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(54) **Title:** LIQUID CRYSTAL MIXTURE AND LIQUID CRYSTAL DISPLAY

(57) **Abstract:** The invention relates to a process for the fabrication of a light modulation element, preferably operated in the IPS/FFS mode, comprising at least the steps of: a) providing a first substrate which includes a pixel electrode and a common electrode for generating an electric field substantially parallel to a surface of the first substrate in the pixel region; b) providing a second substrate, the second substrate being disposed opposite to the first substrate; c) interposing a dual frequency liquid crystal mixture that additionally comprises one or one or more polymerizable liquid crystalline compounds; d) applying an electric field to the liquid crystal mixture having a frequency in the range of from 0.01 Hz to 1500 kHz and subsequently irradiating the liquid crystal mixture with actinic radiation. The invention further relates to a light modulation element obtainable from a process as described above and below, to the use of such light modulation element and to an electrooptical device comprising such light modulation element. Preferably, the electrooptical device is an IPS or FFS display.

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Liquid Crystal Mixture and Liquid Crystal Display

Summary of the Invention

The invention relates to a process for the fabrication of a light modulation element, preferably operated in the IPS/FFS mode, comprising at least the steps of:

a) providing a first substrate which includes a pixel electrode and a common electrode for generating an electric field substantially parallel to a surface of the first substrate in the pixel region;
b) providing a second substrate, the second substrate being disposed opposite to the first substrate;
c) interposing a dual frequency liquid crystal mixture that additionally comprises one or one or more polymerizable liquid crystalline compounds;
d) applying an electric field to the liquid crystal mixture having a frequency in the range of from 0.01Hz to 1500 kHz and subsequently irradiating the liquid crystal mixture with actinic radiation.

The invention further relates to a light modulation element obtainable from a process as described above and below, to the use of such light modulation element and to an electrooptical device comprising such light modulation element. Preferably, the electrooptical device is an IPS or FFS display.

Light modulation elements operable in the FFS/IPS mode produced with method in accordance with the present invention preferably exhibit, more preferably at the same time,

- a favorable dark state,
- a favorable voltage holding ratio,
- a favorable transmission,
- a favorable operational voltage

- a favorable switching time
- a favorable reliability performance,

and can be produced by common known methods of mass production without changing the equipment or setup of modern display production lines.

Background and Prior Art

Liquid-crystalline media have been used for decades in electro-optical displays for information display. The liquid crystal displays used at present are usually those of the TN ("twisted nematic") type. However, these have the disadvantage of a strong viewing-angle dependence of the contrast.

In addition, so-called VA ("vertically aligned") displays are known which have a broader viewing angle. The LC cell of a VA display contains a layer of an LC medium between two transparent electrodes, where the LC medium usually has a negative value of the dielectric (DC) anisotropy. In the switched-off state, the molecules of the LC layer are aligned perpendicular to the electrode surfaces (homeotropically) or have a tilted homeotropic alignment. On application of an electrical voltage to the two electrodes, a realignment of the LC molecules parallel to the electrode surfaces takes place. Furthermore, so-called IPS ("in plane switching") displays and later, FFS ("fringe-field switching") displays have been reported (see, inter alia, S.H. Jung et al., Jpn. J. Appl. Phys., Volume 43, No. 3, 2004, 1028), which contain two electrodes on the same substrate, one of which is structured in a comb-shaped manner and the other is unstructured. A strong, so-called "fringe field" is thereby generated, i.e. a strong electric field close to the edge of the electrodes, and, throughout the cell, an electric field which has both a strong vertical component and a strong horizontal component. FFS displays have a low viewing-angle dependence of the contrast. FFS displays usually contain an LC medium with positive dielectric anisotropy, and an alignment layer, usually of polyimide, which provides planar alignment to the molecules of the LC medium.

Furthermore, FFS displays have been disclosed (see S.H. Lee et al., Appl. Phys. Lett. 73(20), 1998, 2882-2883 and S.H. Lee et al., Liquid Crystals 39(9), 2012, 1141-1148), which have similar electrode design and layer thickness as FFS displays, but comprise a layer of an LC medium with negative dielectric anisotropy instead of an LC medium with positive dielectric anisotropy. The LC medium with negative dielectric anisotropy shows a more favorable director orientation that has less tilt and more twist orientation compared to the LC medium with positive dielectric anisotropy, as a result of which these displays have a higher transmission.

A further development are the so-called PS (polymer sustained) or PSA (polymer sustained alignment) displays, for which the term "polymer stabilised" is also occasionally used. The PSA displays are distinguished by the shortening of the response times without significant adverse effects on other parameters, such as, in particular, the favourable viewing-angle dependence of the contrast.

In these displays, a small amount (for example 0.3% by weight, typically < 1% by weight) of one or more polymerizable compound(s) is added to the LC medium and, after introduction into the LC cell, is polymerised or crosslinked *in situ*, usually by UV photopolymerization, between the electrodes with or without an applied electrical voltage. The addition of polymerizable mesogenic or liquid-crystalline compounds, also known as reactive mesogens or “RMs”, to the LC mixture has proven particularly suitable. PSA technology has hitherto been employed principally for LC media having negative dielectric anisotropy.

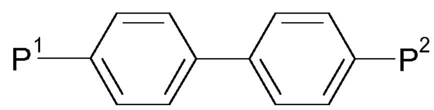
Unless indicated otherwise, the term "PSA" is used below as representative of PS displays and PSA displays.

In the meantime, the PSA principle is being used in diverse classical LC displays. Thus, for example, PSA-VA, PSA-OCB, PSA-IPS, PSA-FFS and PSA-TN displays are known. The polymerisation of the polymerizable compound(s) preferably takes place with an applied electrical voltage in the case of PSA-VA and PSA-OCB displays, and with or without an applied electrical voltage in the case of PSA-IPS displays. As can be demonstrated in test cells, the PS(A) method results in a ‘pretilt’ in the cell. In the case of PSA-OCB displays, for example, it is possible for the bend structure to be stabilised so that an offset voltage is unnecessary or can be reduced. In the case of PSA-VA displays, the pretilt has a positive effect on the response times. A standard MVA or PVA pixel and electrode layout can be used for PSA-VA displays. In addition, however, it is also possible, for example, to manage with only one structured electrode side and no protrusions, which significantly simplifies production and at the same time results in very good contrast at the same time as very good light transmission.

PSA-VA displays are described, for example, in JP 10-036847 A, EP 1 170 626 A2, US 6,861,107, US 7,169,449, US 2004/0191428 A1, US 2006/0066793 A1 and US 2006/0103804 A1. PSA-OCB displays are described, for example, in T.-J- Chen et al., Jpn. J. Appl. Phys. 45, 2006, 2702-2704 and S. H. Kim, L.-C- Chien, Jpn. J. Appl. Phys. 43, 2004, 7643-7647. PSA-IPS displays are described, for example, in US 6,177,972 and Appl. Phys. Lett. 1999, 75(21), 3264. PSA-TN displays are described, for example, in Optics Express 2004, 12(7), 1221. PSA-VA-IPS displays are disclosed, for example, in WO 2010/089092 A1.

Like the conventional LC displays described above, PSA displays can be operated as active-matrix or passive-matrix displays. In the case of active-matrix displays, individual pixels are usually addressed by integrated, non-linear active elements, such as, for example, transistors (for example thin-film transistors or "TFTs"), while in the case of passive-matrix displays, individual pixels are usually addressed by the multiplex method, both methods being known from the prior art.

In the prior art, polymerizable compounds of the following formula, for example, are used for PSA-VA:



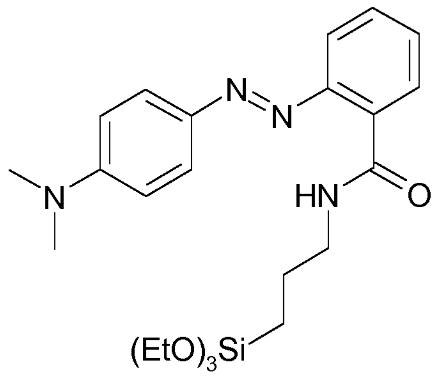
in which P denotes a polymerizable group, usually an acrylate or methacrylate group, as described, for example, in US 7,169,449.

Below the polymer layer which induces the above mentioned pretilt, an orientation layer - usually a polyimide - provides the initial alignment of the liquid crystal regardless of the polymer stabilisation step of the production process.

The effort for the production of a polyimide layer, treatment of the layer and improvement with bumps or polymer layers is relatively great. A simplifying technology which on the one hand reduces production costs and on the other hand helps to optimise the image quality (viewing-angle dependence, contrast, response times) would therefore be desirable. Rubbed polyimide has been used for a long time to align liquid crystals. The rubbing process causes a number of problems: mura, contamination, problems with static discharge, debris, etc.

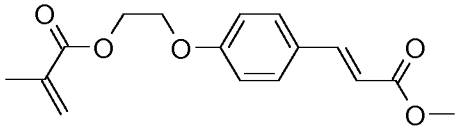
Photoalignment is a technology for achieving liquid crystal (LC) alignment that avoids rubbing by replacing it with a light-induced orientational ordering of the alignment surface. This can be achieved through the mechanisms of photodecomposition, photodimerization, and photoisomerization (N.A. Clark et al. Langmuir **2010**, *26(22)*, 17482–17488, and literature cited therein) by means of polarised light. However, still a suitably derivatised polyimide layer is required that comprises the photoreactive group. A further improvement would be to avoid the use of polyimide at all. For VA displays this was achieved by adding a self-alignment agent to the LC that induces homeotropic alignment *in situ* by a self-assembling mechanism as disclosed in WO 2012/104008 and WO 2012/038026.

N.A. Clark et al. Langmuir **2010**, *26(22)*, 17482–17488 have shown that it is possible to self-assemble a compound of the following structure

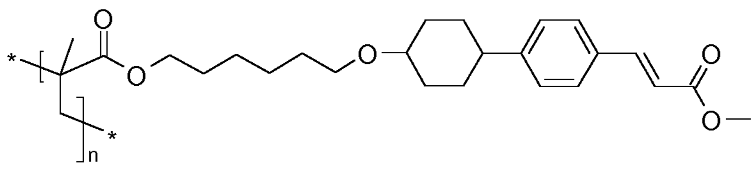


onto a substrate to give a monolayer that is able to be photoaligned to induce homogeneous alignment of a liquid crystal. However, a separate step of self-assembly before manufacture of the LC cell is required and the nature of the azo-group causes reversibility of the alignment when exposed to light.

Another functional group known to enable photoalignment is the phenylethenylcarbonyloxy group (cinnamate). Photocrosslinkable cinnamates are known from the prior art, e.g. of the following structure

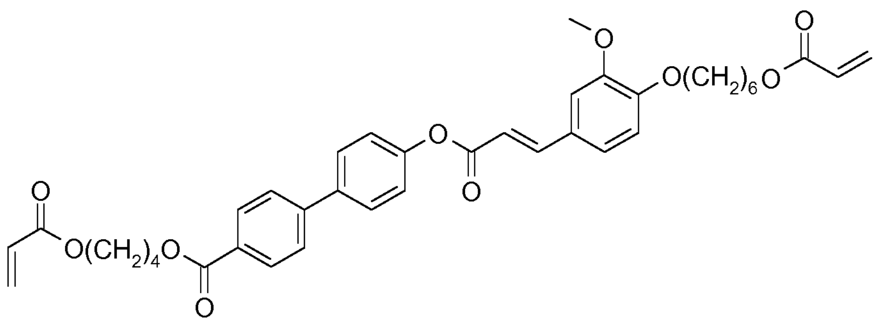


as disclosed in EP0763552. From such compounds, polymers can be obtained, for example the following

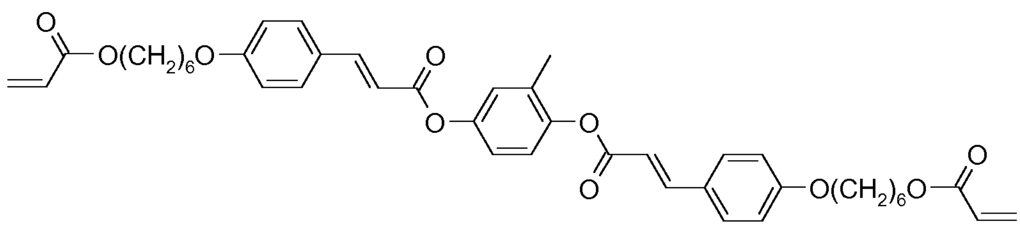


This material was used in a photoalignment process, as disclosed in WO 99/49360, to give an orientation layer for liquid crystals. A disadvantage of orientation layers obtained by this process is that they give lower voltage holding ratios (VHR) than polyimides.

In WO 00/05189 polymerizable direactive mesogenic cinnamates are disclosed for the use in polymerizable LC mixtures for e.g. optical retarders.

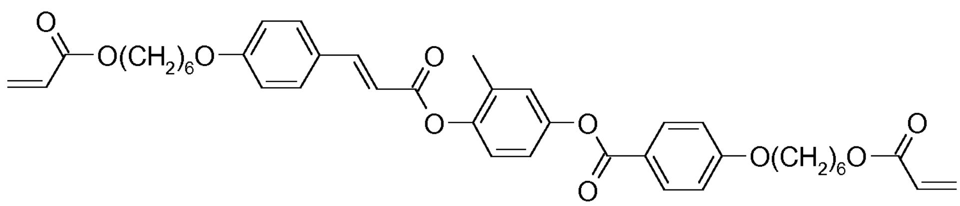


A structurally related compound of the following formula



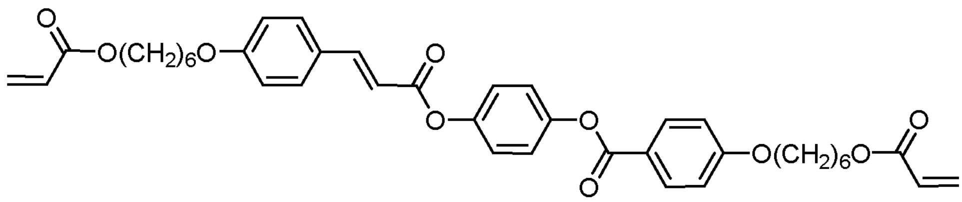
comprising two cinnamic acid moieties is disclosed in GB 2 306 470 A for the use as component in liquid crystalline polymer films. This type of compound has not been used or proposed for the use as photoalignment agent.

A very similar compound is published in B.M.I. van der Zande et al., Liquid Crystals, Vol. 33, No. 6, June 2006, 723–737, in the field of liquid crystalline polymers for patterned retarders, and has the following structure:



WO 2017/102068 A1 discloses the same structure for the purpose of a polyimide-free homogeneous photoalignment method.

Further, M.H. Lee et al. published in Liquid Crystals (https://doi.org/10.1080/02678292.2018.1441459) a polyimide-free homogeneous photoalignment method induced by polymerizable liquid crystal containing cinnamate moiety of the following formula:



However, a corresponding process for the fabrication of a corresponding liquid crystal display, comprises at least the steps of:

- providing a first substrate which includes a pixel electrode and a common electrode for generating an electric field substantially parallel to a surface of the first substrate in the pixel region;
- providing a second substrate, the second substrate being disposed opposite to the first substrate;
- interposing a liquid crystal mixture;
- heating liquid crystal mixture to its isotropic phase,

- irradiating the liquid crystal mixture with linearly polarised light causing photoalignment of the liquid crystal;
- curing the polymerizable compounds of the liquid crystal mixture by irradiation with ultraviolet light or visible light having a wavelength of 450 nm or below.

Especially the steps of heating liquid crystal mixture to its isotropic phase and irradiating the liquid crystal mixture with linearly polarised light causing photoalignment of the liquid crystal requires further equipment, that is not commonly used in modern production lines for mass production.

Thus, there is a great demand for a simplified process for the production of light modulation elements operated in the IPS/FFS mode that do not require an alignment treatment of the cell, that do not require a heating step and that do not require an irradiation step with linear polarized (UV) light to enable photoalignment of a liquid crystal mixture in *situ*, *i.e.* after assembly of the display, by means of linearly polarized light.

In addition to this requirement, the corresponding process should provide, preferably at the same time, a light modulation element operated in the IPS/FFS mode having favourable high dark state and a favourable high voltage holding ratio.

Other aims of the present invention are immediately evident to the person skilled in the art from the following detailed description.

Surprisingly, the inventors have found out that one or more of the above-mentioned aims can be achieved by providing a process according to claim 1.

Terms and Definitions

The term "mesogenic group" as used herein is known to the person skilled in the art and described in the literature, and means a group which, due to the anisotropy of its attracting and repelling interactions, essentially contributes to causing a liquid-crystal (LC) phase in low-molecular-weight or polymeric substances. Compounds containing mesogenic groups (mesogenic compounds) do not necessarily have to have an LC phase themselves. It is also possible for mesogenic compounds to exhibit LC 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 LC compounds is given in *Pure Appl. Chem.* 2001, 73(5), 888 and C. Tschierske, G. Pelzl, S. Diele, *Angew. Chem.* **2004**, 116, 6340-6368.

The term "reactive mesogen" (RM) means a polymerizable mesogenic or liquid crystalline compound, which is preferably a monomeric compound.

The term "organic group" denotes a carbon or hydrocarbon group.

The term "carbon group" denotes a mono- or polyvalent organic group containing at least one carbon atom, where this either contains no further atoms (such as, for example, -C≡C-) or optionally contains one or more further atoms, such as, for example, N, O, S, P, Si, Se, As, Te or Ge (for example carbonyl, etc.). The term "hydrocarbon group" denotes a carbon group which additionally contains one or more H atoms and optionally one or more heteroatoms, such as, for example, N, O, S, P, Si, Se, As, Te or Ge.

"Halogen" denotes F, Cl, Br or I.

A carbon or hydrocarbon group can be a saturated or unsaturated group. Unsaturated groups are, for example, aryl, alkenyl or alkynyl groups. A carbon or hydrocarbon radical having 3 or more atoms can be straight-chain, branched and/or cyclic and may also contain spiro links or condensed rings.

The terms "alkyl", "aryl", "heteroaryl", etc., also encompass polyvalent groups, for example alkylene, arylene, heteroarylene, etc.

The term "aryl" denotes an aromatic carbon group or a group derived therefrom. The term "heteroaryl" denotes "aryl" as defined above, containing one or more heteroatoms.

Preferred carbon and hydrocarbon groups are optionally substituted alkyl, alkenyl, alkynyl, alkoxy, alkylcarbonyl, alkoxycarbonyl, alkylcarbonyloxy and alkoxycarbonyloxy having 1 to 40, preferably 1 to 25, particularly preferably 1 to 18, C atoms, optionally substituted aryl or aryloxy having 6 to 40, preferably 6 to 25, C atoms, or optionally substituted alkylaryl, arylalkyl, alkylaryloxy, arylalkyloxy, arylcarbonyl, aryloxycarbonyl, arylcarbonyloxy and aryloxycarbonyloxy having 6 to 40, preferably 6 to 25, C atoms.

Further preferred carbon and hydrocarbon groups are C_1-C_{40} alkyl, C_2-C_{40} alkenyl, C_2-C_{40} alkynyl, C_3-C_{40} allyl, C_4-C_{40} alkyldienyl, C_4-C_{40} polyenyl, C_6-C_{40} aryl, C_6-C_{40} alkylaryl, C_6-C_{40} arylalkyl, C_6-C_{40} alkylaryloxy, C_6-C_{40} arylalkyloxy, C_2-C_{40} heteroaryl, C_4-C_{40} cycloalkyl, C_4-C_{40} cycloalkenyl, etc. Particular preference is given to C_1-C_{22} alkyl, C_2-C_{22} alkenyl, C_2-C_{22} alkynyl, C_3-C_{22} allyl, C_4-C_{22} alkyldienyl, C_6-C_{12} aryl, C_6-C_{20} arylalkyl and C_2-C_{20} heteroaryl.

Further preferred carbon and hydrocarbon groups are straight-chain, branched or cyclic alkyl radicals having 1 to 40, preferably 1 to 25, C atoms, which are unsubstituted or mono- or polysubstituted by F, Cl, Br, I or CN and in which one more non-adjacent CH_2 groups may each be replaced, independently of one another, by -C(R^z)=C(R^z)-, -C≡C-, -N(R^z)-, -O-, -S-, -CO-, -CO-O-, -O-CO-, -O-CO-O- in such a way that O and/or S atoms are not linked directly to one another.

R^z preferably denotes H, halogen, a straight-chain, branched or cyclic alkyl chain having 1 to 25 C atoms, in which, in addition, one or more non-adjacent C atoms may be replaced by -O-, -S-, -CO-, -CO-O-, -O-CO- or -O-CO-O- and in which one or more H atoms may be replaced by fluorine, an optionally substituted aryl or aryloxy group having 6 to 40 C atoms, or an optionally substituted heteroaryl or heteroaryloxy group having 2 to 40 C atoms.

Preferred alkyl groups are, for example, methyl, ethyl, n-propyl, isopropyl, n-butyl, isobutyl, s-butyl, t-butyl, 2-methylbutyl, n-pentyl, s-pentyl, cyclopentyl, n-hexyl, cyclohexyl, 2-ethylhexyl, n-heptyl, cycloheptyl, n-octyl, cyclooctyl, n-nonyl, n-decyl, n-undecyl, n-dodecyl, trifluoromethyl, perfluoro-n-butyl, 2,2,2-trifluoroethyl, perfluorooctyl and perfluorohexyl.

Preferred alkenyl groups are, for example, ethenyl, propenyl, butenyl, pentenyl, cyclopentenyl, hexenyl, cyclohexenyl, heptenyl, cycloheptenyl, octenyl and cyclooctenyl.

Preferred alkynyl groups are, for example, ethynyl, propynyl, butynyl, pentynyl, hexynyl and octynyl.

Preferred alkoxy groups are, for example, methoxy, ethoxy, 2-methoxyethoxy, n-propoxy, i-propoxy, n-butoxy, i-butoxy, s-butoxy, t-butoxy, 2-methylbutoxy, n-pentoxy, n-hexoxy, n-heptoxy, n-octoxy, n-nonoxy, n-decoxy, n-undecoxy and n-dodecoxy.

Preferred amino groups are, for example, dimethylamino, methylamino, methylphenylamino and phenylamino.

Aryl and heteroaryl groups can be monocyclic or polycyclic, i.e. they can contain one ring (such as, for example, phenyl) or two or more rings, which may also be fused (such as, for example, naphthyl) or covalently bonded (such as, for example, biphenyl), or contain a combination of fused and linked rings. Heteroaryl groups contain one or more heteroatoms, preferably selected from O, N, S and Se. A ring system of this type may also contain individual non-conjugated units, as is the case, for example, in the fluorene basic structure.

Particular preference is given to mono-, bi- or tricyclic aryl groups having 6 to 25 C atoms and mono-, bi- or tricyclic heteroaryl groups having 2 to 25 C atoms, which optionally contain fused rings and are optionally substituted. Preference is furthermore given to 5-, 6- or 7-membered aryl and heteroaryl groups, in which, in addition, one or more CH groups may be replaced by N, S or O in such a way that O atoms and/or S atoms are not linked directly to one another.

Preferred aryl groups are derived, for example, from the parent structures benzene, biphenyl, terphenyl, [1,1':3',1"]terphenyl, naphthalene, anthracene, binaphthyl, phenanthrene, pyrene, dihydropyrene, chrysene, perylene, tetracene, pentacene, benzopyrene, fluorene, indene, indenofluorene, spirobifluorene, etc.

Preferred heteroaryl groups are, for example, 5-membered rings, such as pyrrole, pyrazole, imidazole, 1,2,3-triazole, 1,2,4-triazole, tetrazole, furan, thiophene, selenophene, oxazole, isoxazole, 1,2-thiazole, 1,3-thiazole, 1,2,3-oxadiazole, 1,2,4-oxadiazole, 1,2,5-oxadiazole, 1,3,4-oxadiazole, 1,2,3-thiadiazole, 1,2,4-thiadiazole, 1,2,5-thiadiazole, 1,3,4-thiadiazole, 6-membered rings, such as pyridine, pyridazine, pyrimidine, pyrazine, 1,3,5-triazine, 1,2,4-triazine, 1,2,3-triazine, 1,2,4,5-tetrazine, 1,2,3,4-tetrazine, 1,2,3,5-tetrazine, or condensed groups, such as indole, isoindole, indolizine, indazole, benzimidazole, benzotriazole, purine, naphthimidazole, phenanthrimidazole, pyridimidazole, pyrazinimidazole, quinoxalinimidazole, benzoxazole, naphthoxazole, anthroxazole, phenanthroxazole, isoxazole, benzothiazole, benzofuran, isobenzofuran, dibenzofuran, quinoline, isoquinoline, pteridine, benzo-5,6-quinoline, benzo-6,7-quinoline, benzo-7,8-quinoline, benzoisoquinoline, acridine, phenothiazine, phenoxazine, benzopyridazine, benzopyrimidine, quinoxaline, phenazine, naphthyridine, azacarbazole, benzocarboline, phenanthridine, phenanthroline, thieno[2,3b]thiophene, thieno[3,2b]thiophene, dithienothiophene, dihydrothieno [3,4-b]-1,4-dioxin, isobenzothiophene, dibenzothiophene, benzothiadiazothiophene, or combinations of these groups. The heteroaryl groups may also be substituted by alkyl, alkoxy, thioalkyl, fluorine, fluoroalkyl or further aryl or heteroaryl groups.

The (non-aromatic) alicyclic and heterocyclic groups encompass both saturated rings, i.e. those containing exclusively single bonds, and also partially unsaturated rings, i.e. those which may also contain multiple bonds. Heterocyclic rings contain one or more heteroatoms, preferably selected from Si, O, N, S and Se.

The (non-aromatic) alicyclic and heterocyclic groups can be monocyclic, i.e. contain only one ring (such as, for example, cyclohexane), or polycyclic, i.e. contain a plurality of rings (such as, for example, decahydronaphthalene or bicyclooctane). Particular preference is given to saturated groups. Preference is furthermore given to mono-, bi- or tricyclic groups having 3 to 25 C atoms, which optionally contain fused rings and are optionally substituted. Preference is furthermore given to 5-, 6-, 7- or 8-membered carbocyclic groups, in which, in addition, one or more C atoms may be replaced by Si and/or one or more CH groups may be replaced by N and/or one or more non-adjacent CH_2 groups may be replaced by -O- and/or -S-.

Preferred alicyclic and heterocyclic groups are, for example, 5-membered groups, such as cyclopentane, tetrahydrofuran, tetrahydrothiofuran, pyrrolidine, 6-membered groups, such as cyclohexane, silinane, cyclohexene, tetrahydropyran, tetrahydrothiopyran, 1,3-dioxane, 1,3-dithiane, piperidine, 7-membered groups, such as cycloheptane, and fused groups, such as tetrahydronaphthalene, decahydronaphthalene, indane, bicyclo[1.1.1]pentane-1,3-diyl, bicyclo[2.2.2]octane-1,4-diyl, spiro[3.3]heptane-2,6-diyl, octahydro-4,7-methanoindane-2,5-diyl.

