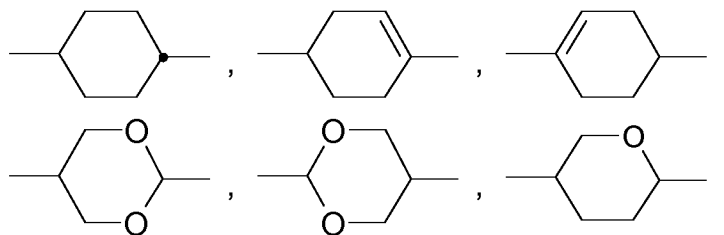
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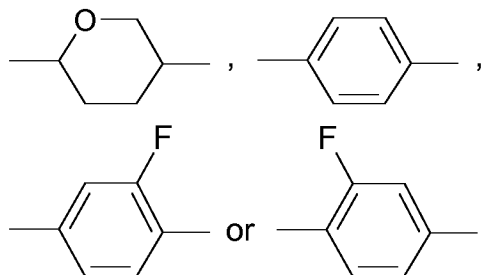
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if present, each, independently of one another, denote

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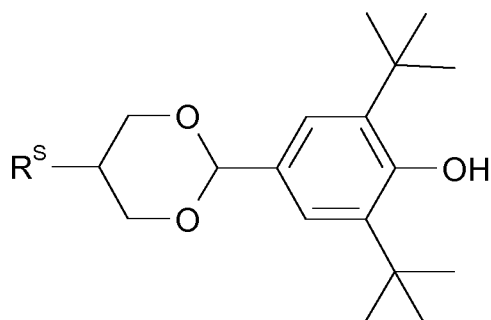
Z^{51} to Z^{53} each, independently of one another, denote $-\text{CH}_2\text{CH}_2-$, $-\text{CH}_2\text{O}-$, $-\text{CH}=\text{CH}-$, $-\text{C}\equiv\text{C}-$, $-\text{COO}-$ or a single bond, and

i and j each, independently of one another, denote 0 or 1.

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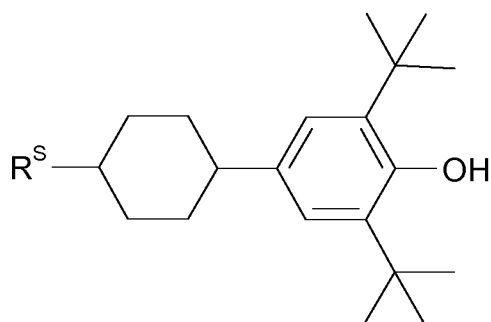
6. Liquid-crystalline medium according to Claim 5, characterized in that it comprises one or more compounds selected from the group of formulae S-1 and S-2

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S-1

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S-2

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wherein

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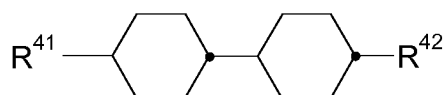
R^S denotes alkyl, alkoxy, fluorinated alkyl or fluorinated alkoxy having 1 to 9 C atoms, or alkenyl, alkenyloxy or alkoxyalkyl having 2 to 9 C atoms.

7. Medium according to at least one of Claims 1 to 6, characterized in that the total concentration of the compounds of formula I in the medium as a whole is 0.001 % or more to 0.05 % or less.

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8. Medium according to at least one of Claims 1 to 7, characterized in that it additionally comprises one or more compounds of formula IV-A

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IV-A

in which

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R⁴¹ denotes an unsubstituted alkyl radical having 1 to 7 C atoms or an unsubstituted alkenyl radical having 2 to 7 C atoms, and

5 R⁴² denotes an unsubstituted alkyl radical having 1 to 7 C atoms, an unsubstituted alkenyl radical having 2 to 7 C atoms, or an unsubstituted alkoxy radical having 1 to 6 C atoms.

10 9. Electro-optical display or electro-optical component, characterized in that it comprises a liquid-crystalline medium according to at least one of Claims 1 to 8.