The aryl, heteroaryl, carbon and hydrocarbon radicals optionally have one or more substituents, which are preferably selected from the group comprising silyl, sulfo, sulfonyl, formyl, amine, imine, nitrile, mercapto, nitro, halogen, C_{1-12} alkyl, C_{6-12} aryl, C_{1-12} alkoxy, hydroxyl, or combinations of these groups.

Preferred substituents are, for example, solubility-promoting groups, such as alkyl or alkoxy, and electron-withdrawing groups, such as fluorine, nitro or nitrile.

Preferred substituents, unless stated otherwise, also referred to as "L" above and below, are F, Cl, Br, I, -CN, $-NO_2$, -NCO, -NCS, -OCN, -SCN, -C(=O)N(R^z)$_2$, -C(=O)Y^1, -C(=O)R^z, -N(R^z)$_2$, in which R^z has the meaning indicated above, and Y^1 denotes halogen, optionally substituted silyl or aryl having 6 to 40, preferably 6 to 20, C atoms, and straight-chain or branched alkyl, alkoxy, alkylcarbonyl, alkoxycarbonyl, alkylcarbonyloxy or alkoxycarbonyloxy having 1 to 25 C atoms, preferably 2 to 12, in which one or more H atoms may optionally be replaced by F or Cl.

"Substituted silyl or aryl" preferably means substituted by halogen, -CN, R^{y1}, -OR^{y1}, -CO-R^{y1}, -CO-O-R^{y1}, -O-CO-R^{y1} or -O-CO-O-R^{y1}, in which R^{y1} has the meaning indicated above.

Particularly preferred substituents L are, for example, F, Cl, CN, CH_3, C_2H_5, -$CH(CH_3)_2$, OCH_3, OC_2H_5, CF_3, OCF_3, $OCHF_2$, OC_2F_5, furthermore phenyl.

Above and below "halogen" denotes F, Cl, Br or I.

Above and below, the terms "alkyl", "aryl", "heteroaryl", etc., also encompass polyvalent groups, for example alkylene, arylene, heteroarylene, etc.

The term "director" is known in prior art and means the preferred orientation direction of the long molecular axes (in case of calamitic compounds) or short molecular axes (in case of discotic compounds) of the liquid-crystalline molecules. In case of uniaxial ordering of such anisotropic molecules, the director is the axis of anisotropy.

The term “alignment” or “orientation” relates to alignment (orientation ordering) of anisotropic units of material such as small molecules or fragments of big molecules in a common direction named “alignment direction”. In an aligned layer of liquid-crystalline material, the liquid-crystalline director coincides with the alignment direction so that the alignment direction corresponds to the direction of the anisotropy axis of the material.

The term "planar orientation/alignment", for example in a layer of an liquid-crystalline material, means that the long molecular axes (in case of calamitic compounds) or the short molecular axes (in case of discotic compounds) of a proportion of the liquid-crystalline molecules are oriented substantially parallel (about 180°) to the plane of the layer.

The term "homeotropic orientation/alignment", for example in a layer of a liquid-crystalline material, means that the long molecular axes (in case of calamitic compounds) or the short molecular axes (in case of discotic compounds) of a proportion of the liquid-crystalline molecules are oriented at an angle θ ("tilt angle") between about 80° to 90° relative to the plane of the layer.

The terms "uniform orientation" or "uniform alignment" of an liquid-crystalline material, for example in a layer of the material, mean that the long molecular axes (in case of calamitic compounds) or the short molecular axes (in case of discotic compounds) of the liquid-crystalline molecules are oriented substantially in the same direction. In other words, the lines of liquid-crystalline director are parallel.
The wavelength of light generally referred to in this application is 550 nm, unless explicitly specified otherwise.

The birefringence Δn herein is defined by the following equation

$$\Delta n = n_e - n_o$$

wherein n_e is the extraordinary refractive index and n_o is the ordinary refractive index and the effective average refractive index $n_{av.}$ is given by the following equation

$$n_{av.} = [(2\, n_o^2 + n_e^2)/3]^{1/2}$$

The extraordinary refractive index n_e and the ordinary refractive index n_o can be measured using an Abbe refractometer.

In the present application the term "dielectrically positive" is used for compounds or components with $\Delta\varepsilon > 3.0$, "dielectrically neutral" with $-1.5 \leq \Delta\varepsilon \leq 3.0$ and "dielectrically negative" with $\Delta\varepsilon < -1.5$. $\Delta\varepsilon$ is determined at a frequency of 1 kHz and at 20°C. The dielectric anisotropy of the respective compound is determined from the results of a solution of 10 % of the respective individual compound in a nematic host mixture. In case the solubility of the respective compound in the host medium is less than 10 % its concentration is reduced by a factor of 2 until the resultant medium is stable enough at least to allow the determination of its properties. Preferably, the concentration is kept at least at 5 %, however, to keep the significance of the results as high as possible. The capacitance of the test mixtures are determined both in a cell with homeotropic and with homogeneous alignment. The cell gap of both types of cells is approximately 20 µm. The voltage applied is a rectangular wave with a frequency of 1 kHz and a root mean square value typically of 0.5 V to 1.0 V; however, it is always selected to be below the capacitive threshold of the respective test mixture.

$\Delta\varepsilon$ is defined as $(\varepsilon_{||} - \varepsilon_{\perp})$, whereas $\varepsilon_{av.}$ is $(\varepsilon_{||} + 2\,\varepsilon_{\perp}) / 3$. The dielectric permittivity of the compounds is determined from the change of the respective values of a host medium upon addition of the compounds of interest. The values are extrapolated to a concentration of the compounds of interest of 100 %. A typical host medium is ZLI-4792 or ZLI-2857 both commercially available from Merck, Darmstadt.

Dual frequency liquid crystal (DFLC) materials or mixtures have a high dielectric dispersion where the dielectric anisotropy, $\Delta\varepsilon(f)=\varepsilon_{II(f)}-\varepsilon_{\perp(f)}$ is frequency dependent, resulting in a change in sign at the crossover frequency f_{co}, where $\Delta\varepsilon_{(fco)}=0$. In some DFLC materials, f_{co} occurs at a few kHz and Δf_{co} changes significantly over the range 1–100 kHz at 20°C. In a

DFLC cell, the director can be driven between either homogeneous or homeotropic alignment by applying an electric field across the sample at a frequency either above or below f_{co}. As the molecules of the LC have a preferred direction (unit vector) along which they tend to be oriented. When an electric field is applied to the LC, it will exert a torque on the unit vector. Depending on the sign of the anisotropy, i.e. $\Delta\varepsilon>0$ or $\Delta\varepsilon<0$, this torque will turn the director respectively toward being parallel or perpendicular to the field direction.

A dual frequency liquid crystalline mixture is usually composed of two categories of materials: compounds exhibiting a positive dielectric anisotropy at low frequencies; and compounds exhibiting a negative dielectric anisotropy at high frequencies.

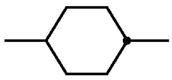
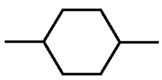
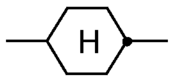
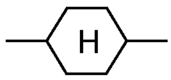
The crossover frequency is defined as the frequency at which the dielectric anisotropy changes sign.

Throughout the description and claims of this specification, the words “comprise” and “contain” and variations of the words, for example “comprising” and “comprises”, mean “including but not limited to”, and are not intended to (and do not) exclude other components. On the other hand, the word “comprise” also encompasses the term “consisting of” but is not limited to it.

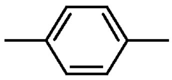
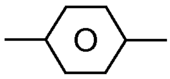
Throughout the description and claims of this specification, the words “obtainable” and “obtained” and variations of the words, mean “including but not limited to”, and are not intended to (and do not) exclude other components. On the other hand, the word “obtainable” also encompasses the term “obtained” but is not limited to it.

All concentrations are quoted in percent by weight and relate to the respective mixture, all temperatures are quoted in degrees Celsius and all temperature differences are quoted in differential degrees.

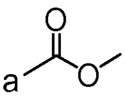
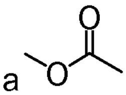
For the present invention,

, ,  and 

denote trans-1,4-cyclohexylene,

 and 

denote 1,4-phenylene.

For the present invention the groups -CO-O-, -COO- -C(=O)O- or $-CO_2-$ denote an ester group of formula , and the groups -O-CO- -OCO-, -OC(=O)-, $-O_2C-$ or -OOC- denote an ester group of formula .

<u>Detailed description</u>

In the following, the production process according to the present invention is described in greater detail.

Typically, the structure of the light modulation element according to the invention corresponds to the conventional structure for displays, which is known to the person skilled in the art.

As substrate, for example, glass or quartz sheets or plastic films can be used. When using two substrates in case of curing by actinic radiation, at least one substrate has to be transmissive for the actinic radiation used for the polymerisation.

Suitable and preferred plastic substrates are for example films of polyester such as polyethyleneterephthalate (PET) or polyethylene-naphthalate (PEN), polyvinylalcohol (PVA), polycarbonate (PC) or triacetylcellulose (TAC), very preferably PET or TAC films. As birefringent substrates for example uniaxially stretched plastic films can be used. PET films are commercially available for example from DuPont Teijin Films under the trade name Melinex ®.

In a preferred embodiment, the substrates are arranged with a separation in the range from approximately 1 μm to approximately 20 μm from one another, preferably in the range from approximately 3 μm to approximately 10 μm from one another, and more preferably in the range from approximately 3 μm to approximately 6 μm from one another. The layer of the liquid-crystalline medium is thereby located in the interspace.

The substrate layers can be kept at a defined separation from one another, for example, by spacers, or projecting structures in the layer. Typical spacer materials are commonly known to the expert, as for example spacers made of plastic, silica, epoxy resins, or the like.

In a further preferred embodiment of the invention, the layer of the liquid-crystalline medium is located between two flexible layers, for example flexible polymer films. The PNLC light modulation element according to the invention is consequently flexible and bendable and can be rolled up, for example. The flexible layers can represent the substrate layer, the alignment layer, and/or polarisers. Further layers, which are preferable flexible, may also, be present. For a more detailed disclosure of the preferred embodiments, in which the layer of the liquid-crystalline medium is located between flexible layers, reference is given to the application US 2010/0045924 A1.

The first substrate includes a pixel electrode and a common electrode for generating an electric field substantially parallel to a surface of the first substrate in the pixel region. Various kinds of displays having at least two electrodes on one substrate are known to the skilled person wherein the most significant difference is that either both the pixel electrode and the common electrode are structured, as it is typical for IPS displays, or only the pixel electrode is structured and the common electrode is unstructured, which is the case for FFS displays.

It has to be understood that the present invention refers to any kind of electrode configurations suitable for generating an electric field substantially parallel to a surface of the first substrate in the pixel region; mentioned above, *i.e.* IPS as well as FFS displays.

Suitable electrode materials are commonly known to the expert, as for example electrode structures made of metal or metal oxides, such as, for example indium tin oxide (ITO), which is preferred according to the present invention.

Thin films of ITO, for example, are preferably deposited on substrates by physical vapour deposition, electron beam evaporation, or sputter deposition techniques.

Preferably, the electrodes of the light modulation element are associated with a switching element, such as a thin film transistor (TFT) or thin film diode (TFD).

In a preferred embodiment, the light modulation element may comprise at least one dielectric layer, which is preferably located on the electrode

structure in order to avoid direct contact of the LC medium with the electrode structure. The presence of a dielectric layer has been proven to be beneficial for avoiding reliability issues.
Typical dielectric layer materials are commonly known to the expert, such as, for example, SiOx, SiNx, Cytop, Teflon, and PMMA.

The dielectric layer materials can be applied onto the substrate or electrode layer by conventional coating techniques like spin coating, roll coating, blade coating, or vacuum deposition such as PVD or CVD. It can also be applied to the substrate or electrode layer by conventional printing techniques, which are known to the expert, like for example screen printing, offset printing, reel-to-reel printing, letterpress printing, gravure printing, rotogravure printing, flexographic printing, intaglio printing, pad printing, heat-seal printing, ink-jet printing or printing by means of a stamp or printing plate.

In a further preferred embodiment, the light modulation element may comprise at least one alignment layer, which is preferably provided on the electrode structure.

In a further preferred embodiment, the light modulation element may have further alignment layers, which are in direct contact with the layer of the liquid-crystalline medium.

The alignment layers may also serve as substrate layers, so that substrate layers are not necessary in the PNLC light modulation element. If substrate layers are additionally present, the alignment layers are in each case arranged between the substrate layer and the layer of the liquid-crystalline medium.

Preferably, the alignment layer(s) induce(s) planar alignment, preferably throughout the entire liquid-crystalline medium.

Suitable planar alignment layer materials are commonly known to the expert, such as, for example, AL-3046 or AL-1254 both commercially available from JSR.

The alignment layer materials can be applied onto the substrate array or electrode structure by conventional coating techniques like spin coating, roll coating, dip coating or blade coating. It can also be applied by vapour deposition or conventional printing techniques, which are known to the expert, like for example screen printing, offset printing, reel-to-reel printing, letterpress printing, gravure printing, rotogravure printing, flexographic printing, intaglio printing, pad printing, heat-seal printing, ink-jet printing or printing by means of a stamp or printing plate.

In a preferred embodiment, the planar alignment layer is processed by rubbing or photo-alignment techniques known to the skilled person, preferably by rubbing techniques. Accordingly, a uniform preferred direction of the director can be achieved without any physical treatment of the cell like shearing of the cell (mechanical treatment in one direction), etc. The rubbing direction is uncritical and mainly influences only the orientation in which the polarizers have to be applied. Typically, the rubbing direction is in the range of +/- 45°, more preferably in the range of +/- 20°, even more preferably, in the range of +/-10, and, in the range of the direction +/- 5° with respect to the substrates largest extension.

In a further preferred embodiment, the light modulation element does not comprise any alignment layers either processed or unprocessed.

In a further preferred embodiment of the invention, the light modulation element optionally comprises two or more polarisers, at least one of which is arranged on one side of the layer of the liquid-crystalline medium and at least one of which is arranged on the opposite side of the layer of the liquid-crystalline medium. The layer of the liquid-crystalline medium and the polarisers here are preferably arranged parallel to one another.

The polarisers can be linear polarisers. Preferably, precisely two polarisers are present in the light modulation element. In this case, it is furthermore preferred for the polarisers either both to be linear polarisers. If two linear polarisers are present in the light modulation element, it is preferred in accordance with the invention for the polarisation directions of the two polarisers to be crossed.

It is furthermore preferred in the case where two circular polarisers are present in the light modulation element for these to have the same polarisation direction, i.e. either both are right-hand circular-polarised or both are left-hand circular-polarised.

The polarisers can be reflective or absorptive polarisers. A reflective polariser in the sense of the present application reflects light having one polarisation direction or one type of circular-polarised light, while being transparent to light having the other polarisation direction or the other type of circular-polarised light. Correspondingly, an absorptive polariser absorbs light having one polarisation direction or one type of circular-polarised light, while being transparent to light having the other polarisation direction or the other type of circular-polarised light. The reflection or absorption is usually not quantitative; meaning that complete polarisation of the light passing through the polariser does not take place.

For the purposes of the present invention, both absorptive and reflective polarisers can be employed. Preference is given to the use of polarisers, which are in the form of thin optical films. Examples of reflective polarisers which can be used in the light modulation element according to the invention are DRPF (diffusive reflective polariser film, 3M), DBEF (dual brightness enhanced film, 3M), DBR (layered-polymer distributed Bragg reflectors, as described in US 7,038,745 and US 6,099,758) and APF (advanced polariser film, 3M).

Examples of absorptive polarisers, which can be employed in the PNLC light modulation elements according to the invention, are the Itos XP38 polariser film and the Nitto Denko GU-1220DUN polariser film. An example of a circular polariser, which can be used in accordance with the invention, is the APNCP37-035-STD polariser (American Polarizers). A further example is the CP42 polariser (ITOS). The PNLC light modulation element may furthermore comprise filters which block light of certain wavelengths, for example, UV filters. In accordance with the invention, further functional layers, such as, for example, protective films, heat-insulation films or metal-oxide layers, may also be present.

In one embodiment of the present invention the liquid crystal composition is injected between the first and second substrates or is filled into the cell by capillary force after combining the first and second substrates. In an alternative embodiment, the liquid crystal composition may be interposed between the first and second substrates by combining the second substrate to the first substrate after loading the liquid crystal composition on the first substrate. Preferably, the liquid crystal is dispensed dropwise onto a first substrate in a process known as "one drop filling" (ODF) process, as disclosed in for example JPS63-179323 and JPH10-239694, or using the Ink Jet Printing (IJP) method.

In a preferred embodiment, the process according to the invention contains a process step where the liquid crystal inside the display panel is allowed to rest for a period of time in order to evenly redistribute the liquid crystal medium inside the panel (herein referred to as "annealing").

In a preferred embodiment, the display panel is, after filling and assembly, annealed for a time between 1min and 3h, preferably between 10min and

1h and most preferably between 20min and 30min. The annealing is preferably performed at room temperature.

In an alternative embodiment, the annealing is performed at elevated temperature, preferably at above 20°C and below 140°C, more preferably above 40°C and below 100°C and most preferably above 50°C and below 80°C.

In a preferred embodiment, the dual frequency liquid crystal mixture according to the present invention comprises one or more, preferably two or more, low-molecular-weight (i.e. monomeric or unpolymerized) compounds. The latter are stable or unreactive with respect to a polymerisation reaction or under the conditions used for the polymerisation of the polymerizable compounds.

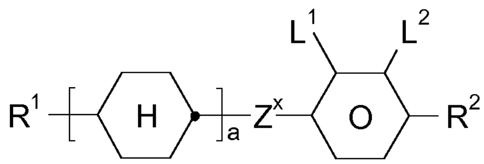
Suitable dual frequency liquid crystal mixtures are known to the person skilled in the art and are described in the literature.

Suitable dual frequency liquid crystal mixtures preferably exhibit a value of $\Delta\varepsilon$, at 1 kHz and 20 °C of the liquid crystal medium is in the range from 1.0 to 20.0 while at the same time the value of $\Delta\varepsilon$, at 100 kHz, 500 kHz or 1000 kHz and 20 °C of the LC mixture is less than 0.

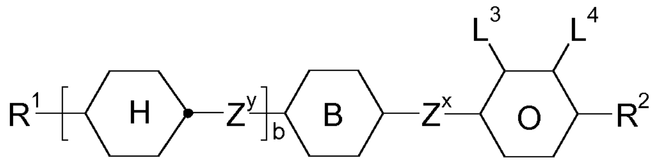
The dual frequency liquid crystal mixtures are preferably nematic LC mixtures, and preferably do not have a chiral LC phase.

In a preferred embodiment of the present invention the dual frequency liquid crystal mixture utilized for the process according to the present invention comprises one or more compounds with negative dielectric anisotropy as defined above and described below:

a) LC medium which comprises one or more compounds of the formulae CY and/or PY:



CY

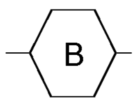
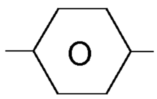
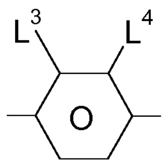


PY

wherein

a denotes 1 or 2,

b denotes 0 or 1,

 denotes  or 

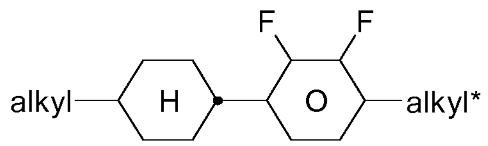
R^1 and R^2 each, independently of one another, denote alkyl having 1 to 12 C atoms, where, in addition, one or two non-adjacent CH_2 groups may be replaced by -O-, -CH=CH-, -CO-, -OCO- or -COO- in such a way that O atoms are not linked directly to one another, preferably alkyl or alkoxy having 1 to 6 C atoms,

Z^x and Z^y each, independently of one another, denote $-CH_2CH_2-$, -CH=CH-, $-CF_2O-$, $-OCF_2-$, $-CH_2O-$, -O CH_2-, -CO-O-, -O-CO-, $-C_2F_4-$, -CF=CF-, -CH=CH- CH_2O- or a single bond, preferably a single bond,

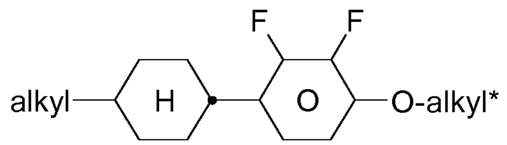
L^{1-4} each, independently of one another, denote F, Cl, OCF_3, CF_3, CH_3, CH_2F, CHF_2.

Preferably, both L^1 and L^2 denote F or one of L^1 and L^2 denotes F and the other denotes Cl, or both L^3 and L^4 denote F or one of L^3 and L^4 denotes F and the other denotes Cl.

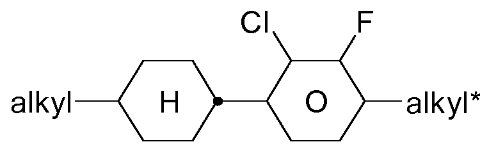
The compounds of the formula CY are preferably selected from the group consisting of the following sub-formulae:



CY1



CY2



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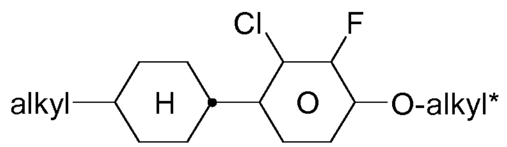

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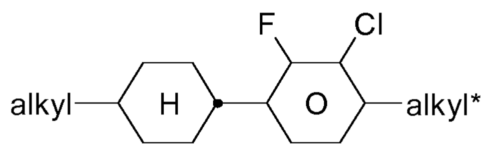

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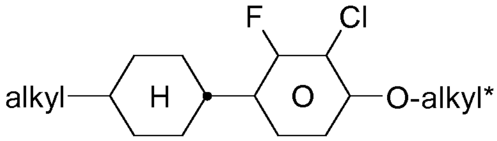
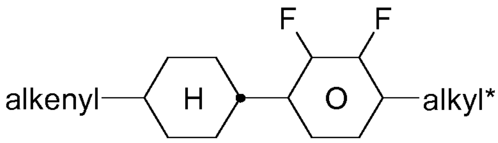
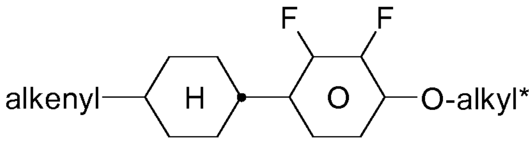


CY6



CY7



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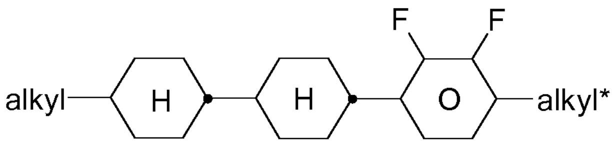

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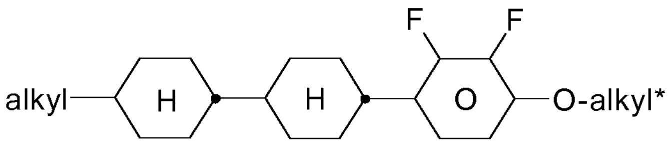

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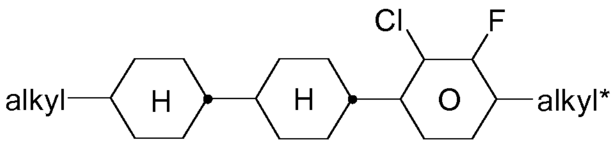

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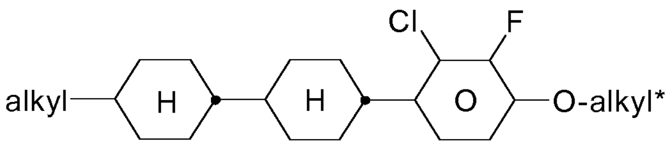

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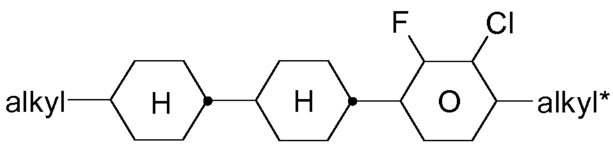
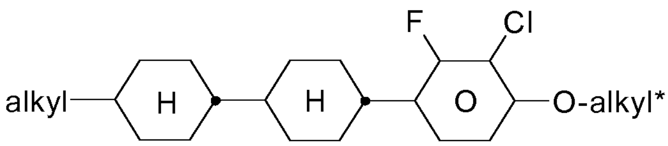
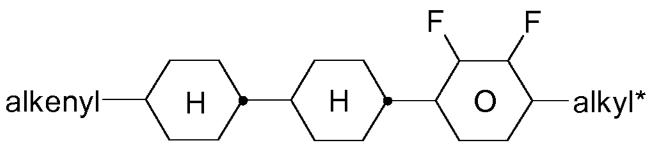


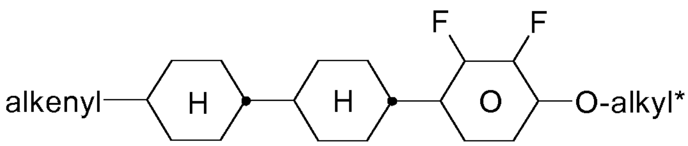
CY13



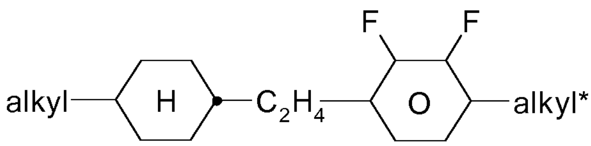
CY14



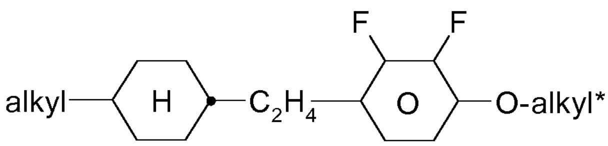
CY15



CY16



CY17



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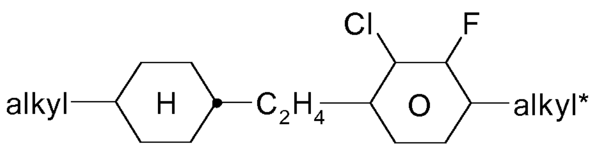

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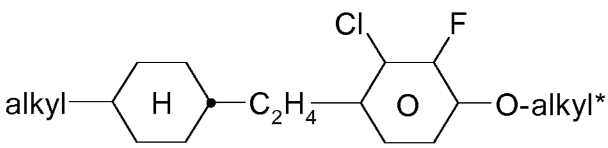
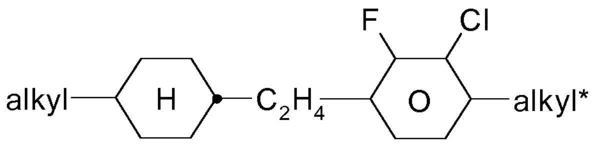
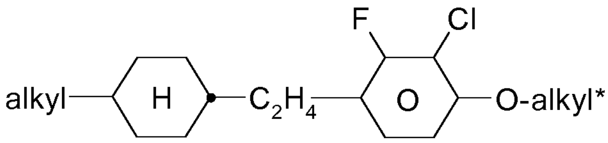


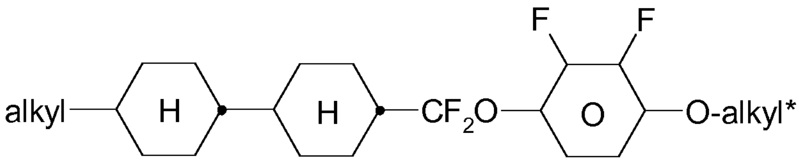
CY20



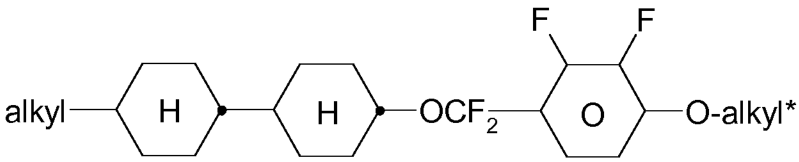
CY21



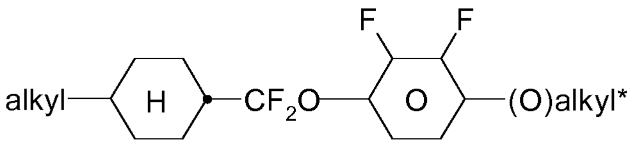
CY22



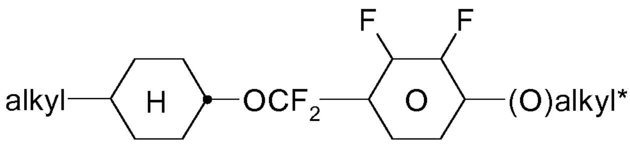
CY23



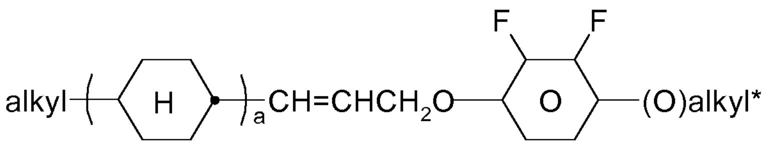
CY24



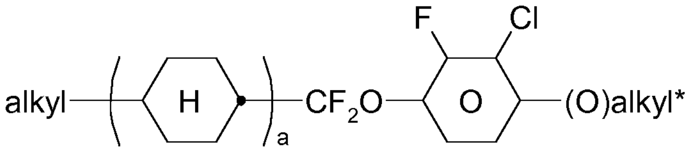
CY25



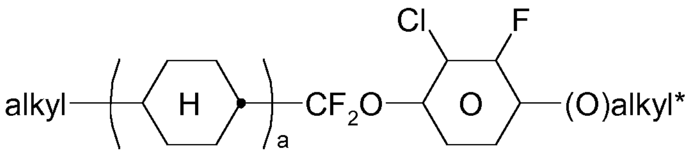
CY26



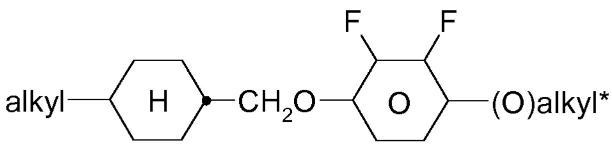
CY27



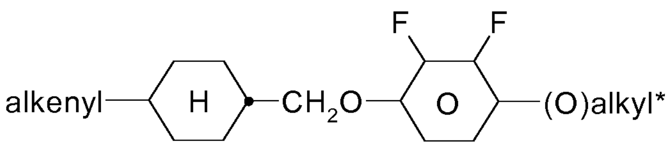
CY28



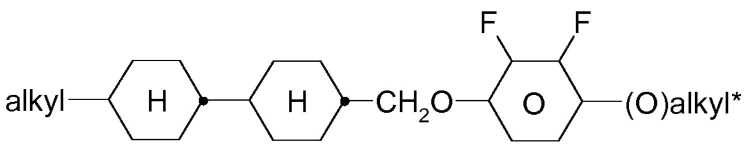
CY29



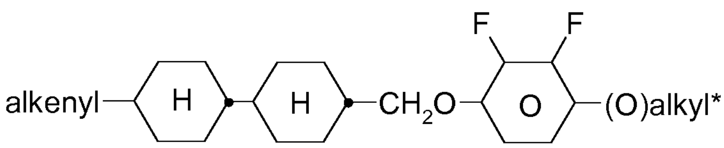
CY30



CY31



CY32

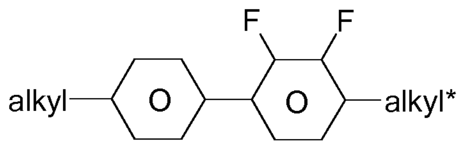


CY33

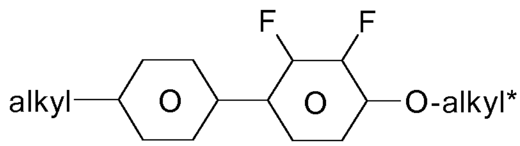
wherein a denotes 1 or 2, alkyl and alkyl* each, independently of one another, denote a straight-chain alkyl radical having 1-6 C atoms, and alkenyl denotes a straight-chain alkenyl radical having 2-6 C atoms, and (O) denotes an oxygen atom or a single bond. Alkenyl preferably denotes CH_2=CH-, CH_2=CH$CH_2$$CH_2$-, CH_3-CH=CH-,

CH_3-CH_2-CH=CH-, CH_3-$(CH_2)_2$-CH=CH-, CH_3-$(CH_2)_3$-CH=CH- or CH_3-CH=CH-$(CH_2)_2$-.

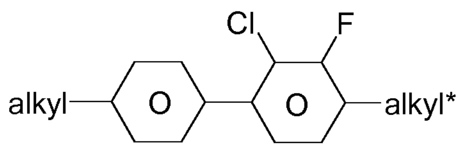
The compounds of the formula PY are preferably selected from the group consisting of the following sub-formulae:



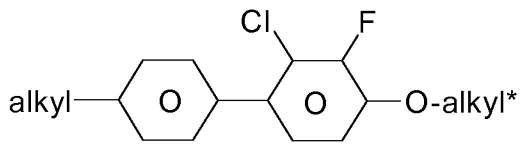
PY1



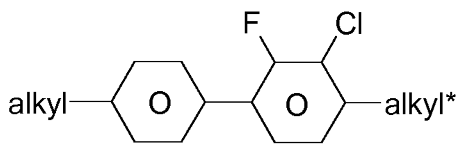
PY2



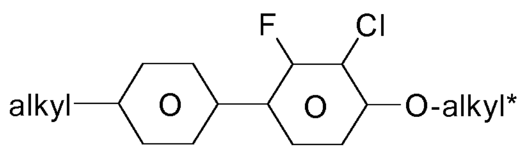
PY3



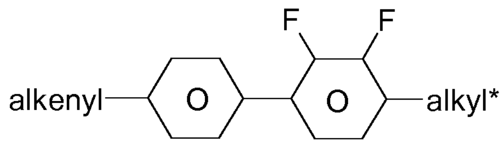
PY4



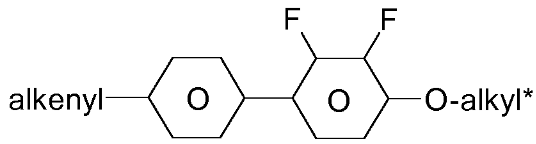
PY5



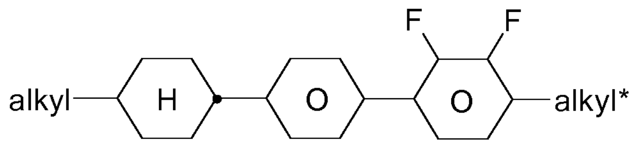
PY6



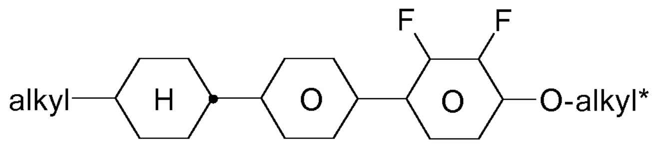
PY7



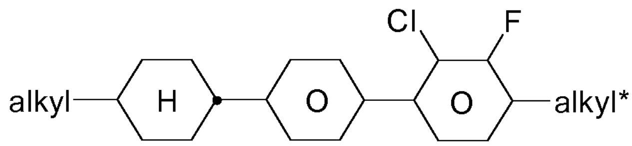
PY8



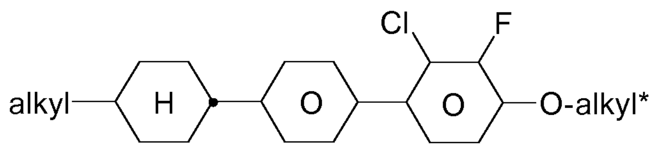
PY9



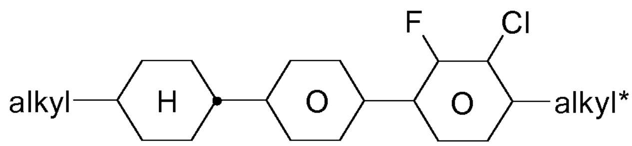
PY10



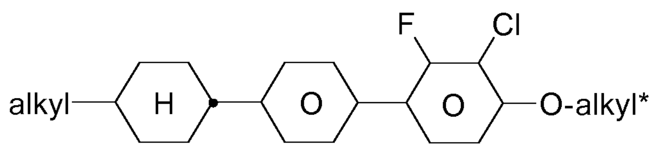
PY11



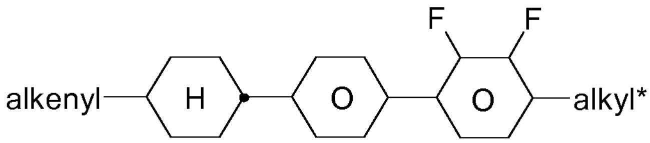
PY12



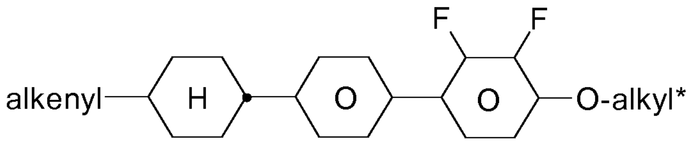
PY13



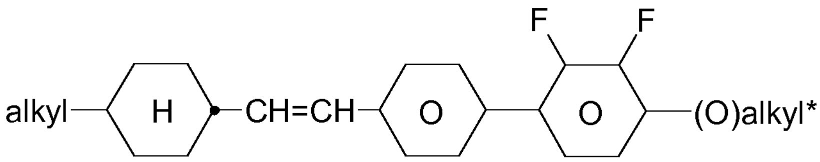
PY14



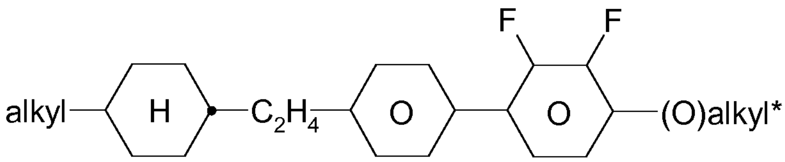
PY15



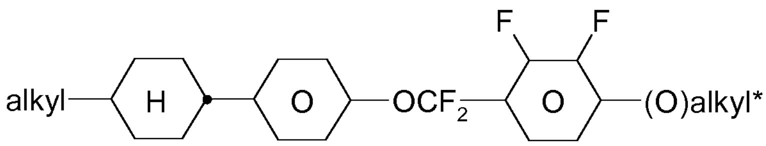
PY16



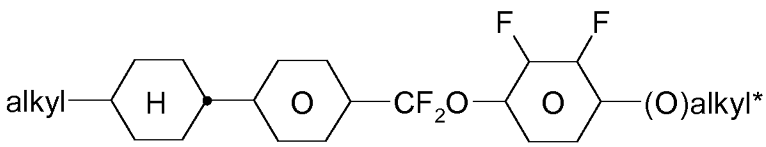
PY17



PY18



PY19

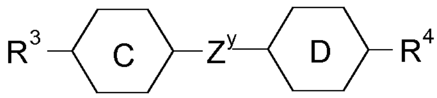


PY20

wherein alkyl and alkyl* each, independently of one another, denote a straight-chain alkyl radical having 1-6 C atoms, and alkenyl denotes a straight-chain alkenyl radical having 2-6 C atoms, and (O) denotes an oxygen atom or a single bond. Alkenyl preferably denotes CH_2=CH-, CH_2=$CHCH_2CH_2$-, CH_3-CH=CH-, CH_3-CH_2-

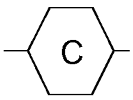
CH=CH-, CH_3-$(CH_2)_2$-CH=CH-, CH_3-$(CH_2)_3$-CH=CH- or CH_3-CH=CH-$(CH_2)_2$-.

b) LC medium which additionally comprises one or more compounds of the following formula:

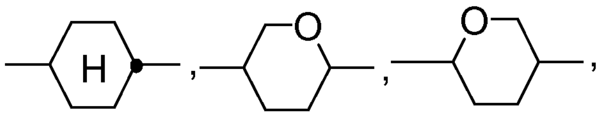


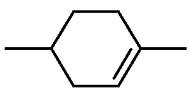
ZK

in which the individual radicals have the following meanings:

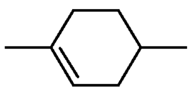


denotes

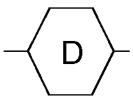




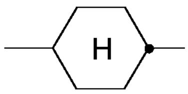
or



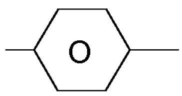
,



denotes



or

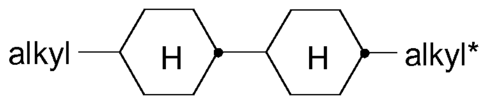


,

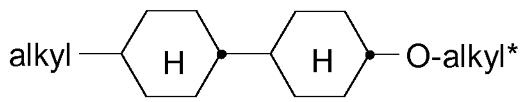
R^3 and R^4 each, independently of one another, denote alkyl having 1 to 12 C atoms, in which, in addition, one or two non-adjacent CH_2 groups may be replaced by -O-, -CH=CH-, -CO-, -O-CO- or -CO-O- in such a way that O atoms are not linked directly to one another,

Z^y denotes -CH_2CH_2-, -CH=CH-, -CF_2O-, -OCF_2-, -CH_2O-, -OCH_2-, -CO-O-, -O-CO-, -C_2F_4-, -CF=CF-, -CH=CH-CH_2O- or a single bond, preferably a single bond.

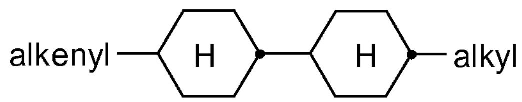
The compounds of the formula ZK are preferably selected from the group consisting of the following sub-formulae:



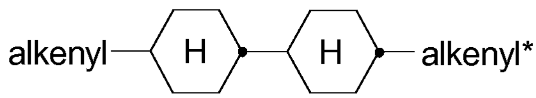
ZK1



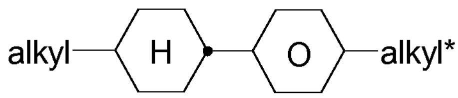
ZK2



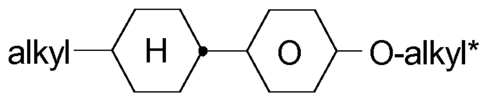
ZK3



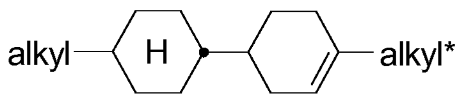
ZK4



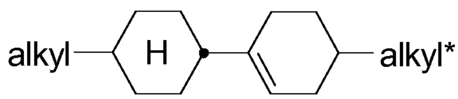
ZK5



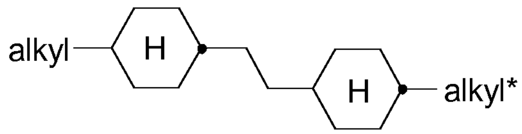
ZK6



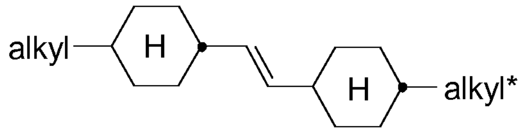
ZK7



ZK8



ZK9

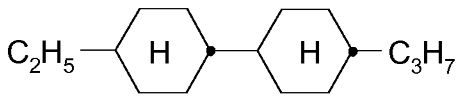


ZK10

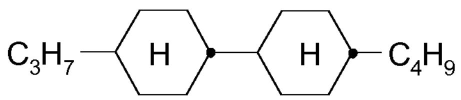
in which alkyl and alkyl* each, independently of one another, denote a straight-chain alkyl radical having 1-6 C atoms, and alkenyl denotes a straight-chain alkenyl radical having 2-6 C atoms. Alkenyl preferably denotes CH_2=CH-, CH_2=CH$CH_2$$CH_2$-, CH_3-CH=CH-, CH_3-CH_2-CH=CH-, CH_3-(CH_2)$_2$-CH=CH-, CH_3-(CH_2)$_3$-CH=CH- or CH_3-CH=CH-(CH_2)$_2$-.

Especially preferred are compounds of formula ZK1 and ZK3.

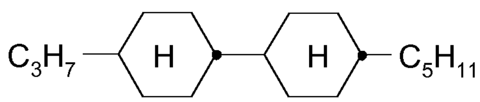
Particularly preferred compounds of formula ZK are selected from the following sub-formulae:



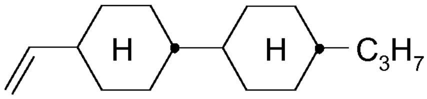
ZK1a

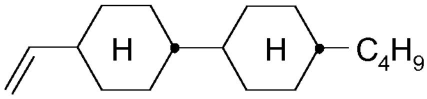


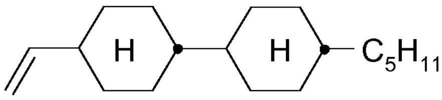
ZK1b

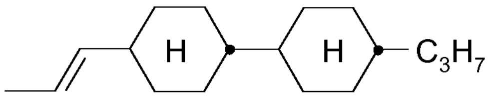


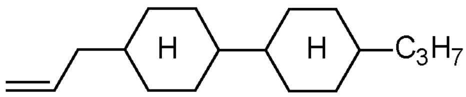
ZK1c

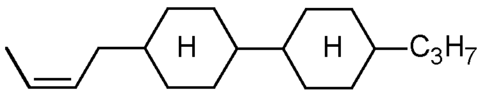

ZK3a

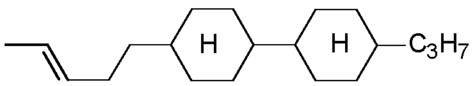

ZK3b


ZK3c


ZK3d


ZK3e

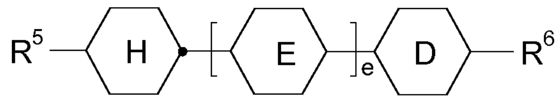

ZK3f


ZK3g

wherein the propyl, butyl and pentyl groups are straight-chain groups.

Most preferred are compounds of formula ZK1a and ZK3a.

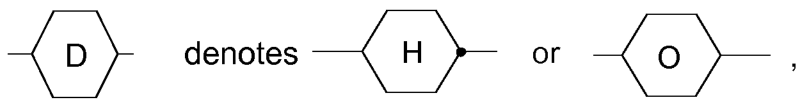
c) LC medium which additionally comprises one or more compounds of the following formula:

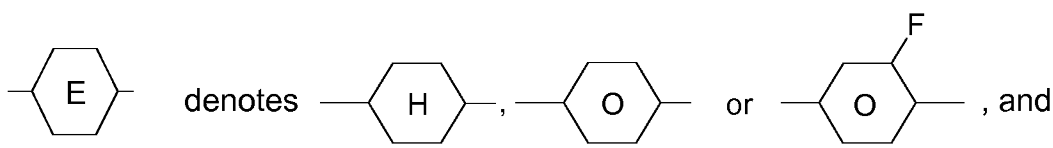


DK

in which the individual radicals on each occurrence, identically or differently, have the following meanings:

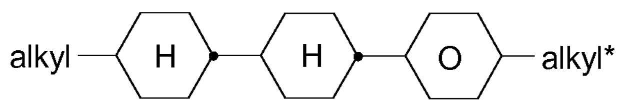
R^5 and R^6 each, independently of one another, denote alkyl having 1 to 12 C atoms, where, in addition, one or two non-adjacent CH_2 groups may be replaced by -O-, -CH=CH-, -CO-, -OCO- or -COO- in such a way that O atoms are not linked directly to one another, preferably alkyl or alkoxy having 1 to 6 C atoms,



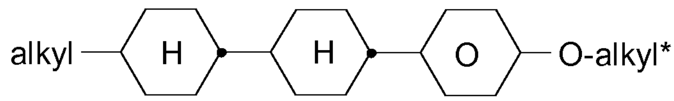


e denotes 1 or 2.

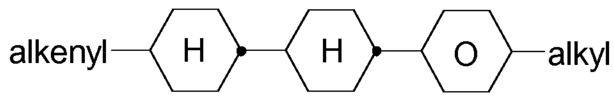
The compounds of the formula DK are preferably selected from the group consisting of the following sub-formulae:



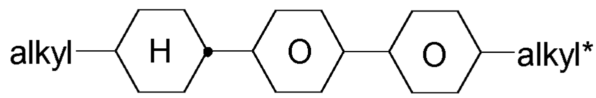
DK1



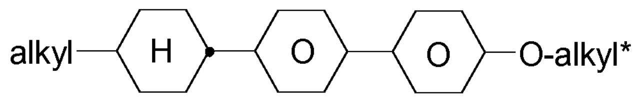
DK2



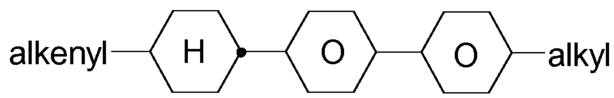
DK3



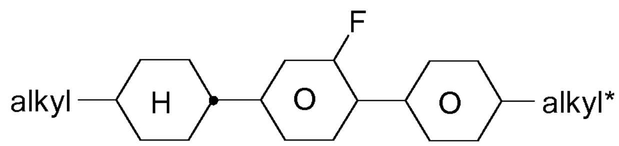
DK4



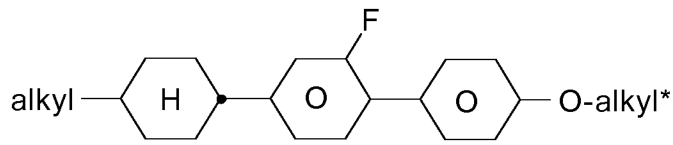
DK5



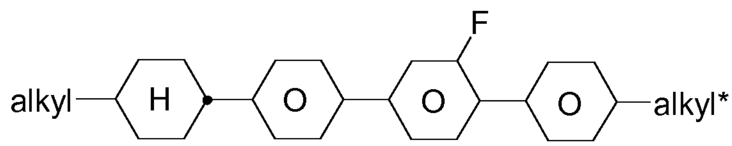
DK6



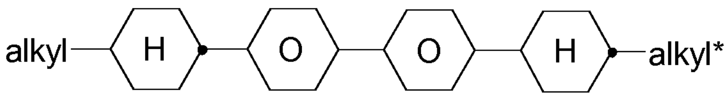
DK7

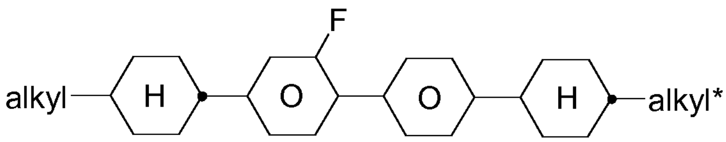


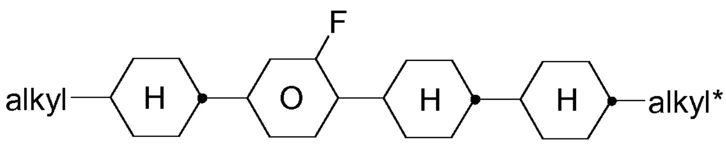
DK8



DK9

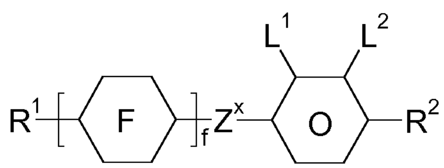

DK10


DK11

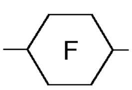
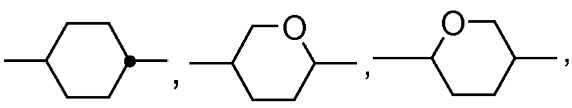

DK12

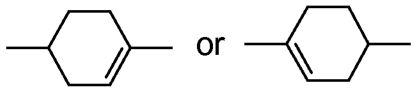
in which alkyl and alkyl* each, independently of one another, denote a straight-chain alkyl radical having 1-6 C atoms, and alkenyl denotes a straight-chain alkenyl radical having 2-6 C atoms. Alkenyl preferably denotes CH_2=CH-, CH_2=$CHCH_2CH_2$-, CH_3-CH=CH-, CH_3-CH_2-CH=CH-, CH_3-$(CH_2)_2$-CH=CH-, CH_3-$(CH_2)_3$-CH=CH- or CH_3-CH=CH-$(CH_2)_2$-.

d) LC medium which additionally comprises one or more compounds of the following formula:


LY

in which the individual radicals have the following meanings:

 denotes 



with at least one ring F being different from cyclohexylene,

f denotes 1 or 2,

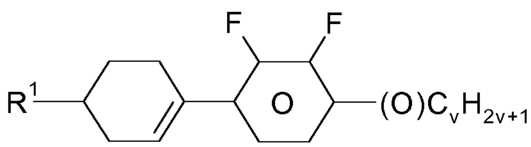
R^1 and R^2 each, independently of one another, denote alkyl having 1 to 12 C atoms, where, in addition, one or two non-adjacent CH_2 groups may be replaced by -O-, -CH=CH-, -CO-, -OCO- or -COO- in such a way that O atoms are not linked directly to one another,

Z^x denotes $-CH_2CH_2-$, -CH=CH-, $-CF_2O-$, $-OCF_2-$, $-CH_2O-$, $-OCH_2-$, -CO-O-, -O-CO-, $-C_2F_4-$, -CF=CF-, $-CH=CH-CH_2O-$ or a single bond, preferably a single bond,

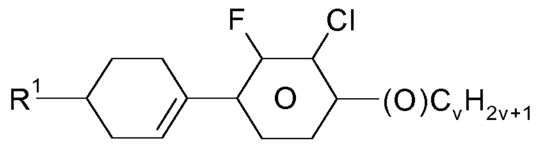
L^1 and L^2 each, independently of one another, denote F, Cl, OCF_3, CF_3, CH_3, CH_2F, CHF_2.