10. Display according to Claim 9, characterized in that it is based on the IPS- or FFS mode.

15 11. Display according to Claim 9 or 10, characterized in that it contains an active-matrix addressing device.

20 12. Use of a medium according to at least one of Claims 1 to 8 in an electro-optical display or in an electro-optical component.

25 13. Process for the preparation of a liquid-crystalline medium according to one or more of Claims 1 to 8, characterized in that one or more compounds of formula I are mixed with one or more additional mesogenic compounds and optionally one or more additives.

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INTERNATIONAL SEARCH REPORT

International application No
PCT/EP2018/053988

A. CLASSIFICATION OF SUBJECT MATTER		
INV. C09K19/54	C09K19/04	C09K19/34 C09K19/12 C09K19/30
ADD.		
According to International Patent Classification (IPC) or to both national classification and IPC		
B. FIELDS SEARCHED		
Minimum documentation searched (classification system followed by classification symbols) C09K		
Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched		
Electronic data base consulted during the international search (name of data base and, where practicable, search terms used) EPO-Internal, WPI Data		
C. DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	WO 2016/116119 A1 (MERCK PATENT GMBH [DE]) 28 July 2016 (2016-07-28) cited in the application	1-5,7-13
Y	page 1, lines 3-7; claim 1; compounds (1),(2),(3) page 145, lines 20-23 pages 141-143	6
X	DE 10 2011 119144 A1 (MERCK PATENT GMBH [DE]) 14 June 2012 (2012-06-14)	1-5,7-13
Y	paragraph [0001]; examples; compounds I-1b-3, I-1b-4	6
Y	WO 2012/076104 A1 (MERCK PATENT GMBH [DE]; GOEBEL MARK [DE]; MONTENEGRO ELVIRA [DE]; MANA) 14 June 2012 (2012-06-14)	6
A	page 23; example 4.2; compounds OH-1, OH-2 ----- -/-	1-5,7-13
☒ Further documents are listed in the continuation of Box C. ☒ See patent family annex.		
* Special categories of cited documents : "A" document defining the general state of the art which is not considered to be of particular relevance "E" earlier application or patent but published on or after the international filing date "L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified) "O" document referring to an oral disclosure, use, exhibition or other means "P" document published prior to the international filing date but later than the priority date claimed "T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention "X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone "Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art "&" document member of the same patent family		
Date of the actual completion of the international search 23 April 2018		Date of mailing of the international search report 02/05/2018
Name and mailing address of the ISA/ European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Fax: (+31-70) 340-3016		Authorized officer Schoenhentz, Jérôme

INTERNATIONAL SEARCH REPORT

International application No
PCT/EP2018/053988

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A,P	EP 3 263 673 A1 (MERCK PATENT GMBH [DE]) 3 January 2018 (2018-01-03) claims; examples; compounds RH-1, RH-2, RH-3 -----	1-13

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No

PCT/EP2018/053988

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
WO 2016116119 A1	28-07-2016	CN 107109228 A EP 3247774 A1 JP 2018504494 A KR 20170105553 A TW 201631132 A US 2018010046 A1 WO 2016116119 A1	29-08-2017 29-11-2017 15-02-2018 19-09-2017 01-09-2016 11-01-2018 28-07-2016
DE 102011119144 A1	14-06-2012	DE 102011119144 A1 TW 201231628 A WO 2012076121 A1	14-06-2012 01-08-2012 14-06-2012
WO 2012076104 A1	14-06-2012	CN 103249809 A EP 2649153 A1 JP 5784746 B2 JP 2014505745 A KR 20140032964 A TW 201229217 A US 2013258268 A1 WO 2012076104 A1	14-08-2013 16-10-2013 24-09-2015 06-03-2014 17-03-2014 16-07-2012 03-10-2013 14-06-2012
EP 3263673 A1	03-01-2018	CN 107557024 A EP 3263673 A1 JP 2018016791 A KR 20180003462 A US 2018002604 A1	09-01-2018 03-01-2018 01-02-2018 09-01-2018 04-01-2018