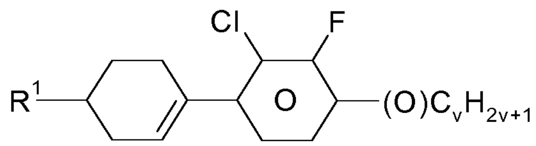
Preferably, both radicals L^1 and L^2 denote F or one of the radicals L^1 and L^2 denotes F and the other denotes Cl.

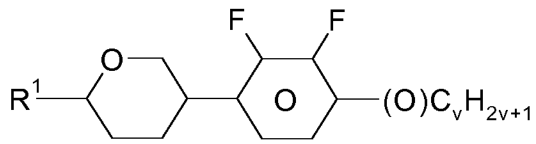
The compounds of the formula LY are preferably selected from the group consisting of the following sub-formulae:

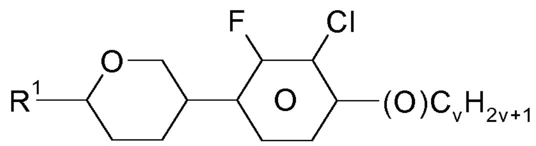


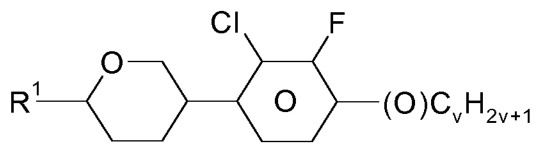
LY1

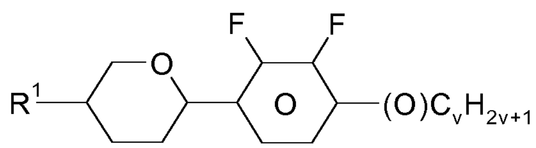

LY2

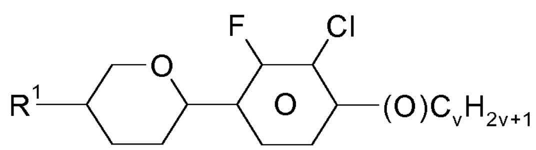

LY3

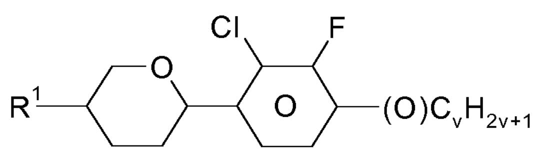

LY4

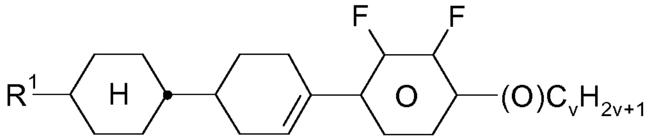

LY5


LY6

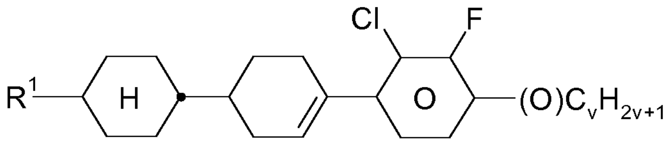

LY7


LY8

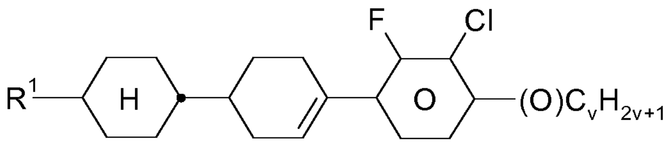

LY9



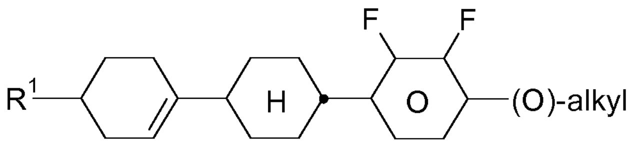
LY10



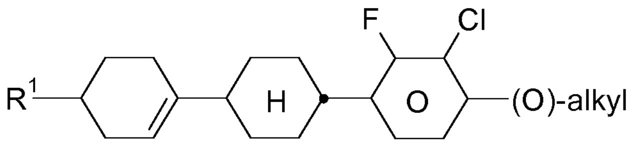
LY11



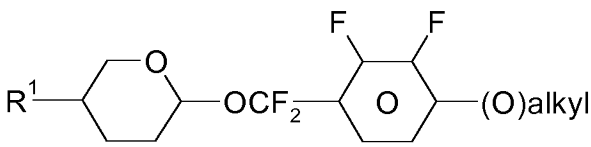
LY12



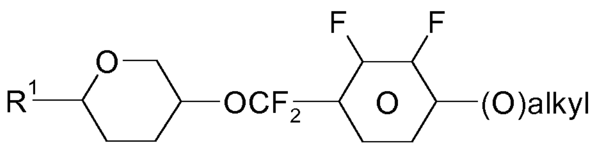
LY13



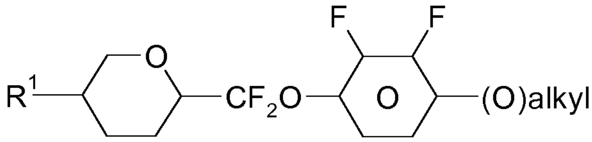
LY14



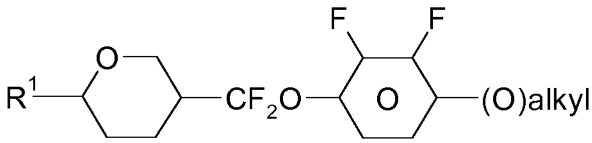
LY15



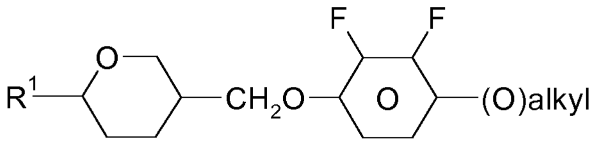
LY16



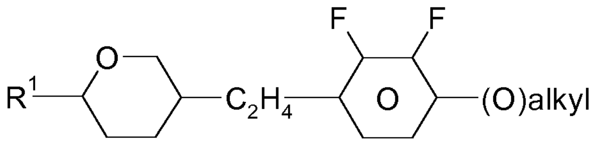
LY17



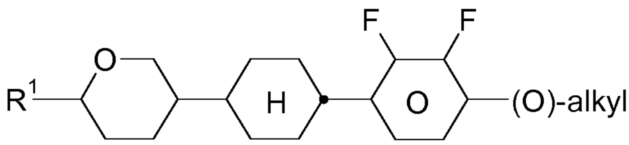
LY18



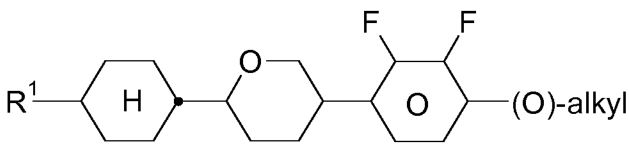
LY19



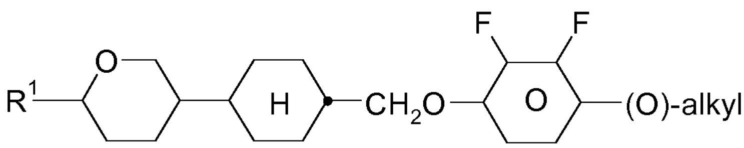
LY20



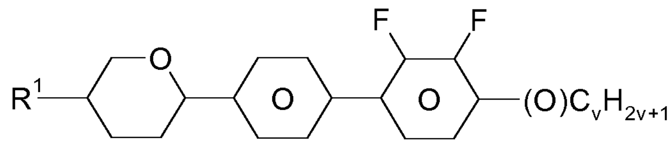
LY21



LY22



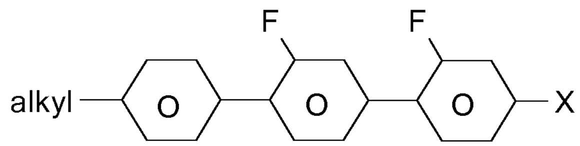
LY23



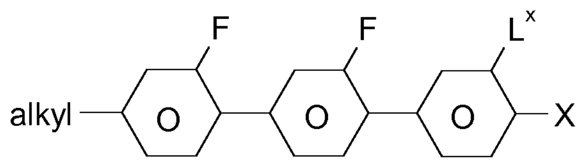
LY24

in which R^1 has the meaning indicated above, alkyl denotes a straight-chain alkyl radical having 1-6 C atoms, (O) denotes an oxygen atom or a single bond, and v denotes an integer from 1 to 6. R^1 preferably denotes straight-chain alkyl having 1 to 6 C atoms or straight-chain alkenyl having 2 to 6 C atoms, in particular CH_3, C_2H_5, n-C_3H_7, n-C_4H_9, n-C_5H_{11}, CH_2=CH-, CH_2=$CHCH_2CH_2$-, CH_3-CH=CH-, CH_3-CH_2-CH=CH-, CH_3-$(CH_2)_2$-CH=CH-, CH_3-$(CH_2)_3$-CH=CH- or CH_3-CH=CH-$(CH_2)_2$-.

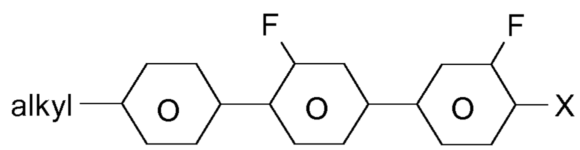
e) LC medium which additionally comprises one or more compounds selected from the group consisting of the following formulae:



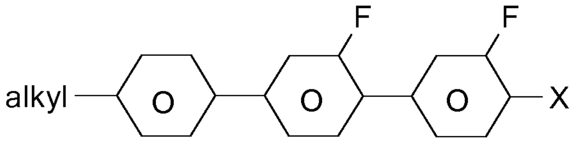
G1



G2



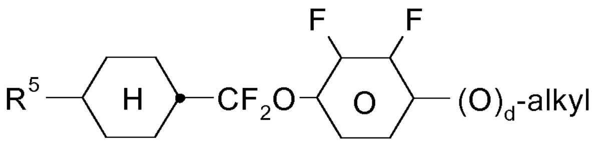
G3



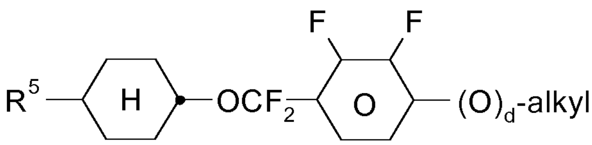
G4

in which alkyl denotes C_{1-6}-alkyl, L^x denotes H or F, and X denotes F, Cl, OCF_3, $OCHF_2$ or $OCH=CF_2$. Particular preference is given to compounds of the formula G1 in which X denotes F.

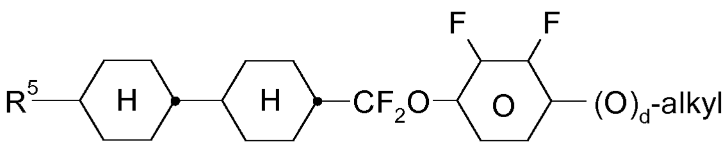
f) LC medium which additionally comprises one or more compounds selected from the group consisting of the following formulae:



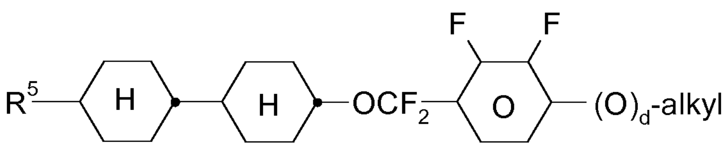
Y1



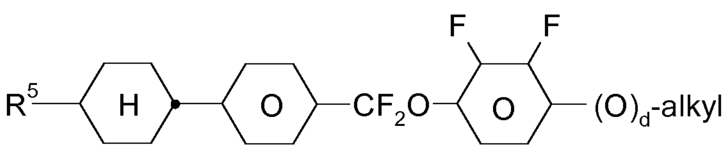
Y2



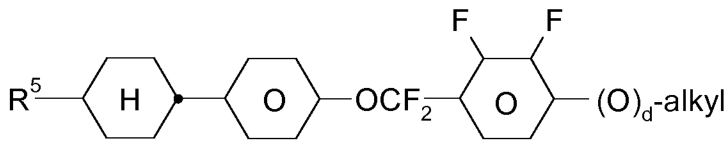
Y3



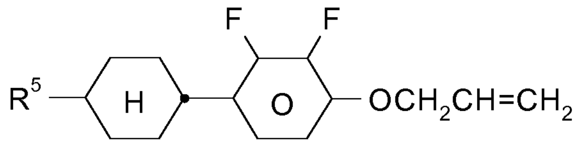
Y4



Y5



Y6



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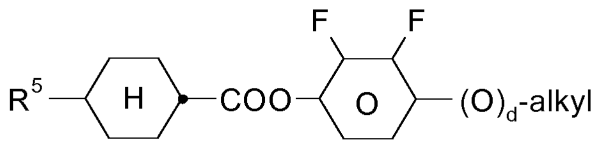
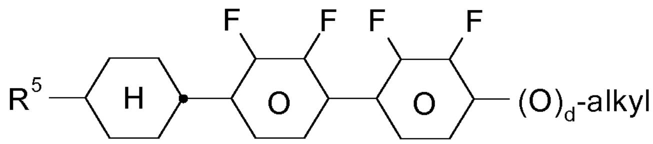


Y8



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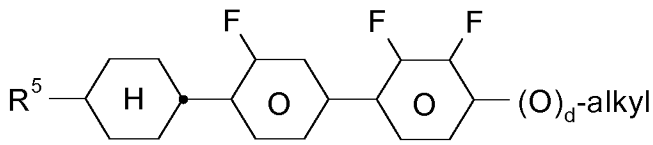
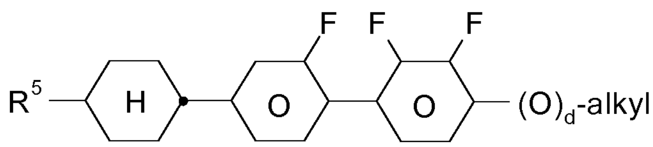
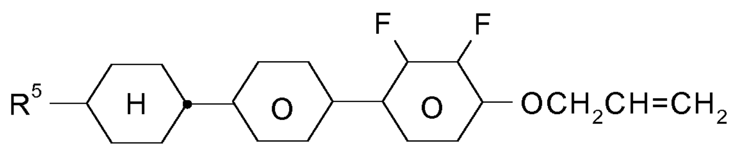


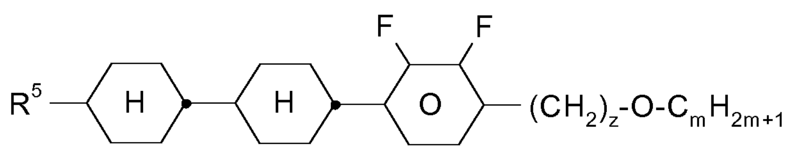
Y10



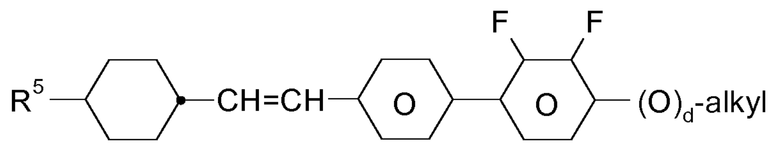
Y11



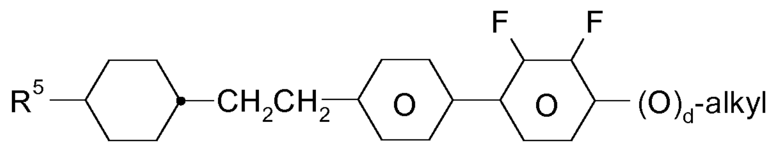
Y12



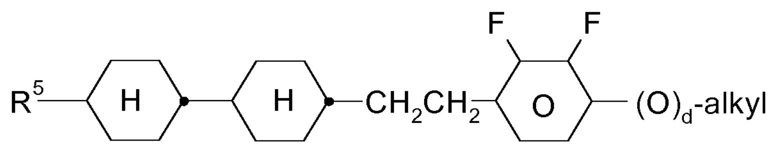
Y13



Y14



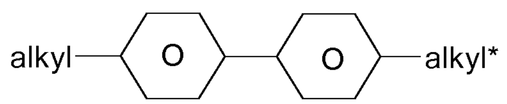
Y15



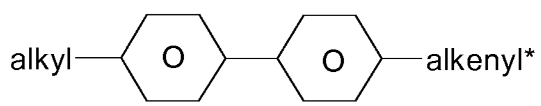
Y16

in which R^5 has one of the meanings indicated above for R^1, alkyl denotes C_{1-6}-alkyl, d denotes 0 or 1, and z and m each, independently of one another, denote an integer from 1 to 6. R^5 in these compounds is particularly preferably C_{1-6}-alkyl or -alkoxy or C_{2-6}-alkenyl, d is preferably 1.

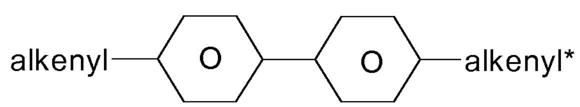
g) LC medium which additionally comprises one or more biphenyl compounds selected from the group consisting of the following formulae:



B1



B2

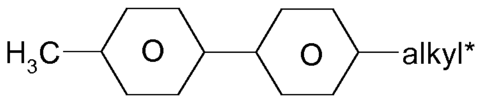


B3

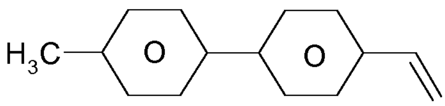
in which alkyl and alkyl* each, independently of one another, denote a straight-chain alkyl radical having 1-6 C atoms, and alkenyl and alkenyl* each, independently of one another, denote a straight-chain alkenyl radical having 2-6 C atoms. Alkenyl and alkenyl* preferably denote $CH_2=CH$-, $CH_2=CHCH_2CH_2$-, CH_3-CH=CH-, CH_3-CH_2-CH=CH-, CH_3-$(CH_2)_2$-CH=CH-, CH_3-$(CH_2)_3$-CH=CH- or CH_3-CH=CH-$(CH_2)_2$-.

The compounds of the formula B2 are particularly preferred.

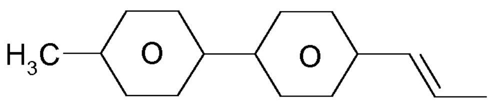
The compounds of the formulae B1 to B3 are preferably selected from the group consisting of the following sub-formulae:



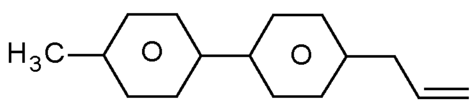
B1a



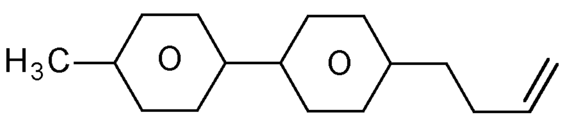
B2a



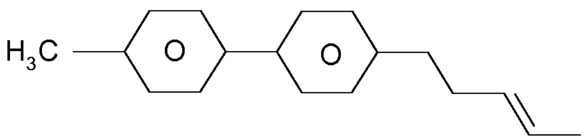
B2b



B2c



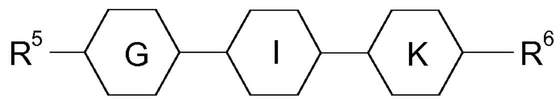
B2d



B2e

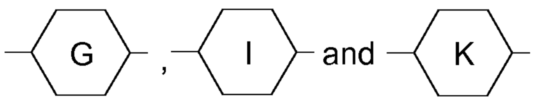
in which alkyl* denotes an alkyl radical having 1-6 C atoms. The medium according to the invention particularly preferably comprises one or more compounds of the formulae B1a and/or B2e.

h) LC medium which additionally comprises one or more terphenyl compounds of the following formula:

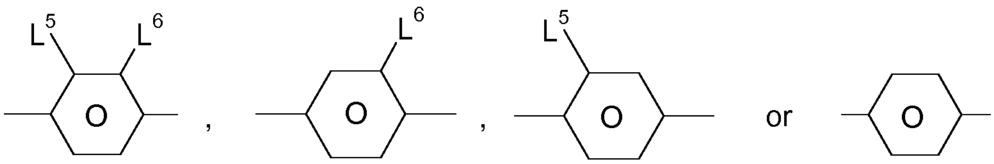


T

in which R^5 and R^6 each, independently of one another, have one of the meanings indicated above, and

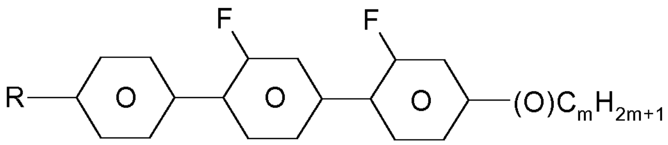


each, independently of one another, denote

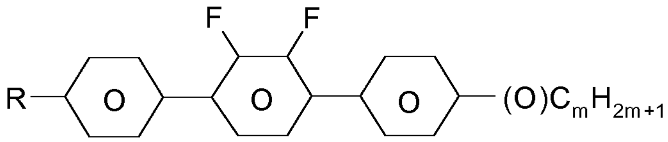


in which L^5 denotes F or Cl, preferably F, and L^6 denotes F, Cl, OCF_3, CF_3, CH_3, CH_2F or CHF_2, preferably F.

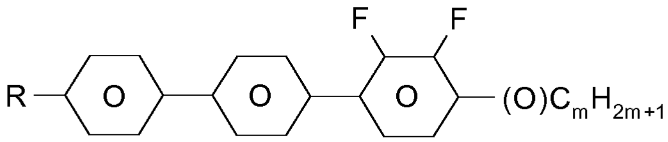
The compounds of the formula T are preferably selected from the group consisting of the following sub-formulae:



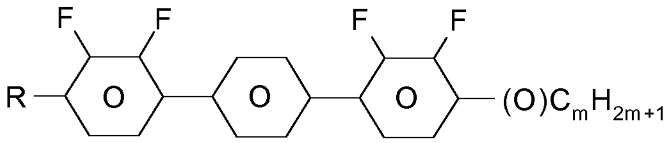
T1



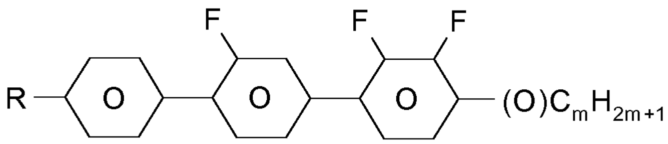
T2



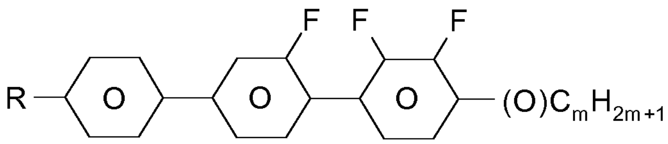
T3



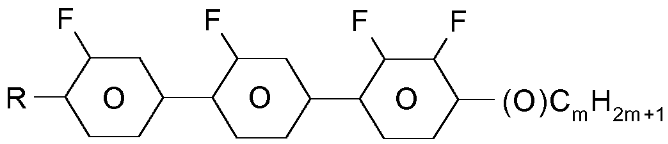
T4



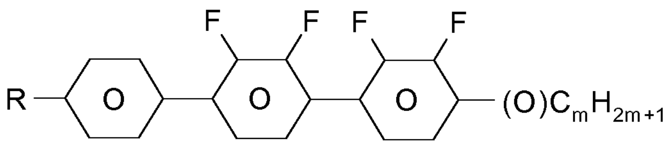
T5



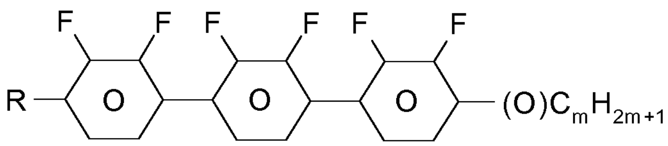
T6



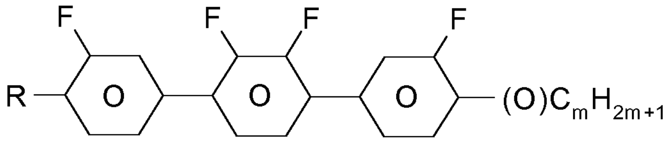
T7



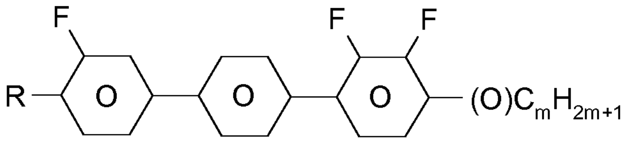
T8



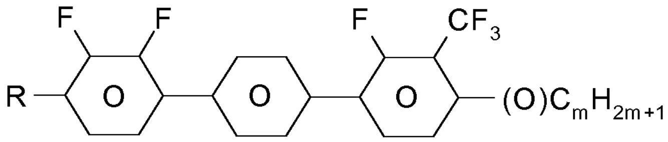
T9



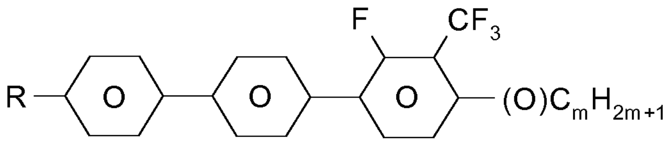
T10



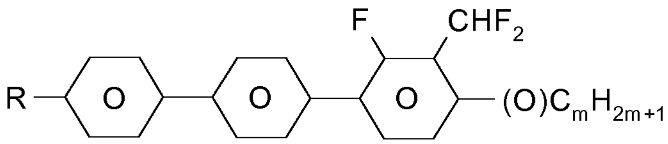
T11



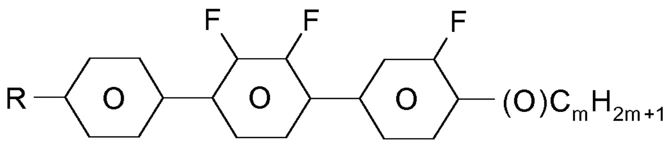
T12



T13



T14



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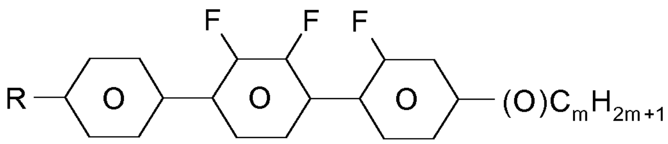

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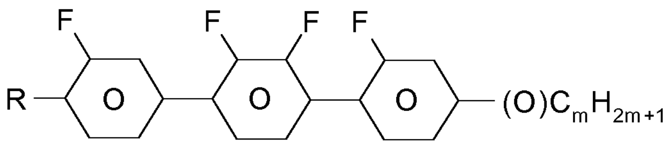
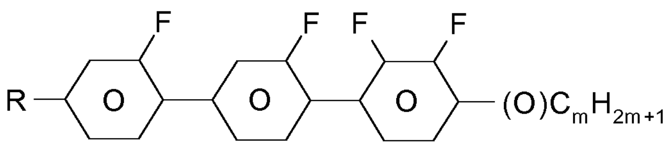
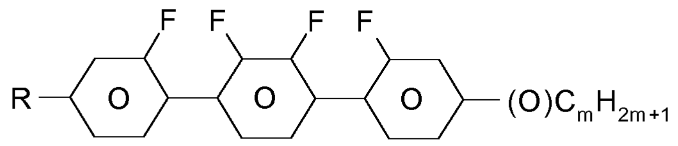


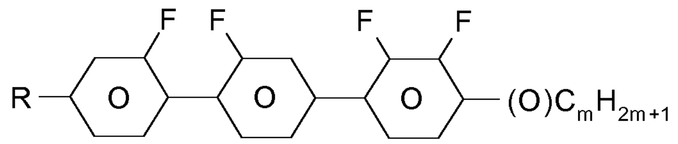
T17



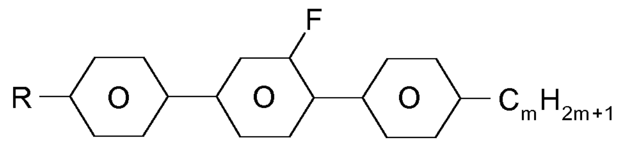
T18



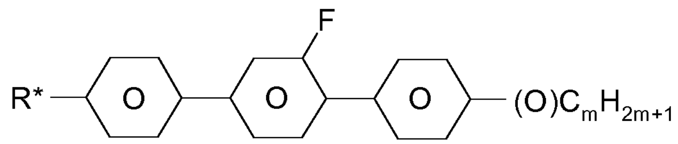
T19



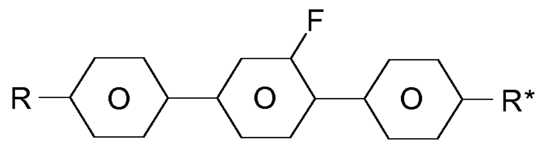
T20



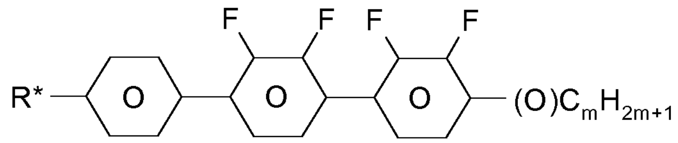
T21



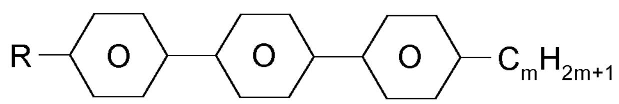
T22



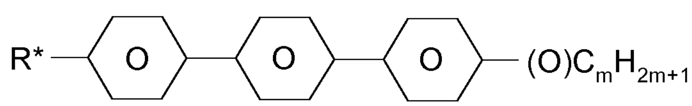
T23



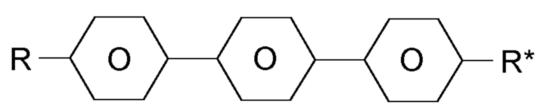
T24



T25



T26



T27

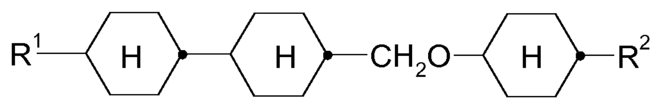
in which R denotes a straight-chain alkyl or alkoxy radical having 1-7 C atoms, R* denotes a straight-chain alkenyl radical having 2-7 C atoms, (O) denotes an oxygen atom or a single bond, and m denotes an integer from 1 to 6. R* preferably denotes CH_2=CH-, CH_2=$CHCH_2CH_2$-, CH_3-CH=CH-, CH_3-CH_2-CH=CH-, CH_3-$(CH_2)_2$-CH=CH-, CH_3-$(CH_2)_3$-CH=CH- or CH_3-CH=CH-$(CH_2)_2$-.

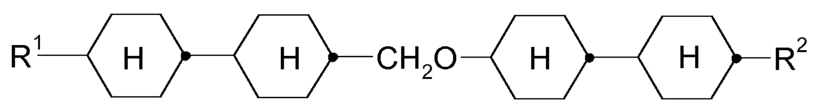
R preferably denotes methyl, ethyl, propyl, butyl, pentyl, hexyl, methoxy, ethoxy, propoxy, butoxy or pentoxy.

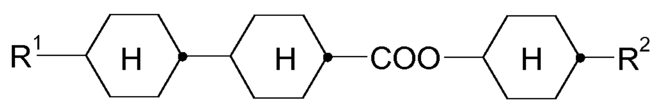
Particular preference is given to compounds of the formulae T1, T2, T3 and T21. In these compounds, R preferably denotes alkyl, furthermore alkoxy, each having 1-5 C atoms.

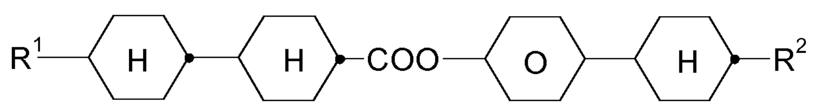
The terphenyls are preferably employed in mixtures according to the invention if the Δn value of the mixture is to be ≥ 0.1. Preferred mixtures comprise one or more terphenyl compounds of the formula T, preferably selected from the group of compounds T1 to T22.

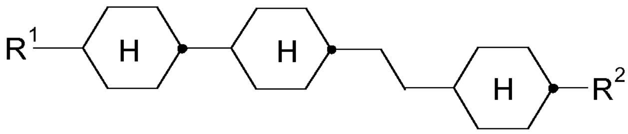
i) LC medium which additionally comprises one or more compounds selected from the group consisting of the following formulae:

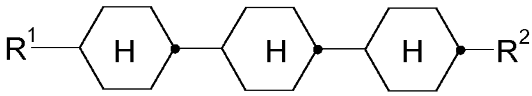

O1

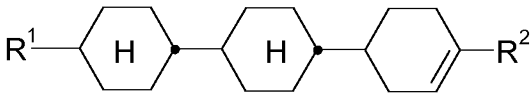

O2

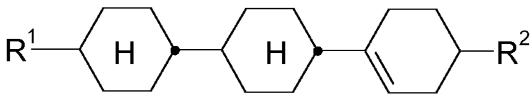

O3

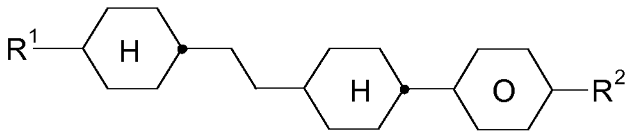

O4

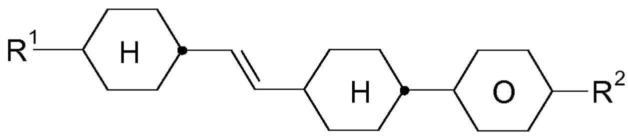

O5

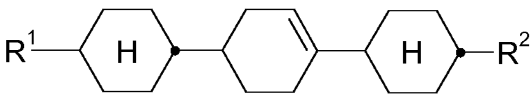

O6


O7


O8


O9

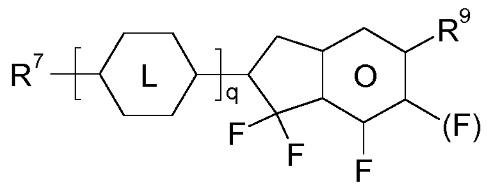

O10


O11

in which R^1 and R^2 have the meanings indicated above and preferably each, independently of one another, denote straight-chain alkyl having 1 to 6 C atoms or straight-chain alkenyl having 2 to 6 C atoms.

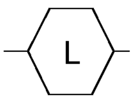
Preferred media comprise one or more compounds selected from the formulae O1, O3 and O4.

k) LC medium which additionally comprises one or more compounds of the following formula:

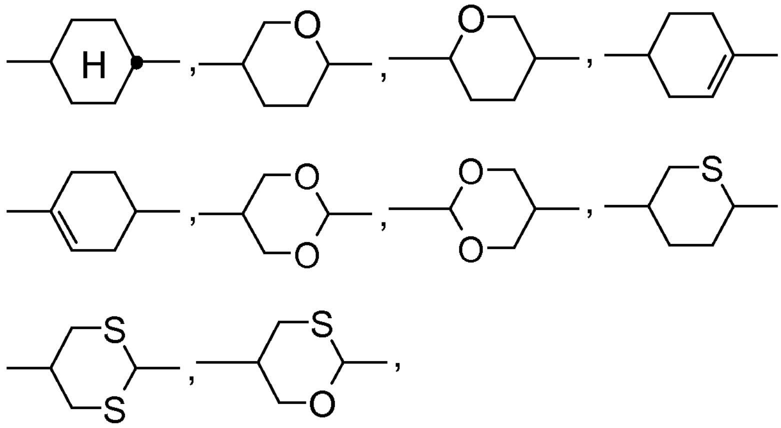


FI

in which

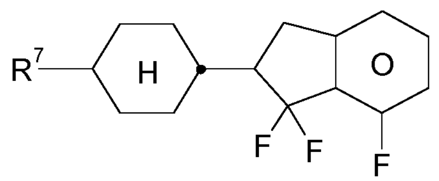


denotes

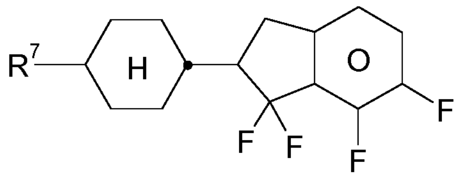


R^9 denotes H, CH_3, C_2H_5 or n-C_3H_7, (F) denotes an optional fluorine substituent, and q denotes 1, 2 or 3, and R^7 has one of the meanings indicated for R^1.

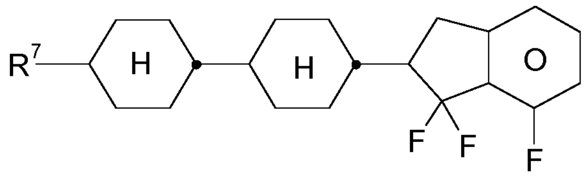
Particularly preferred compounds of the formula FI are selected from the group consisting of the following sub-formulae:



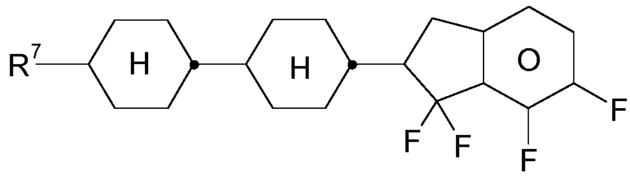
FI1



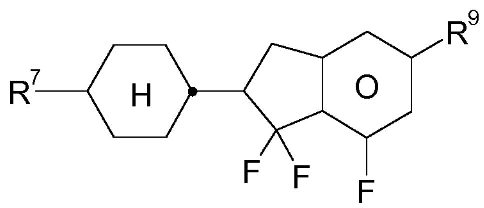
FI2



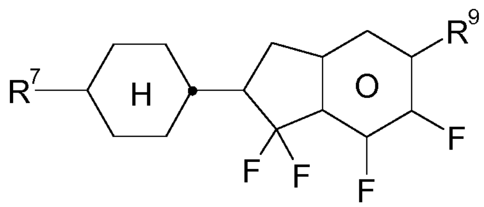
FI3



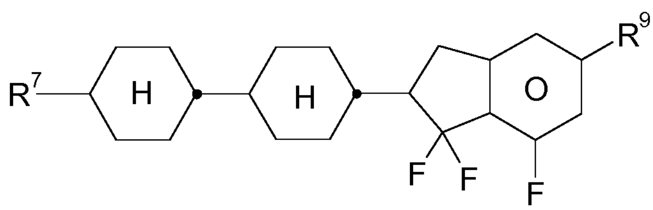
FI4



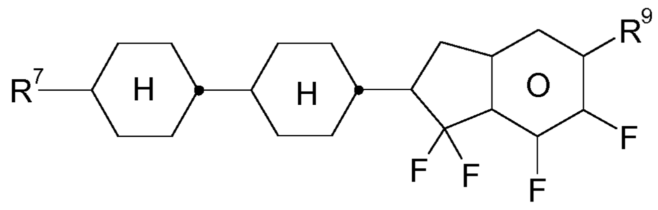
FI5



FI6



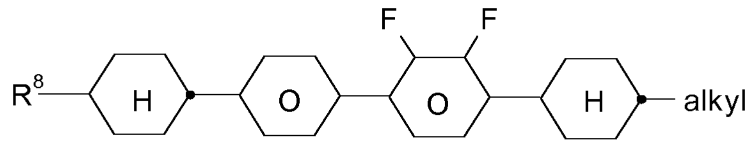
FI7



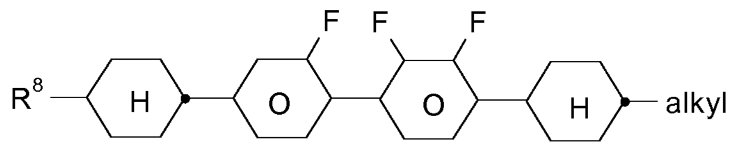
FI8

in which R^7 preferably denotes straight-chain alkyl, and R^9 denotes CH_3, C_2H_5 or n-C_3H_7. Particular preference is given to the compounds of the formulae FI1, FI2 and FI3.

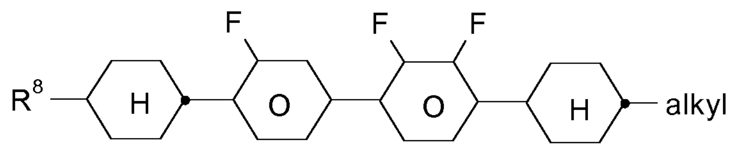
l) LC medium which additionally comprises one or more compounds selected from the group consisting of the following formulae:



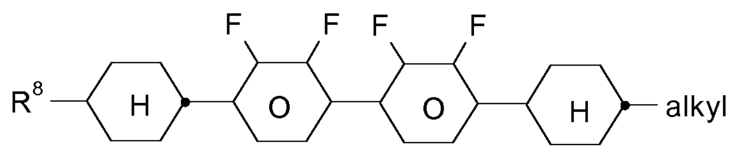
VK1



VK2



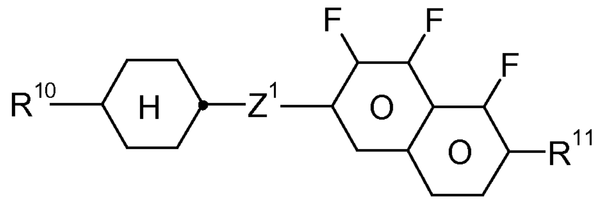
VK3



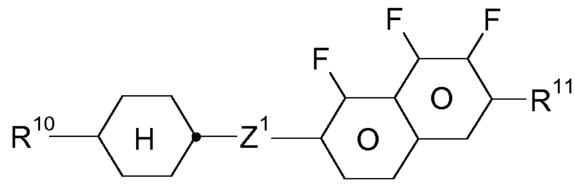
VK4

in which R^8 has the meaning indicated for R^1, and alkyl denotes a straight-chain alkyl radical having 1-6 C atoms.

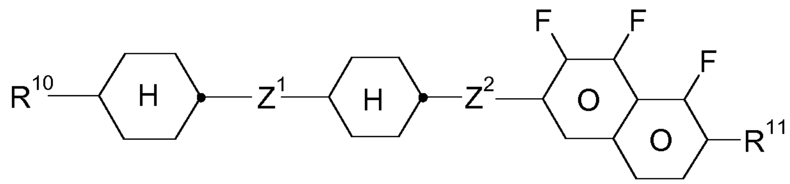
m) LC medium which additionally comprises one or more compounds which contain a tetrahydronaphthyl or naphthyl unit, such as, for example, the compounds selected from the group consisting of the following formulae:



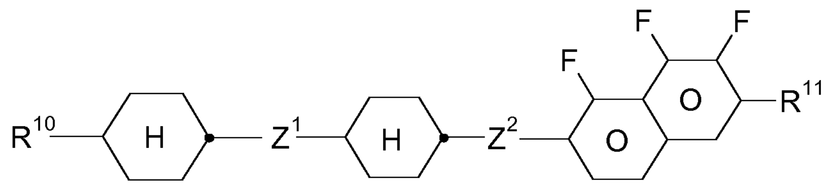
N1



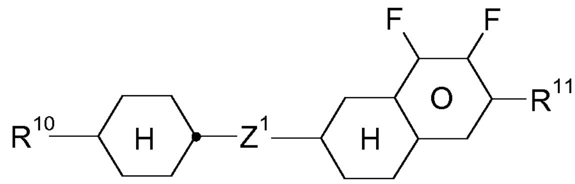
N2



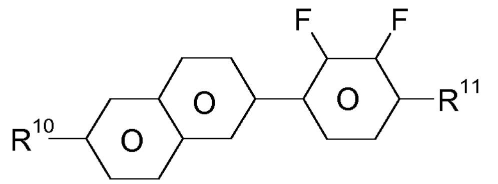
N3



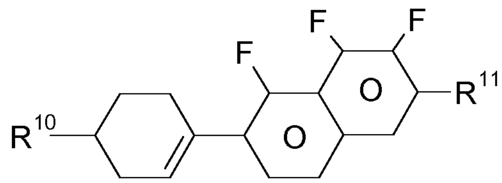
N4



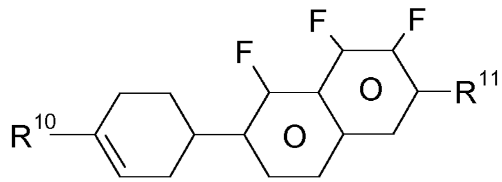
N5



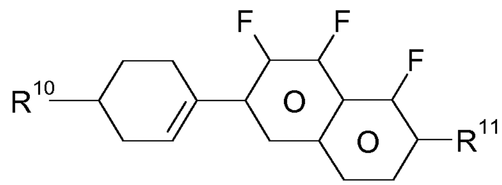
N6



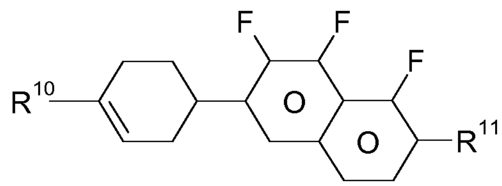
N7



N8



N9



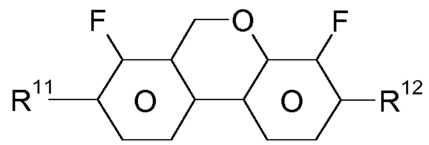
N10

in which

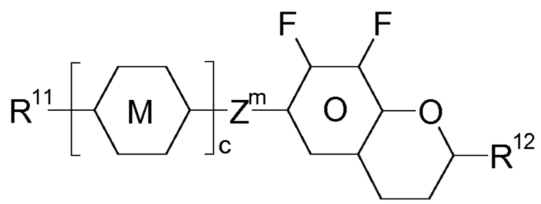
R^{10} and R^{11} each, independently of one another, denote alkyl having 1 to 12 C atoms, where, in addition, one or two non-adjacent CH_2 groups may be replaced by -O-, -CH=CH-, -CO-, -OCO- or -COO- in such a way that O atoms are not linked directly to one another, preferably alkyl or alkoxy having 1 to 6 C atoms, and R^{10} and R^{11} preferably denote straight-chain alkyl or alkoxy having 1 to 6 C atoms or straight-chain alkenyl having 2 to 6 C atoms, and

Z^1 and Z^2 each, independently of one another, denote $-C_2H_4-$, -CH=CH-, $-(CH_2)_4-$, $-(CH_2)_3O-$, $-O(CH_2)_3-$, $-CH=CH-CH_2CH_2-$, $-CH_2CH_2CH=CH-$, $-CH_2O-$, $-OCH_2-$, -CO-O-, -O-CO-, $-C_2F_4-$, -CF=CF-, -CF=CH-, -CH=CF-, $-CH_2-$ or a single bond.

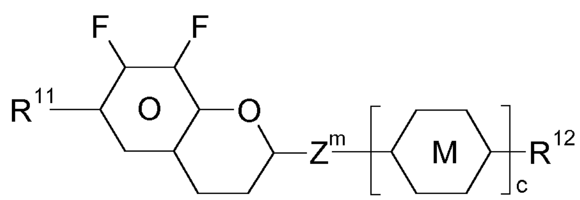
n) LC medium which additionally comprises one or more difluoro-dibenzochromans and/or chromans of the following formulae:



BC



CR



RC

in which

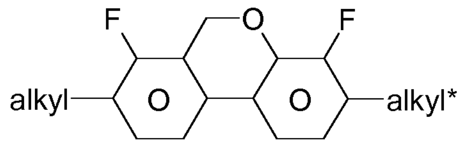
R^{11} and R^{12} each, independently of one another, have one of the meanings indicated above for R^{11} under formula N1

ring M is trans-1,4-cyclohexylene or 1,4-phenylene,

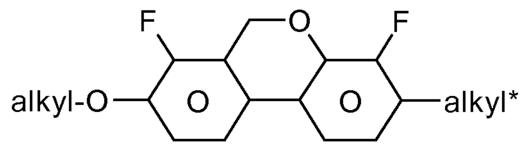
Z^m $-C_2H_4-$, $-CH_2O-$, $-OCH_2-$, -CO-O- or -O-CO-,

c is 0, 1 or 2.

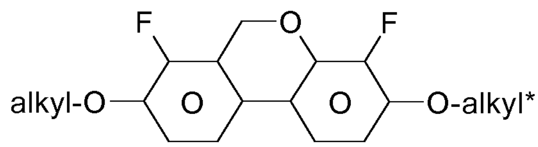
Particularly preferred compounds of the formulae BC, CR and RC are selected from the group consisting of the following sub-formulae:



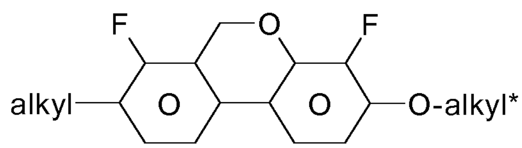
BC1



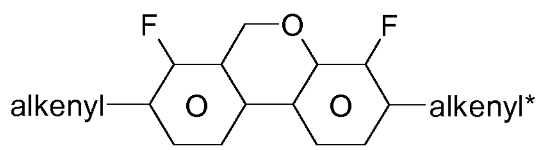
BC2



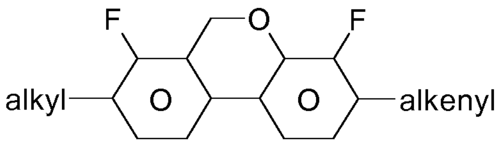
BC3



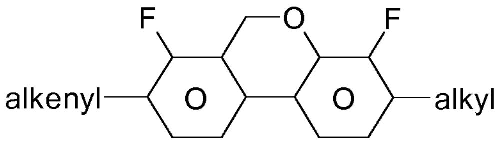
BC4



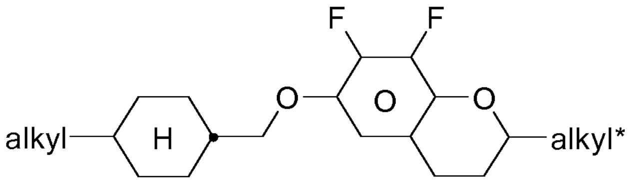
BC5



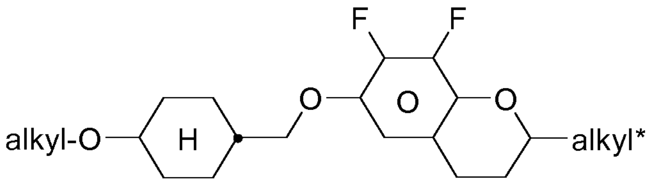
BC6



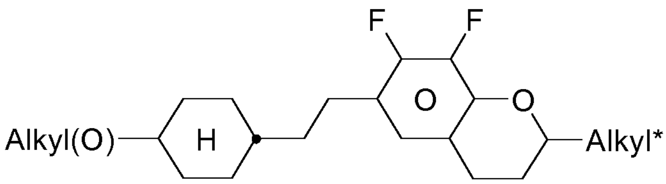
BC7



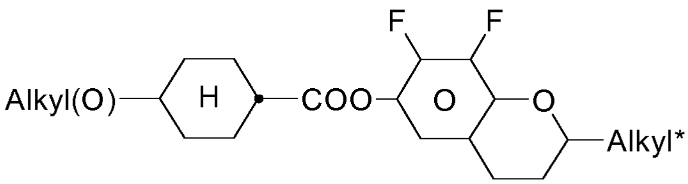
CR1



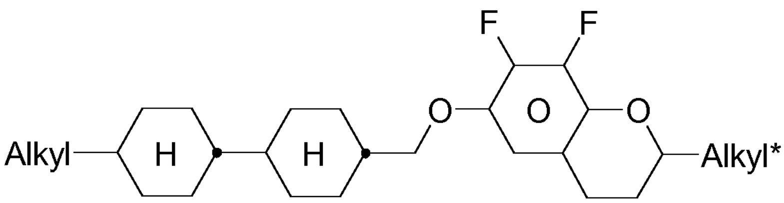
CR2



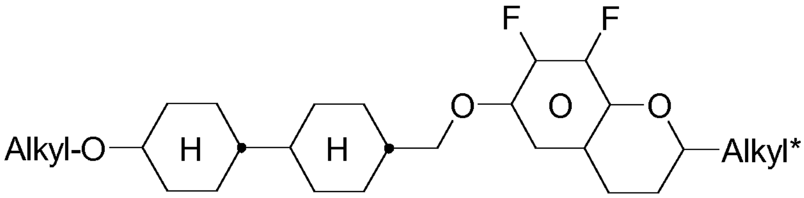
CR3



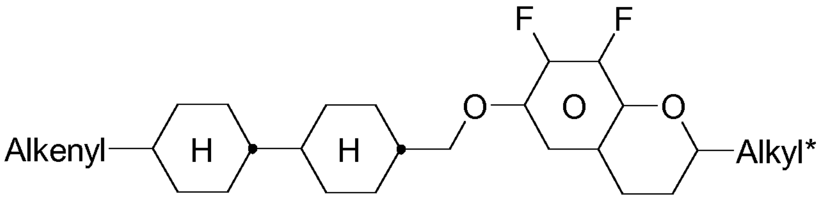
CR4



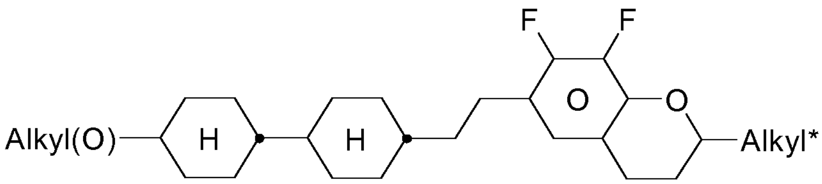
CR5



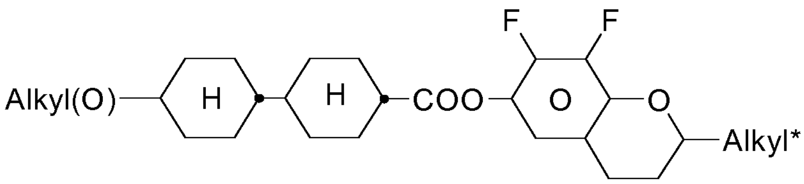
CR6



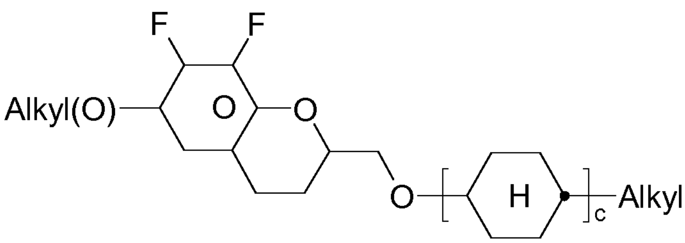
CR7



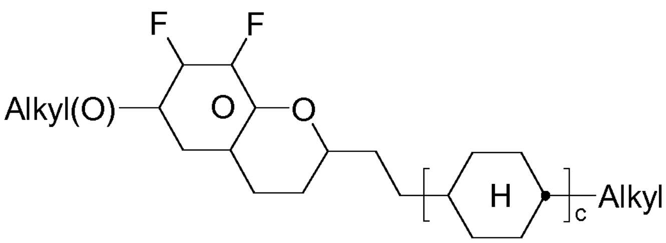
CR8



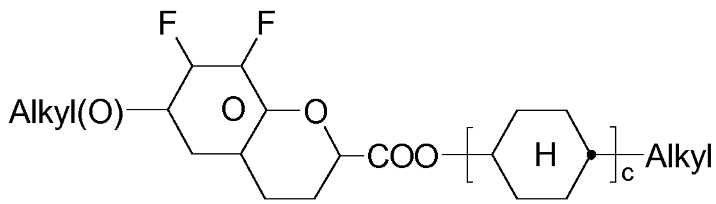
CR9



RC1



RC2

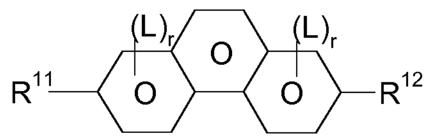


RC3

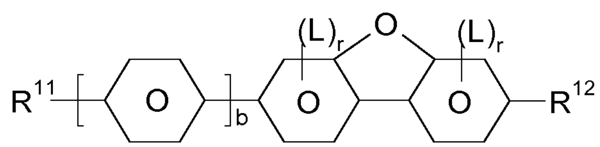
in which alkyl and alkyl* each, independently of one another, denote a straight-chain alkyl radical having 1-6 C atoms, (O) denotes an oxygen atom or a single bond, c is 1 or 2, and alkenyl and alkenyl* each, independently of one another, denote a straight-chain alkenyl radical having 2-6 C atoms. Alkenyl and alkenyl* preferably denote CH_2=CH-, CH_2=$CHCH_2CH_2$-, CH_3-CH=CH-, CH_3-CH_2-CH=CH-, CH_3-$(CH_2)_2$-CH=CH-, CH_3-$(CH_2)_3$-CH=CH- or CH_3-CH=CH-$(CH_2)_2$-.

Very particular preference is given to mixtures comprising one, two or three compounds of the formula BC-2.

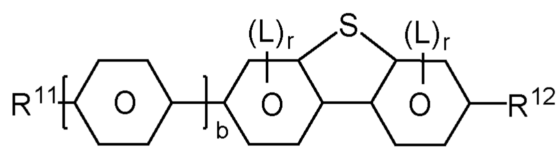
o) LC medium which additionally comprises one or more fluorinated phenanthrenes and/or dibenzofurans of the following formulae:



PH



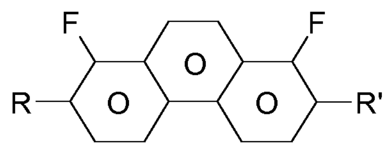
BF



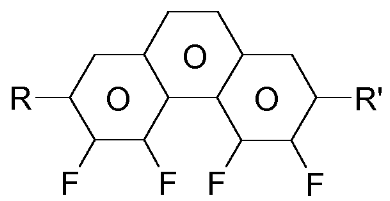
BS

in which R^{11} and R^{12} each, independently of one another, have one of the meanings indicated above for R^{11} under formula N1, b denotes 0 or 1, L denotes F, and r denotes 1, 2 or 3.

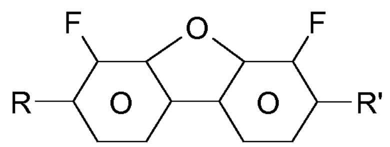
Particularly preferred compounds of the formulae PH and BF are selected from the group consisting of the following sub-formulae:



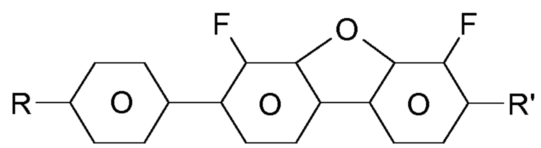
PH1



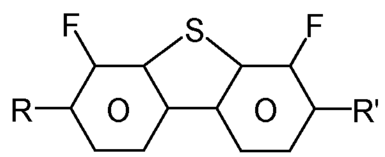
PH2



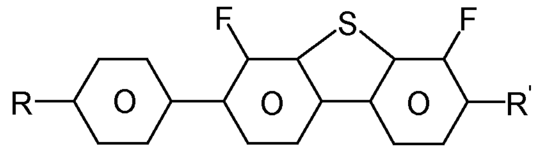
BF1



BF2



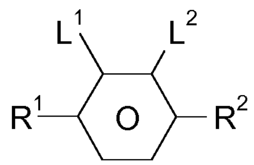
BS1



BS2

in which R and R' each, independently of one another, denote a straight-chain alkyl or alkoxy radical having 1-7 C atoms.

p) LC medium which additionally comprises one or more monocyclic compounds of the following formula



Y

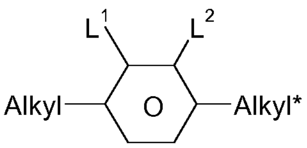
wherein

R^1 and R^2 each, independently of one another, denote alkyl having 1 to 12 C atoms, where, in addition, one or two non-adjacent CH_2 groups may be replaced by -O-, -CH=CH-, -CO-, -OCO- or -COO- in such a way that O atoms are not linked directly to one another, preferably alkyl or alkoxy having 1 to 6 C atoms,

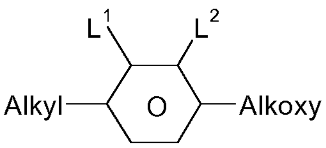
L^1 and L^2 each, independently of one another, denote F, Cl, OCF_3, CF_3, CH_3, CH_2F, CHF_2.

Preferably, both L^1 and L^2 denote F or one of L^1 and L^2 denotes F and the other denotes Cl,

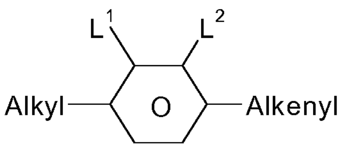
The compounds of the formula Y are preferably selected from the group consisting of the following sub-formulae:



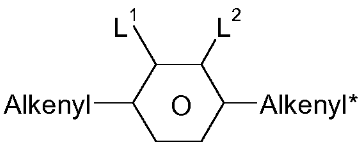
Y1



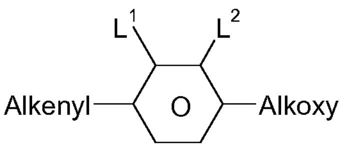
Y2



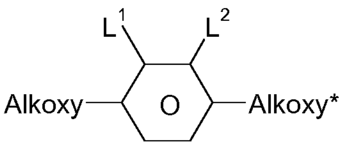
Y3



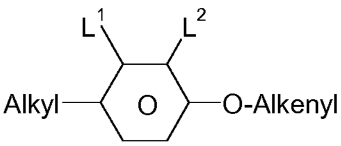
Y4



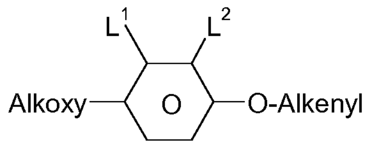
Y5



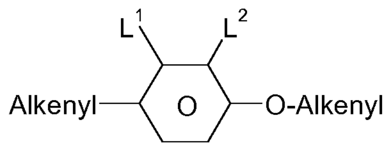
Y6



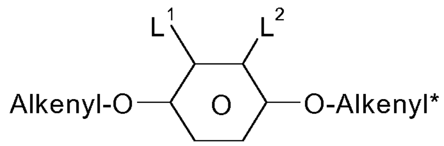
Y7



Y8



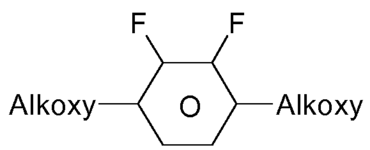
Y9



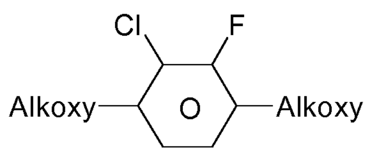
Y10,

in which, Alkyl and Alkyl* each, independently of one another, denote a straight-chain alkyl radical having 1-6 C atoms, Alkoxy denotes a straight-chain alkoxy radical having 1-6 C atoms, Alkenyl and Alkenyl* each, independently of one another, denote a straight-chain alkenyl radical having 2-6 C atoms, and O denotes an oxygen atom or a single bond. Alkenyl and Alkenyl* preferably denote CH_2=CH-, CH_2=$CHCH_2CH_2$-, CH_3-CH=CH-, CH_3-CH_2-CH=CH-, CH_3-$(CH_2)_2$-CH=CH-, CH_3-$(CH_2)_3$-CH=CH- or CH_3-CH=CH-$(CH_2)_2$-.

Particularly preferred compounds of the formula Y are selected from the group consisting of the following sub-formulae:



Y6A

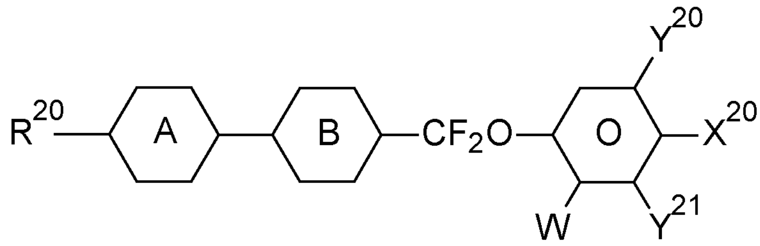


Y6B

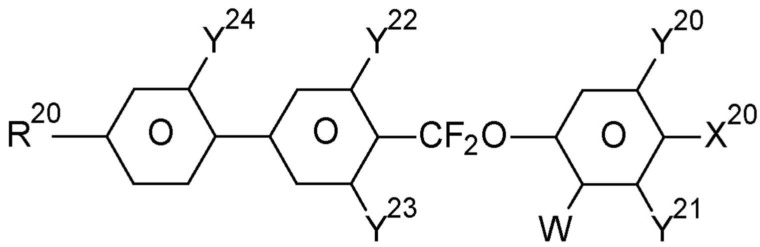
wherein Alkoxy preferably denotes straight-chain alkoxy with 3, 4, or 5 C atoms.

In another preferred embodiment of the present invention the dual frequency liquid crystal mixture contains one or more compounds with positive dielectric anisotropy as defined above and given below:

aa) LC-medium, characterised in that it comprises one or more compounds selected from the group of compounds of the formulae II and III



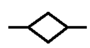
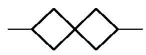
II



III

wherein

R^{20} each, identically or differently, denote a halogenated or un-substituted alkyl or alkoxy radical having 1 to 15 C atoms, where, in addition, one or more CH_2 groups in these radicals may each be replaced, independently of one another,

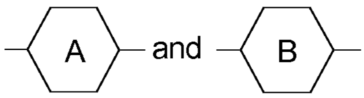
by -C≡C-, $-CF_2O-$, -CH=CH-, , , -O-, -CO-

O- or -O-CO- in such a way that O atoms are not linked directly to one another,

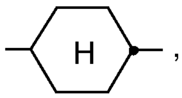
X^{20} each, identically or differently, denote F, Cl, CN, SF_5, SCN, NCS, a halogenated alkyl radical, a halogenated alkenyl radical, a halogenated alkoxy radical or a halogenated alkenyloxy radical, each having up to 6 C atoms, and

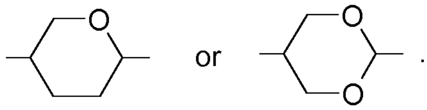
Y^{20-24} each, identically or differently, denote H or F;

W denotes H or methyl,

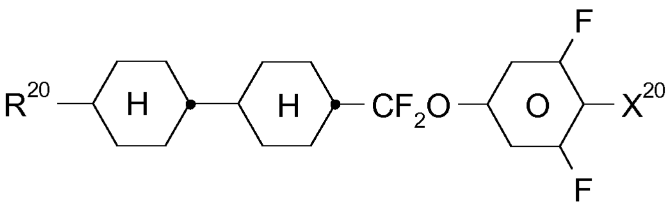


each, independently of one another, denote

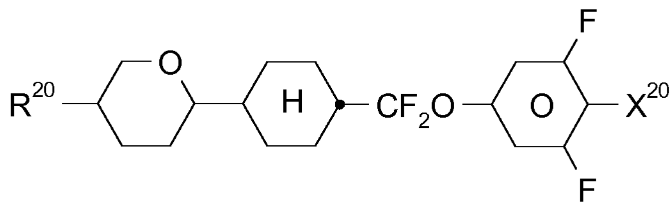




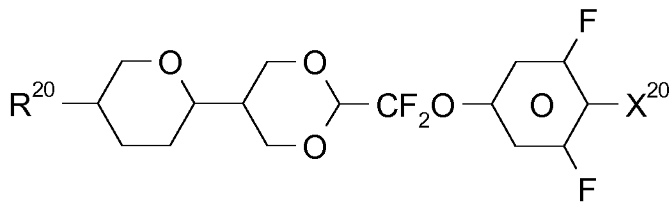
The compounds of the formula II are preferably selected from the following formulae:



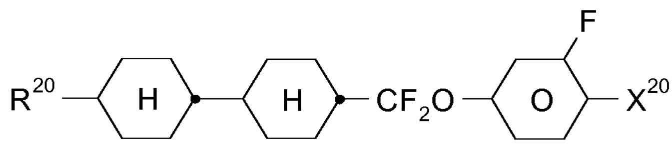
IIa



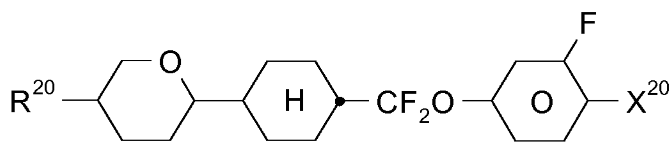
IIb



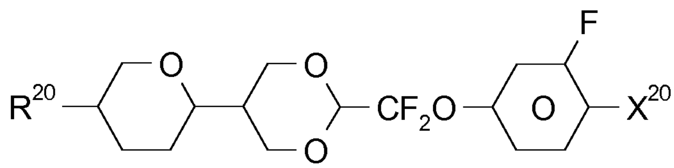
IIc



IId



IIe

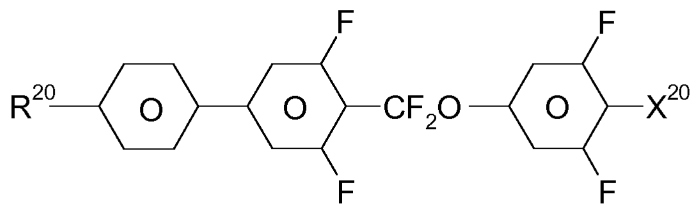


IIf

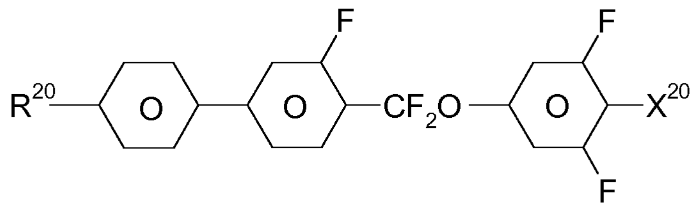
wherein R^{20} and X^{20} have the meanings indicated above.

R^{20} preferably denotes alkyl having 1 to 6 C atoms. X^{20} preferably denotes F. Particular preference is given to compounds of the formulae IIa and IIb, in particular compounds of the formulae IIa and IIb wherein X denotes F.

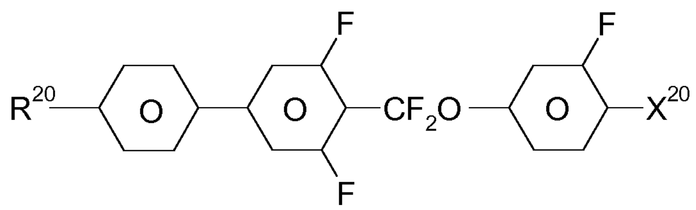
The compounds of the formula III are preferably selected from the following formulae:



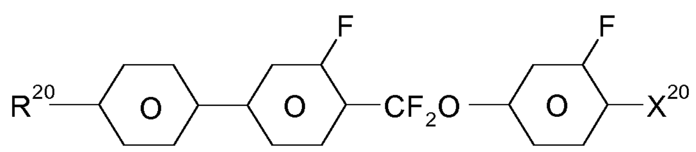
IIIa



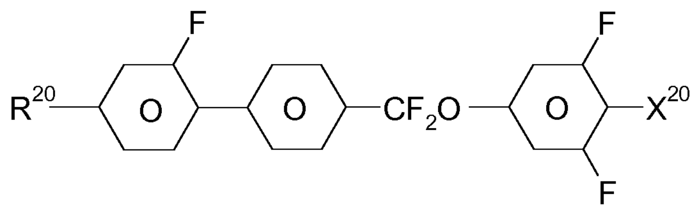
IIIb



IIIc



IIId

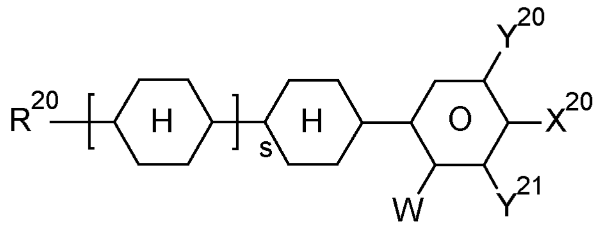


IIIe

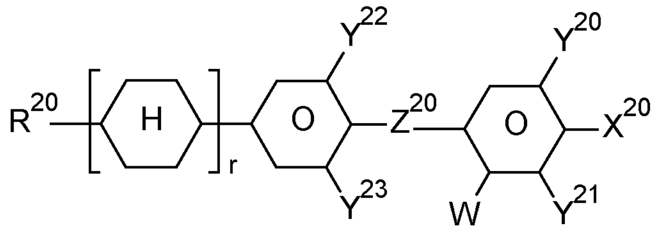
wherein R^{20} and X^{20} have the meanings indicated above.

R^{20} preferably denotes alkyl having 1 to 6 C atoms. X^{20} preferably denotes F. Particular preference is given to compounds of the formulae IIIa and IIIe, in particular compounds of the formula IIIa;

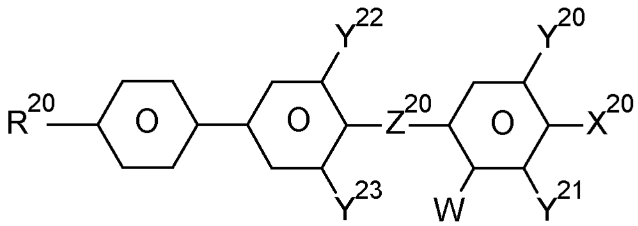
bb) LC-medium additionally comprising one or more compounds selected from the following formulae:



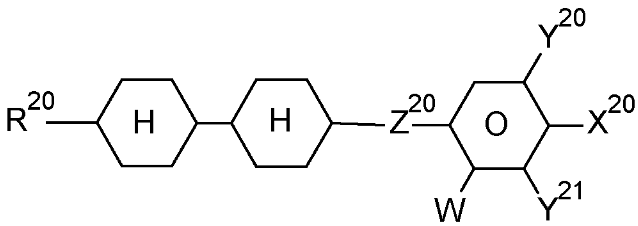
IV



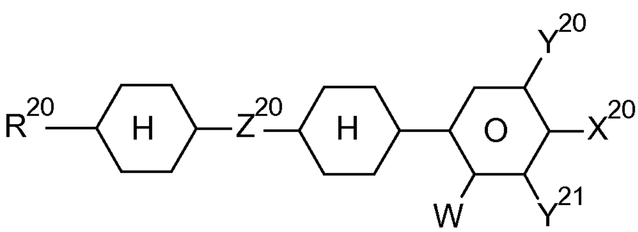
V



VI



VII



VIII

wherein

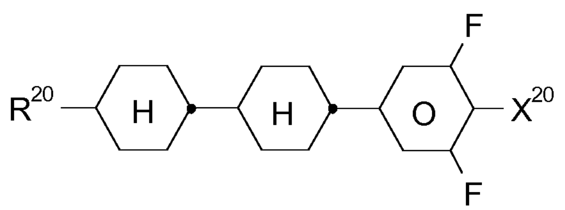
R^{20}, X^{20} , W and Y^{20-23} have the meanings indicated above under formula II, and

Z^{20} denotes $-C_2H_4-$, $-(CH_2)_4-$, -CH=CH-, -CF=CF, $-C_2F_4-$, $-CH_2CF_2-$, $-CF_2CH_2-$, $-CH_2O-$, $-OCH_2-$, -COO- or $-OCF_2-$, in formulae V and VI also a single bond, in formulae V and VIII also $-CF_2O-$,

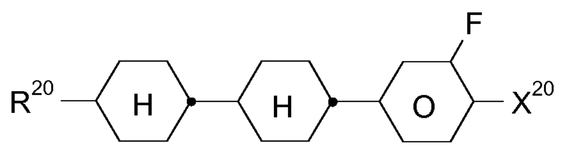
r denotes 0 or 1, and

s denotes 0 or 1;

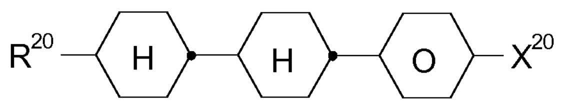
- The compounds of the formula IV are preferably selected from the following formulae:



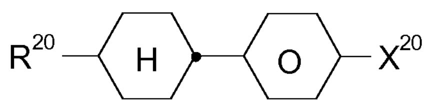
IVa



IVb



IVc

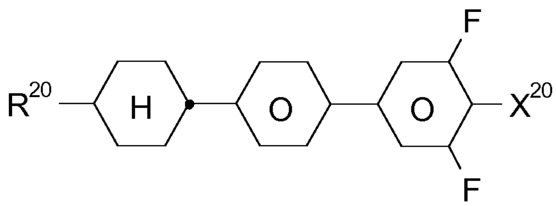


IVd

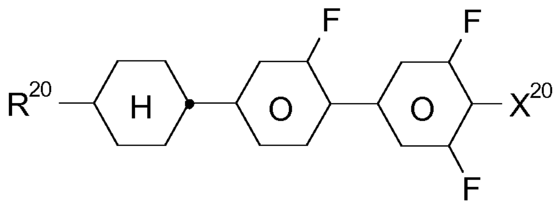
wherein R^{20} and X^{20} have the meanings indicated above.

R^{20} preferably denotes alkyl having 1 to 6 C atoms. X^{20} preferably denotes F or OCF_3, furthermore $OCF=CF_2$ or Cl;

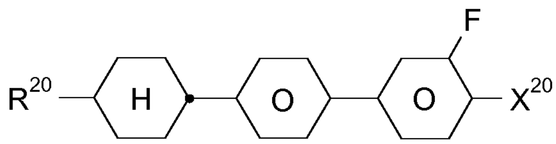
- The compounds of the formula V are preferably selected from the following formulae:



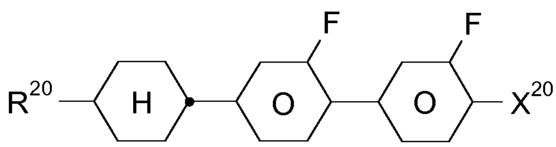
Va



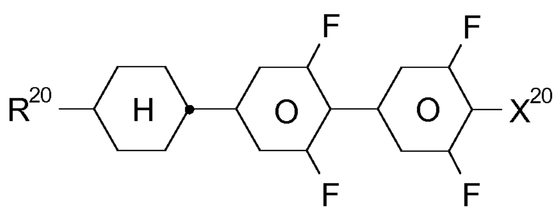
Vb



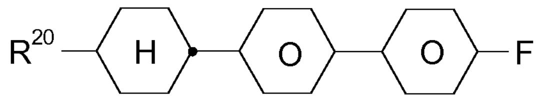
Vc



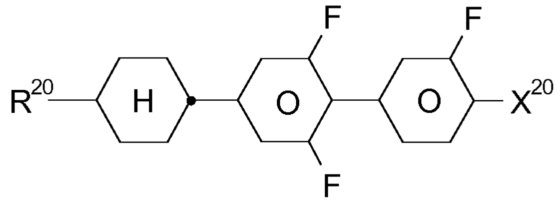
Vd



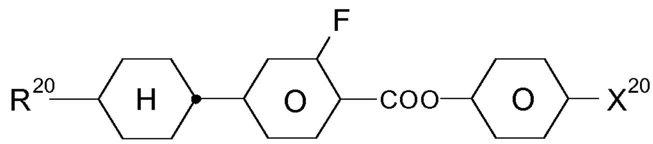
Ve



Vf



Vg

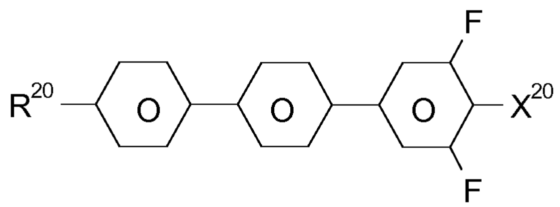


Vh

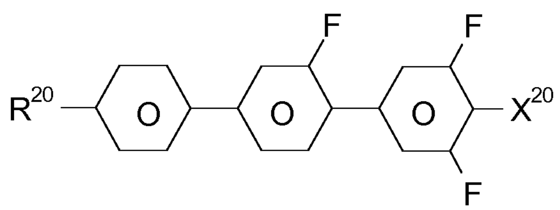
wherein R^{20} and X^{20} have the meanings indicated above.

R^{20} preferably denotes alkyl having 1 to 6 C atoms. X^{20} preferably denotes F and OCF_3, furthermore $OCHF_2$, CF_3, $OCF{=}CF_2$ and $OCH{=}CF_2$;

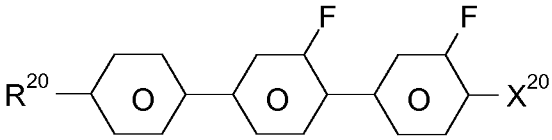
- The compounds of the formula VI are preferably selected from the following formulae:



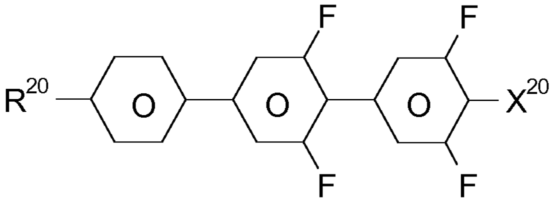
VIa



VIb



VIc

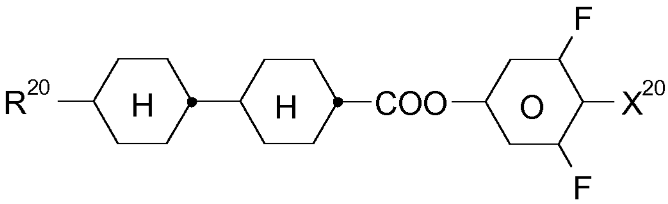


VId

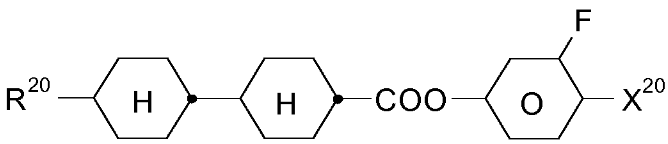
wherein R^{20} and X^{20} have the meanings indicated above.

R^{20} preferably denotes alkyl having 1 to 6 C atoms. X^{20} preferably denotes F, furthermore OCF_3, CF_3, $CF=CF_2$, $OCHF_2$ and $OCH=CF_2$;

- The compounds of the formula VII are preferably selected from the following formulae:



VIIa



VIIb

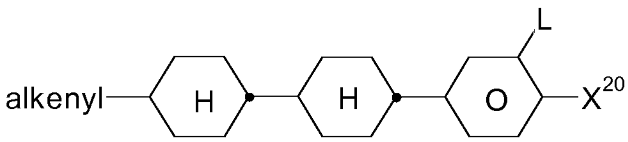
wherein R^{20} and X^{20} have the meanings indicated above.

R^{20} preferably denotes alkyl having 1 to 6 C atoms. X^{20} preferably denotes F, furthermore OCF_3, $OCHF_2$ and $OCH=CF_2$.

cc) The medium additionally comprises one or more compounds selected from the formulae ZK1 to ZK10 given above. Especially preferred are compounds of formula ZK1 and ZK3. Particularly preferred compounds of formula ZK are selected from the sub-formulae ZK1a, ZK1b, ZK1c, ZK3a, ZK3b, ZK3c and ZK3d.

dd) The medium additionally comprises one or more compounds selected from the formulae DK1 to DK12 given above. Especially preferred compounds are DK3.

ee) The medium additionally comprises one or more compounds selected from the following formulae:



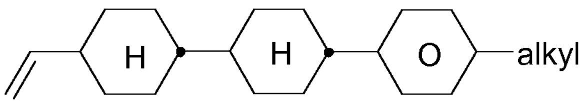
IX

wherein X^{20} has the meanings indicated above, and

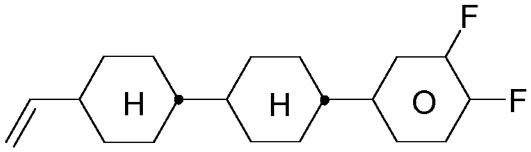
L denotes H or F,

"alkenyl" denotes C_{2-6}-alkenyl.

ff) The compounds of the formulae DK-3a and IX are preferably selected from the following formulae:



DK3a

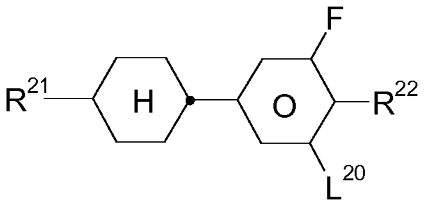


IXa

wherein "alkyl" denotes C_{1-6}-alkyl, preferably n-C_3H_7, n-C_4H_9 or n-C_5H_{11}, in particular n-C_3H_7.

gg) The medium additionally comprises one or more compounds selected from the formulae B1, B2 and B3 given above, preferably from the formula B2. The compounds of the formulae B1 to B3 are particularly preferably selected from the formulae B1a, B2a, B2b and B2c.

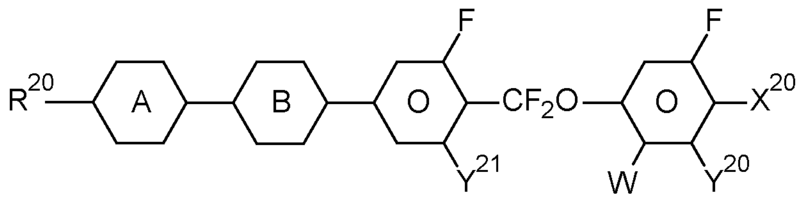
hh) The medium additionally comprises one or more compounds selected from the following formula:



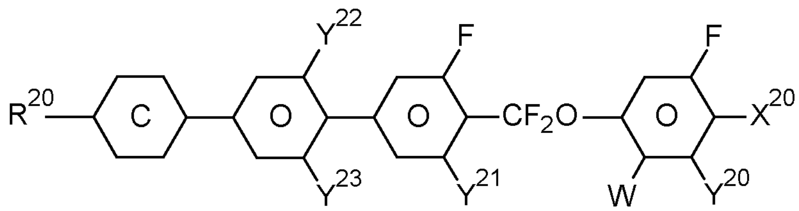
X

wherein L^{20} denotes H or F, and R^{21} and R^{22} each, identically or differently, denote n-alkyl, alkoxy, oxaalkyl, fluoroalkyl or alkenyl, each having up to 6 C atoms, and preferably each, identically or differently, denote alkyl having 1 to 6 C atoms.

ii) The medium additionally comprises one or more compounds of the following formulae:

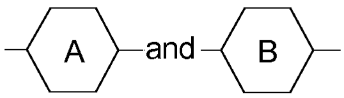


XI

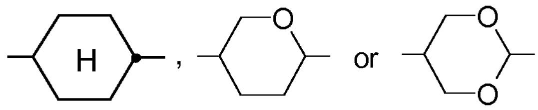


XII

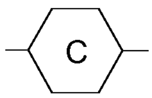
Wherein W, R^{20}, X^{20} and $Y^{20\text{-}23}$ have the meanings indicated in formula III, and



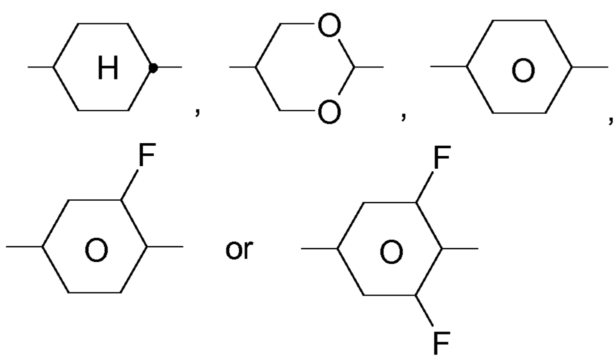
each, independently of one another, denote



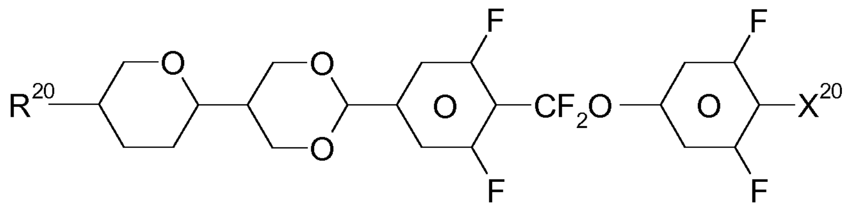
and



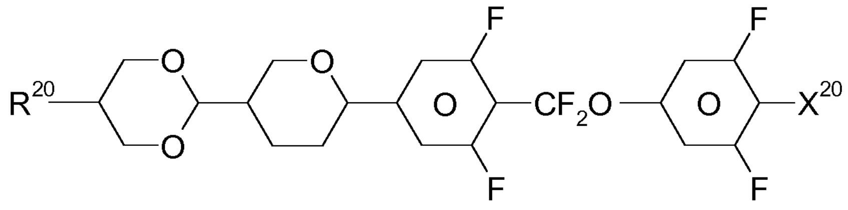
denotes



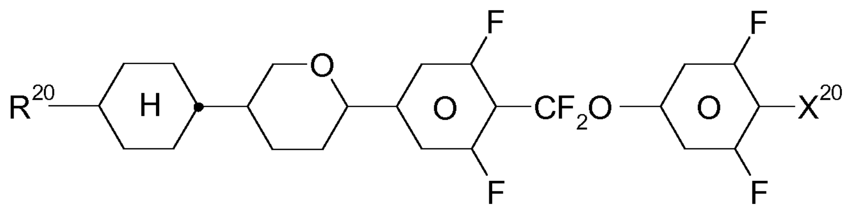
The compounds of the formulae XI and XII are preferably selected from the following formulae:



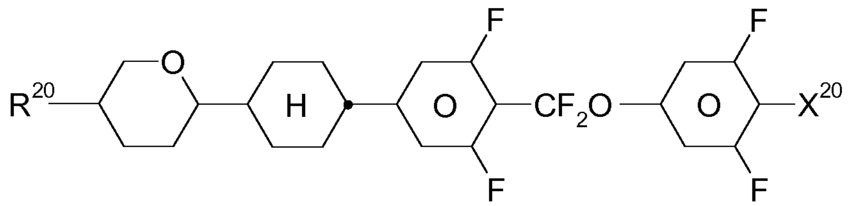
XIa



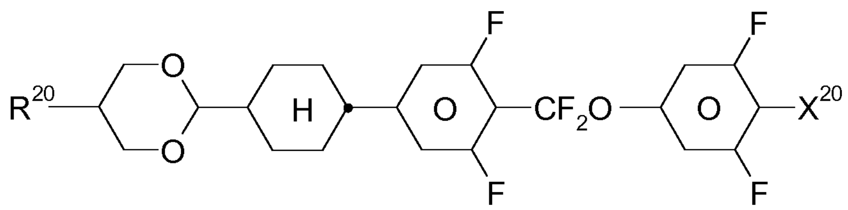
XIb



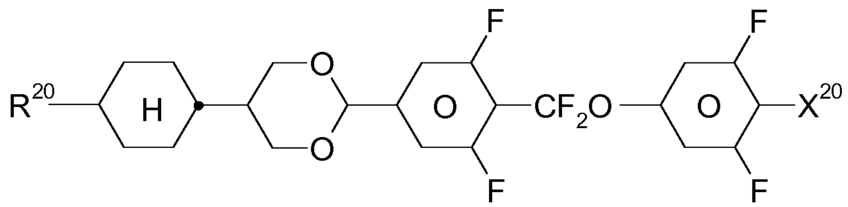
XIc



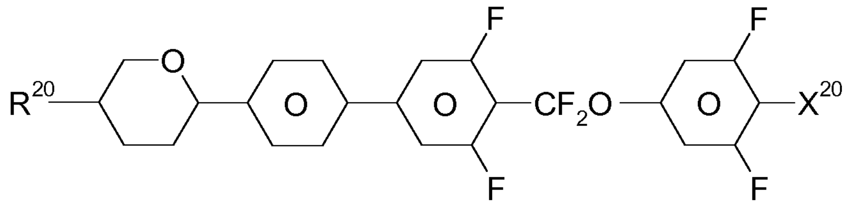
XId



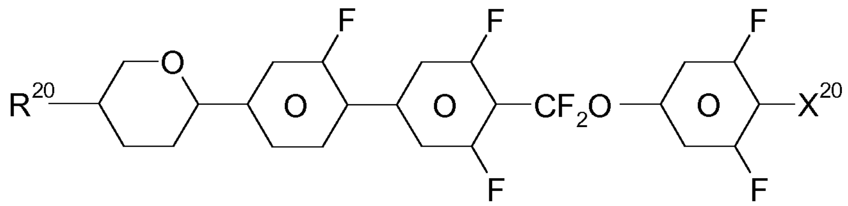
XIe



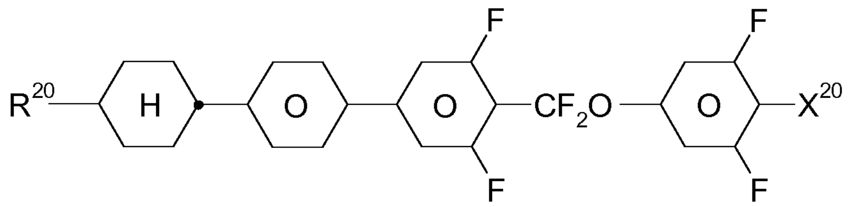
XIf



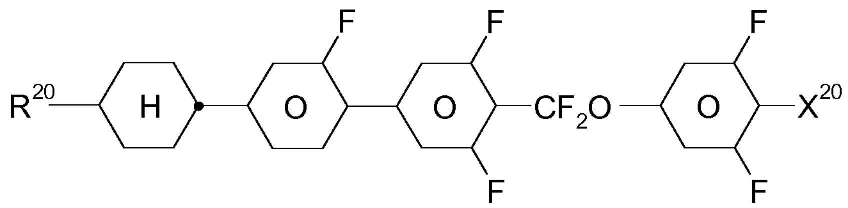
XIIa



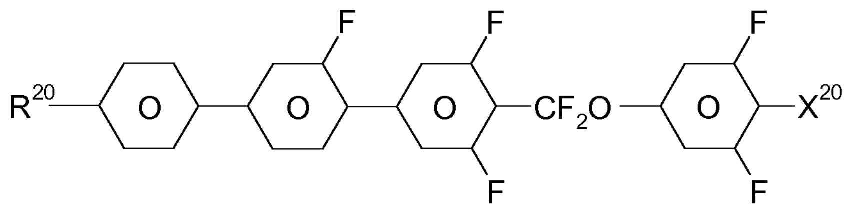
XIIb



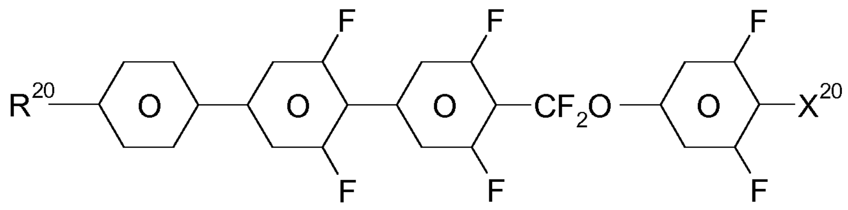
XIIc



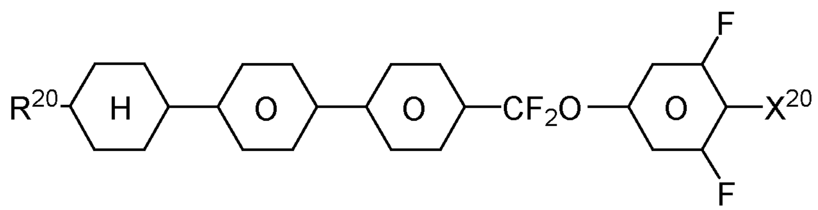
XIId



XIIe



XIIf



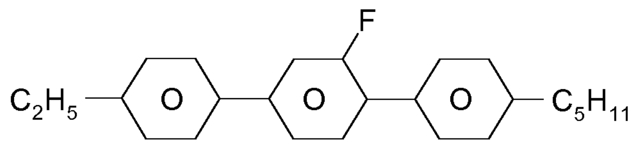
XIIg

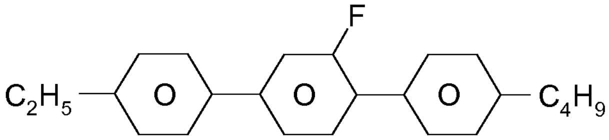
wherein R^{20} and X^{20} have the meaning indicated above and preferably R^{20} denotes alkyl having 1 to 6 C atoms and X^{20} denotes F.

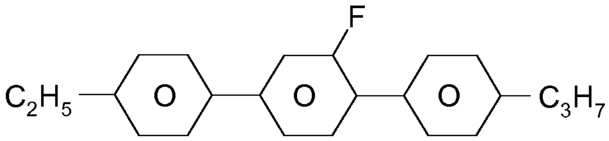
The mixture according to the invention particularly preferably comprises at least one compound of the formula XIIa and/or XIIe.

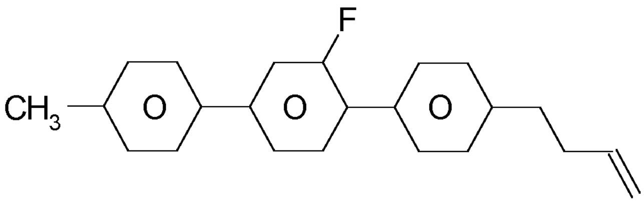
jj) The medium comprises one or more compounds of formula T given above, preferably selected from the group of compounds of the formulae T21 toT23 and T25 to T27.

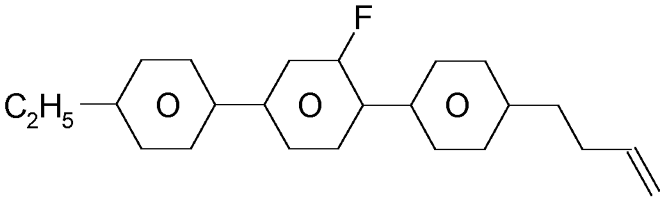
Particular preference is given to the compounds of the formulae T21 to T23. Very particular preference is given to the compounds of the formulae

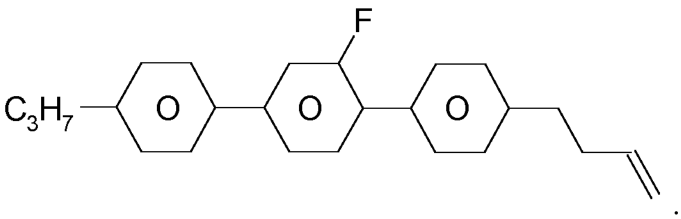






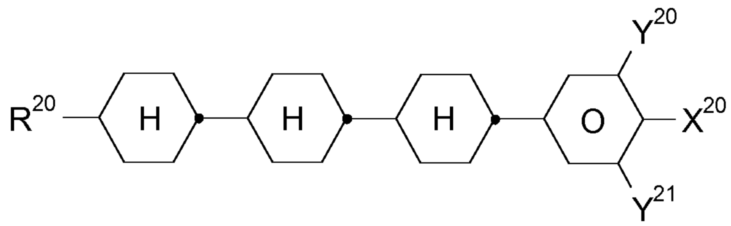




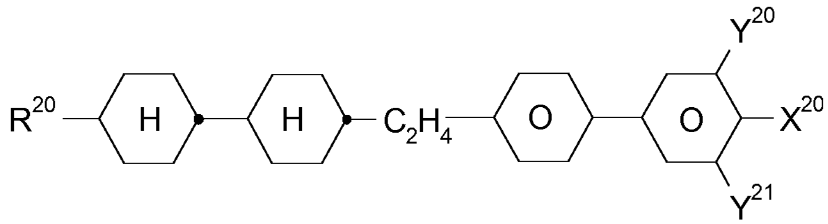


kk) The medium comprises one or more compounds selected from the group of formulae DK9, DK10 and DK11 given above.

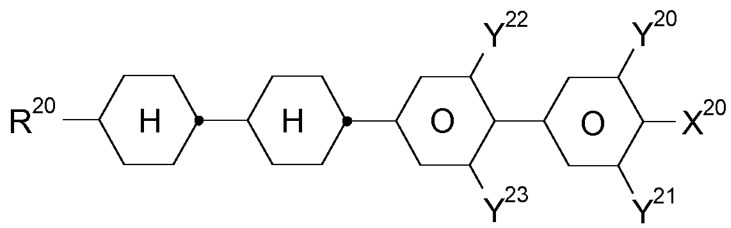
ll) The medium additionally comprises one or more compounds selected from the following formulae:



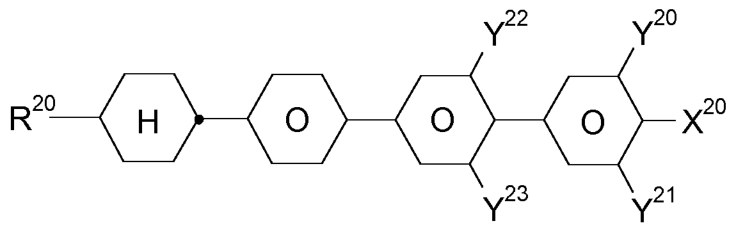
XIII



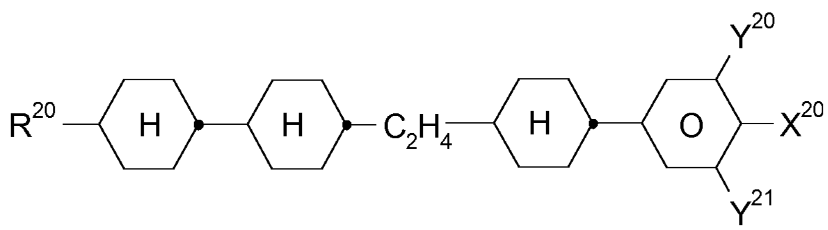
XIV



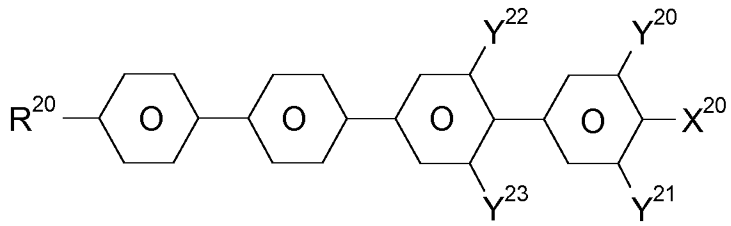
XV



XVI



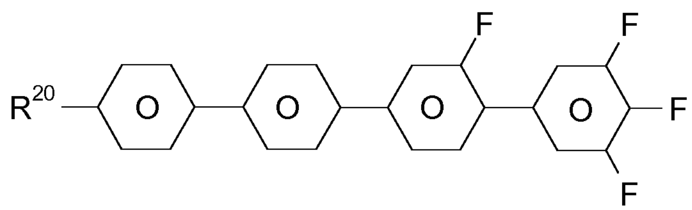
XVII



XVIII

wherein R^{20} and X^{20} each, independently of one another, have one of the meanings indicated above, and Y^{20-23} each, independently of one another, denote H or F. X^{20} is preferably F, Cl, CF_3, OCF_3 or $OCHF_2$. R^{20} preferably denotes alkyl, alkoxy, oxaalkyl, fluoroalkyl or alkenyl, each having up to 6 C atoms.

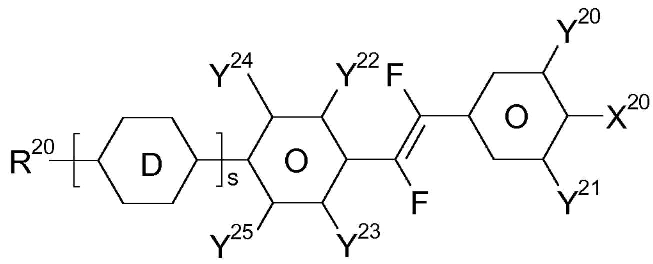
The mixture according to the invention particularly preferably comprises one or more compounds of the formula XVIII-a,



XVIII-a

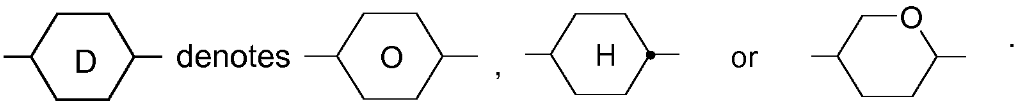
wherein R^{20} has the meanings indicated above. R^{20} preferably denotes straight-chain alkyl, in particular ethyl, n-propyl, n-butyl and n-pentyl and very particularly preferably n-propyl. The compound(s) of the formula XVIII, in particular of the formula XVIII-a.

mm) The medium additionally comprises one or more compounds of the formula XIX,



XIX

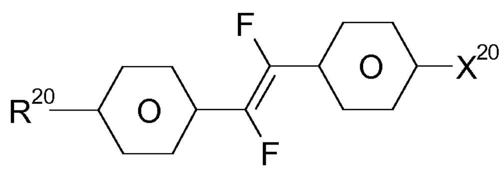
wherein R^{20}, X^{20} and Y^{20-25} have the meanings indicated in formula I, s denotes 0 or 1, and



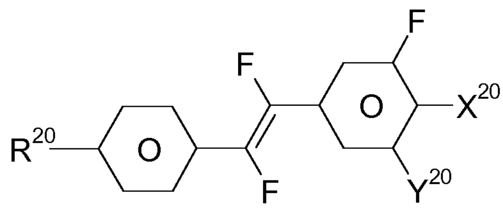
In the formula XIX, X^{20} may also denote an alkyl radical having 1-6 C atoms or an alkoxy radical having 1-6 C atoms. The alkyl or alkoxy radical is preferably straight-chain.

R^{20} preferably denotes alkyl having 1 to 6 C atoms. X^{20} preferably denotes F;

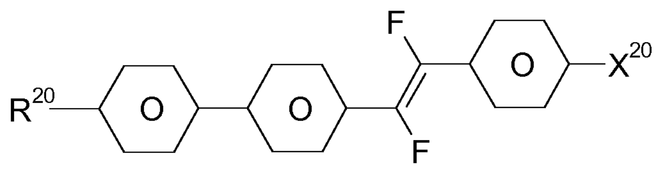
- The compounds of the formula XIX are preferably selected from the following formulae:



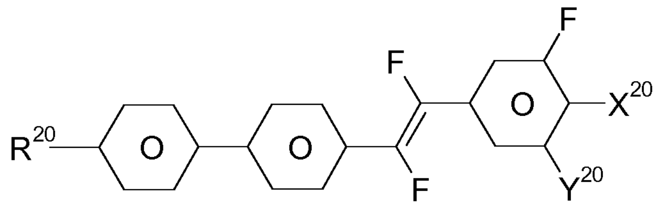
XIXa



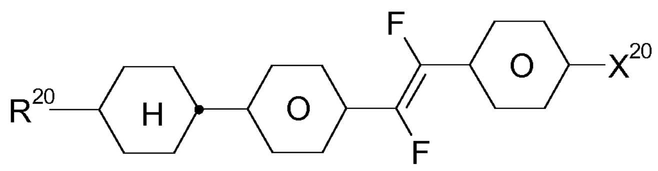
XIXb



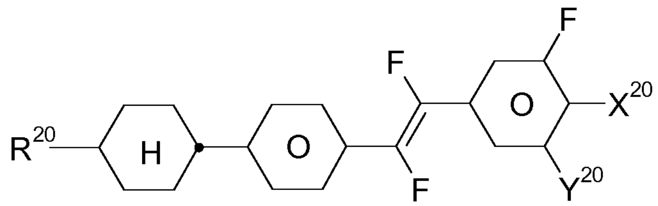
XIXc



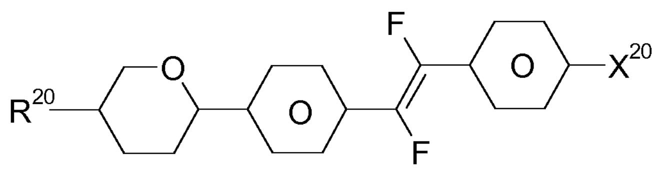
XIXd



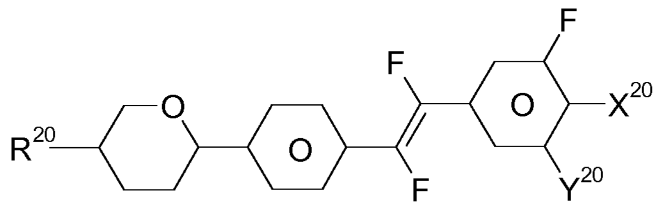
XIXe



XIXf

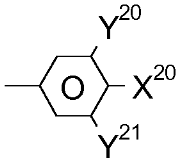
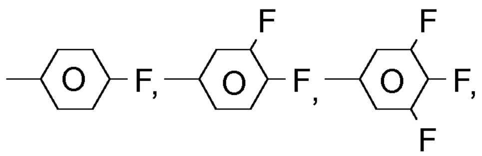


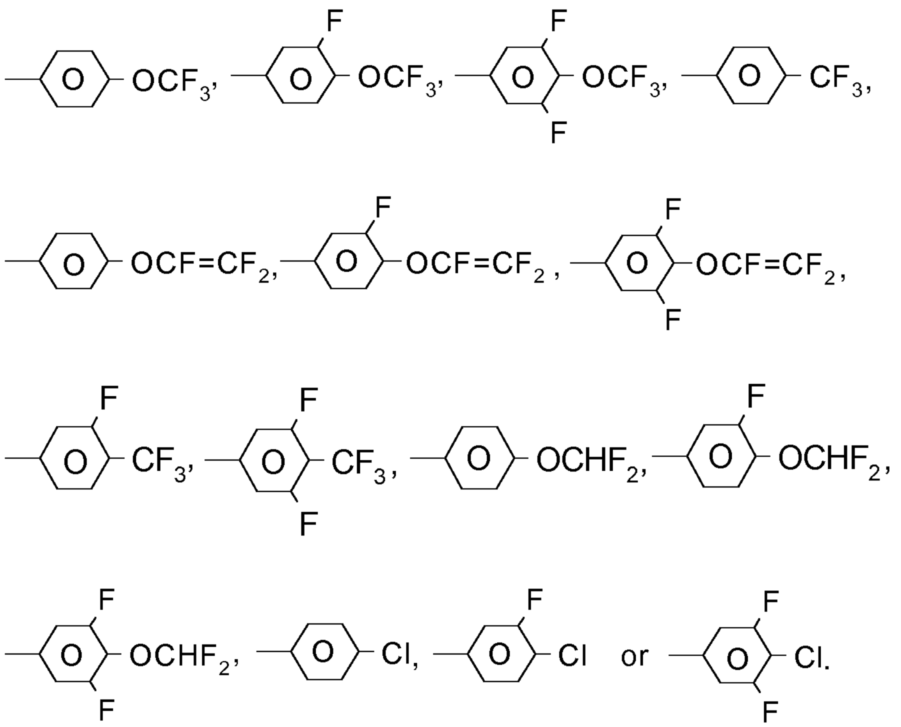
XIXg



XIXh

wherein R^{20}, X^{20} and Y^{20} have the meanings indicated above. R^{20} preferably denotes alkyl having 1 to 6 C atoms. X^{20} preferably denotes F, and Y^{20} is preferably F;

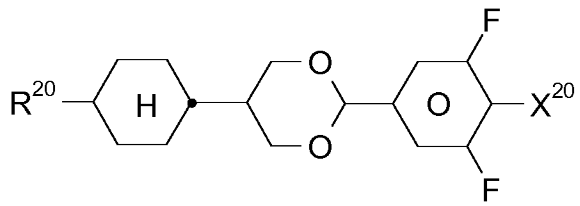
-  is preferably 



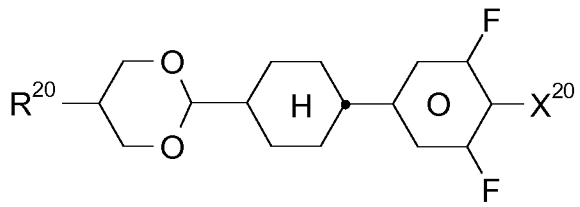
- R^{20} is straight-chain alkyl or alkenyl having 2 to 6 C atoms;

nn) The medium comprises one or more compounds of the formulae G1 to G4 given above, preferably selected from G1 and G2 wherein alkyl denotes C_{1-6}-alkyl, L^x denotes H and X denotes F or Cl. In G2, X particularly preferably denotes Cl.

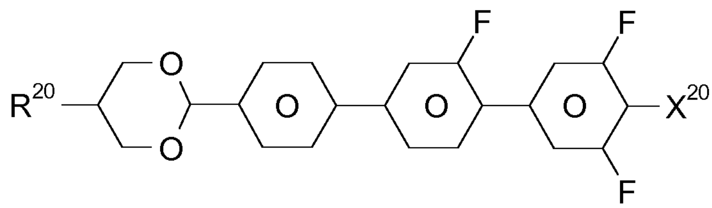
oo) The medium comprises one or more compounds of the following formulae:



XX



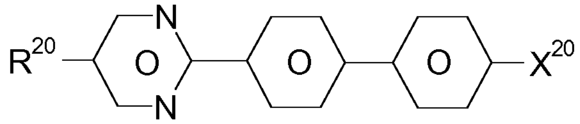
XXI



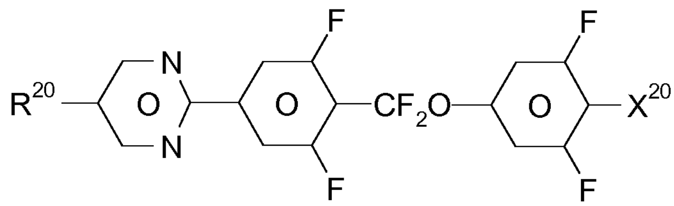
XXII

wherein R^{20} and X^{20} have the meanings indicated above. R^{20} preferably denotes alkyl having 1 to 6 C atoms. X^{20} preferably denotes F. The medium according to the invention particularly preferably comprises one or more compounds of the formula XXII wherein X^{20} preferably denotes F. Particularly preferred mixtures comprise at least one compound of the formula XXII.

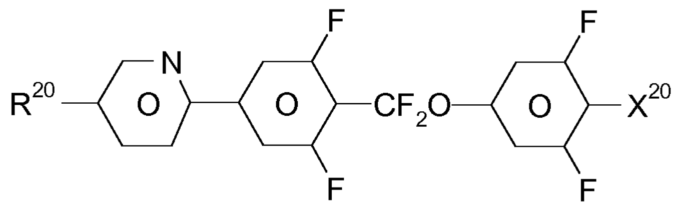
pp) The medium comprises one or more compounds of the following pyrimidine or pyridine compounds of the formulae



M-1



M-2



M-3

wherein R^{20} and X^{20} have the meanings indicated above. R^{20} preferably denotes alkyl having 1 to 6 C atoms. X^{20} preferably denotes F. The medium according to the invention particularly preferably comprises one or more compounds of the formula M-1, wherein X^{20} preferably denotes F.

The liquid crystal mixture utilized for the process according to the present invention further comprises one or more polymerizable liquid crystalline compounds, preferably selected from compounds of formula P,

$$P^a\text{-}(Sp^a)_{s1}\text{-}A^2\text{-}(Z^a\text{-}A^1)_{n2}\text{-}(Sp^b)_{s2}\text{-}P^b \qquad P$$

wherein the individual radicals have the following meanings:

P^a, P^b each, independently of one another, denote a polymerizable group,

Sp^a, Sp^b on each occurrence, identically or differently, denote a spacer group,

s1, s2 each, independently of one another, denote 0 or 1,

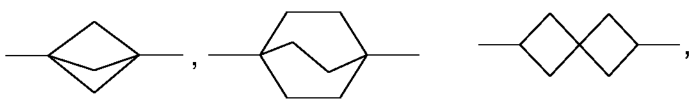
A^1, A^2 each, independently of one another, denote a radical selected from the following groups:

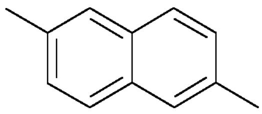
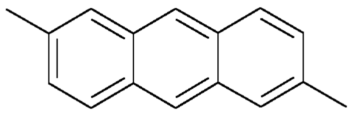
a) the group consisting of trans-1,4-cyclohexylene, 1,4-cyclohexenylene and 4,4´-bicyclohexylene, wherein, in addition, one or more non-adjacent CH_2 groups may be replaced by -O- and/or -S- and wherein, in addition, one or more H atoms may be replaced by F,

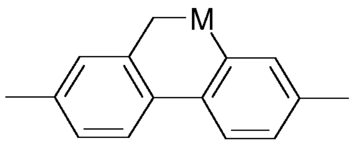
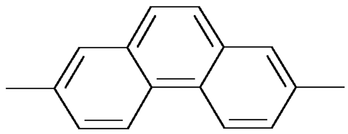
b) the group consisting of 1,4-phenylene and 1,3-phenylene, wherein, in addition, one or two CH groups may be replaced by N and wherein, in addition, one or more H atoms may be replaced by L,

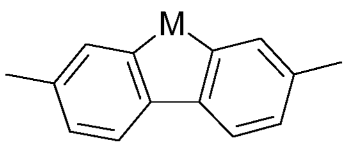
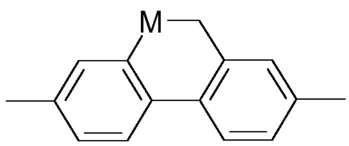
c) the group consisting of tetrahydropyran-2,5-diyl, 1,3-dioxane-2,5-diyl, tetrahydrofuran-2,5-diyl, cyclobutane-1,3-diyl, piperidine-1,4-diyl, thiophene-2,5-diyl and selenophene-2,5-diyl, each of which may also be mono- or polysubstituted by L,

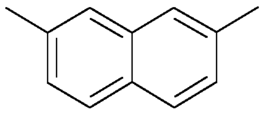
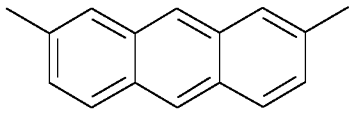
d) the group consisting of saturated, partially unsaturated or fully unsaturated, and optionally substituted, polycyclic radicals having 5 to 20 cyclic C atoms, one or more of which may, in addition, be replaced by heteroatoms, preferably selected from the group consisting of

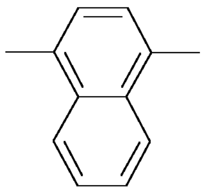
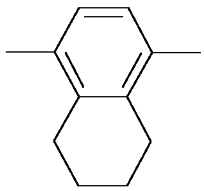


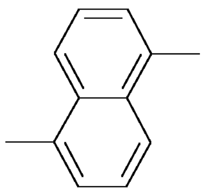
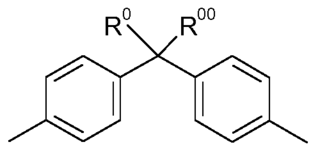
 ,  ,

 ,  ,

 ,  ,

 ,  ,

 ,  ,

 , 

where, in addition, one or more H atoms in these radicals may be replaced by L, and/or one or more double bonds may be replaced by single bonds, and/or one or more CH groups may be replaced by N,

n2 denotes 0, 1, 2 or 3,

Z^a in each case, independently of one another, denotes -CO-O-, -O-CO-, $-CH_2O-$, $-OCH_2-$, $-CF_2O-$, $-OCF_2-$, or $-(CH_2)_n-$, where n is 2, 3 or 4, -O-, -CO-, $-C(R^yR^z)-$, $-CH_2CF_2-$, $-CF_2CF_2-$ or a single bond, L on each occurrence, identically or differently, denotes F, Cl, CN, SCN, SF_5 or straight-chain or branched, in each case optionally fluorinated, alkyl, alkoxy, alkylcarbonyl, alkoxycarbonyl, alkylcarbonyloxy or alkoxycarbonyloxy having 1 to 12 C atoms,

R^y, R^z each, independently of one another, denote H, F or straight-chain or branched alkyl having 1 to 12 C atoms, wherein, in addition, one or more H atoms may be replaced by F,

M denotes -O-, -S-, $-CH_2-$, $-CHY^1-$ or $-CY^1Y^2-$, and

Y^1 and Y^2 each, independently of one another, have one of the meanings indicated above for R^y or denote Cl or CN.

Preferred spacer groups $Sp^{a,b}$ are selected from the formula Sp"-X", so that the radicals P-Sp- and $P^{a/b}$-$Sp^{a/b}$- conforms to the formulae P-Sp"-X"- and $P^{a/b}$-Sp"-X"-, respectively, wherein

Sp" denotes alkylene having 1 to 20, preferably 2 to 12, more preferably 3 to 9 C atoms, which is optionally mono- or polysubstituted by F, Cl, Br, I or CN and wherein, in addition, one or more non-adjacent CH_2 groups may each be replaced, independently of one another, by -O-, -S-, -NH-, $-N(R^0)-$, $-Si(R^{00}R^{000})-$, -CO-, -CO-O-, -O-CO-, -O-CO-O-, -S-CO-, -CO-S-, $-N(R^{00})-CO-O-$, $-O-CO-N(R^{00})-$, $-N(R^{00})-CO-N(R^{00})-$, -CH=CH- or -C≡C- in such a way that O and/or S atoms are not linked directly to one another, X" denotes -O-, -S-, -CO-, -CO-O-, -O-CO-, -O-CO-O-, -CO-N(R^{00})-, -N(R^{00})-CO-, -N(R^{00})-CO-N(R^{00})-, -OCH_2-, -CH_2O-, -SCH_2-, -CH_2S-, -CF_2O-, -OCF_2-, -CF_2S-, -SCF_2-, -CF_2CH_2-, -CH_2CF_2-, -CF_2CF_2-, -CH=N-, -N=CH-, -N=N-, -CH=CR^0-, -CY^3=CY^4-, -C≡C-, -CH=CH-CO-O-, -O-CO-CH=CH- or a single bond,

R^0, R^{00} and R^{000} each, independently of one another, denote H or alkyl having 1 to 12 C atoms, and

Y^3 and Y^4 each, identically or differently, denote H, F, Cl or CN.

X" is preferably -O-, -S-, -CO-, -C(O)O-, -OC(O)-, -O-C(O)O-, -CO-NR^0-, -NR^0-CO-, -NR^0-CO-NR^0- or a single bond.

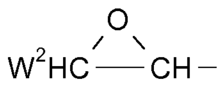
Typical spacer groups Sp" are, for example, -$(CH_2)_{p1}$-, -$(CH_2CH_2O)_{q1}$-CH_2CH_2-, -CH_2CH_2-S-CH_2CH_2-, -CH_2CH_2-NH-CH_2CH_2- or -$(SiR^{00}R^{000}\text{-}O)_{p1}$-, wherein p1 is an integer from 1 to 12 preferably 2 to 10, more preferably 3 to 9 C atoms, q1 is an integer from 1 to 3, and R^{00} and R^{000} have the meanings indicated above.

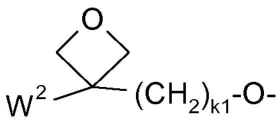
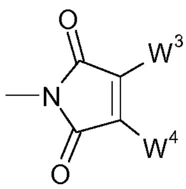
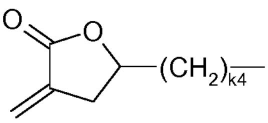
Particularly preferred groups -Sp"-X"- are -$(CH_2)_{p1}$-, -$(CH_2)_{p1}$-O-, -$(CH_2)_{p1}$-O-CO-, -$(CH_2)_{p1}$-O-CO-O-, wherein p1 and q1 have the meanings indicated above.

Particularly preferred groups Sp" are, for example, in each case straight-chain ethylene, propylene, butylene, pentylene, hexylene, heptylene, octylene, nonylene, decylene, undecylene, dodecylene, octadecylene, ethyleneoxyethylene, methyleneoxybutylene, ethylenethioethylene, ethylene-

N-methyliminoethylene, 1-methylalkylene, ethenylene, propenylene and butenylene.

“Polymerisable groups” (P) are preferably selected from groups containing a C=C double bond or C≡C triple bond, and groups which are suitable for polymerisation with ring opening, such as, for example, oxetane or epoxide groups.

Preferably, polymerizable groups (P) are selected from the group consisting of CH_2=CW^1-COO-, CH_2=CW^1-CO-,  ,

 ,  ,  , CH_2=CW^2-$(O)_{k3}$-, CW^1=CH-CO-$(O)_{k3}$-, CW^1=CH-CO-NH-, CH_2=CW^1-CO-NH-, CH_3-CH=CH-O-, $(CH_2=CH)_2$CH-OCO-, $(CH_2=CH-CH_2)_2$CH-OCO-, $(CH_2=CH)_2$CH-O-, $(CH_2=CH-CH_2)_2$N-, $(CH_2=CH-CH_2)_2$N-CO-, CH_2=CW^1-CO-NH-, CH_2=CH-$(COO)_{k1}$-Phe-$(O)_{k2}$-, CH_2=CH-$(CO)_{k1}$-Phe-$(O)_{k2}$-, Phe-CH=CH-,
in which

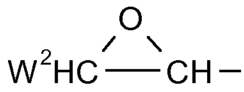
W^1 denotes H, F, Cl, CN, CF_3, phenyl or alkyl having 1 to 5 C atoms, in particular H, F, Cl or CH_3,

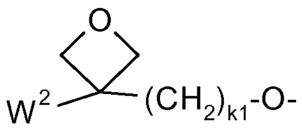
W^2 denotes H or alkyl having 1 to 5 C atoms, in particular H, methyl, ethyl or n-propyl,

W^3 and W^4 each, independently of one another, denote H, Cl or alkyl having 1 to 5 C atoms, Phe denotes 1,4-phenylene, which is optionally substituted by one or more radicals L as being defined above but being different from P-Sp, preferably preferred substituents L are F, Cl, CN,

NO_2, CH_3, C_2H_5, OCH_3, OC_2H_5, $COCH_3$, COC_2H_5, $COOCH_3$, $COOC_2H_5$, CF_3, OCF_3, $OCHF_2$, OC_2F_5, furthermore phenyl, and

k_1, k_2 and k_3 each, independently of one another, denote 0 or 1, k_3 preferably denotes 1, and k_4 is an integer from 1 to 10.

Particularly preferred polymerizable groups P are CH_2=CH-COO-, CH_2=C(CH_3)-COO-, CH_2=CF-COO-, CH_2=CH-, CH_2=CH-O-, (CH_2=CH)$_2$CH-OCO-, (CH_2=CH)$_2$CH-O-,  and

 , in which W^2 denotes H or alkyl having 1 to 5 C atoms, in particular H, methyl, ethyl or n-propyl,

Further preferred polymerizable groups (P) are vinyloxy, acrylate, methacrylate, fluoroacrylate, chloroacrylate, oxetane and epoxide, most preferably acrylate or methacrylate, in particular acrylate.

Preferably, all multireactive polymerizable compounds and sub-formulae thereof contain instead of one or more radicals P-Sp-, one or more branched radicals containing two or more polymerizable groups P (multireactive polymerizable radicals).

Suitable radicals of this type, and polymerizable compounds containing them, are described, for example, in US 7,060,200 B1 or US 2006/0172090 A1.

Particular preference is given to multireactive polymerizable radicals selected from the following formulae:

-X-alkyl-CHP^x-CH_2-CH_2P^y I*a

-X-alkyl-C(CH$_2$P^x)(CH$_2$P^y)-CH$_2$P^z I*b

-X-alkyl-CHP^{x}CHP^y-CH$_2$P^z I*c

-X-alkyl-C(CH$_2$P^x)(CH$_2$P^y)-C$_{aa}$H$_{2aa+1}$ I*d

-X-alkyl-CHP^x-CH$_2$P^y I*e

-X-alkyl-CHP^{x}P^y I*f

-X-alkyl-CP^{x}P^y-C$_{aa}$H$_{2aa+1}$ I*g

-X-alkyl-C(CH$_2$P^v)(CH$_2$P^w)-CH$_2$OCH$_2$-C(CH$_2$P^x)(CH$_2$Py)CH$_2$P^z I*h

-X-alkyl-CH((CH$_2$)$_{aa}$P^x)((CH$_2$)$_{bb}$P^y) I*i

-X-alkyl-CHP^{x}CHP^y-C$_{aa}$H$_{2aa+1}$ I*k

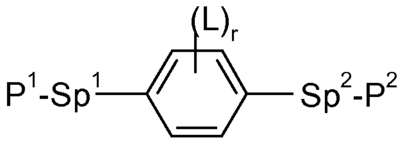
in which

alkyl denotes a single bond or straight-chain or branched alkylene having 1 to 12 C atoms, in which one or more non-adjacent CH$_2$ groups may each be replaced, independently of one another, by -C(R^x)=C(R^x)-, -C≡C-, -N(R^x)-, -O-, -S-, -CO-, -CO-O-, -O-CO-, -O-CO-O- in such a way that O and/or S atoms are not linked directly to one another, and in which, in addition, one or more H atoms may be replaced by F, Cl or CN, where R^x has one the above-mentioned meaning,

$_{aa}$ and $_{bb}$ each, independently of one another, denote 0, 1, 2, 3, 4, 5 or 6, X has one of the meanings indicated for X', and

P^v to P^z each, independently of one another, have one of the meanings indicated above for P.

Particularly preferred monomers of formula P are the following:



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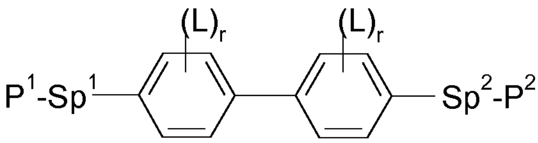

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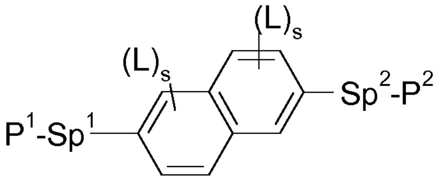

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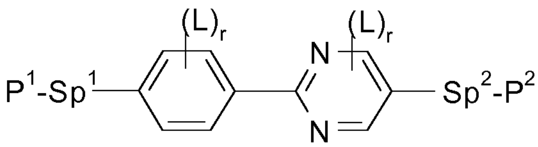

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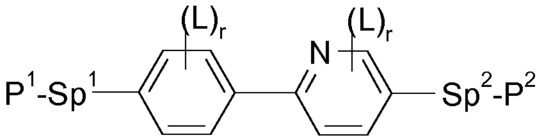

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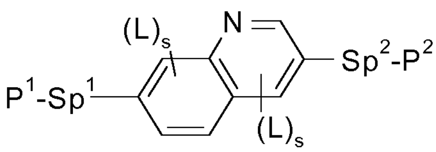

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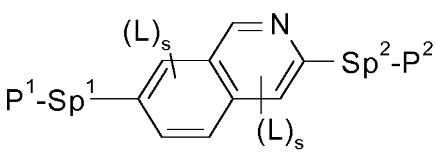

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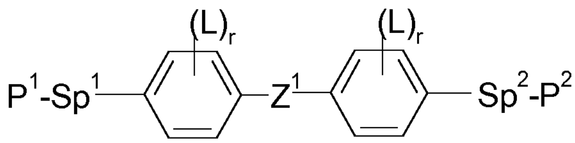

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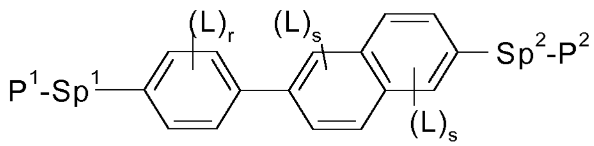

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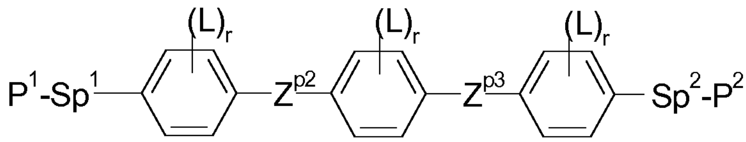

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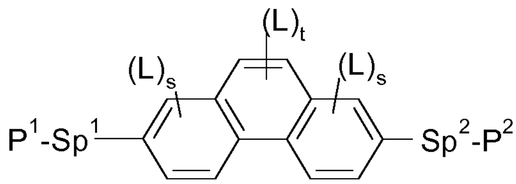

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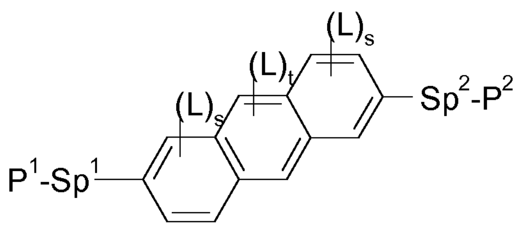

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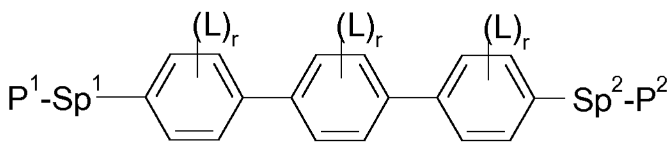

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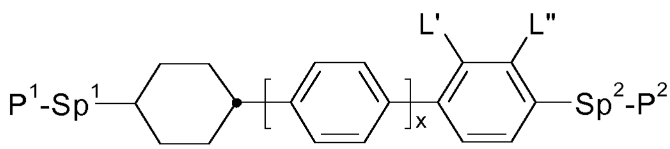

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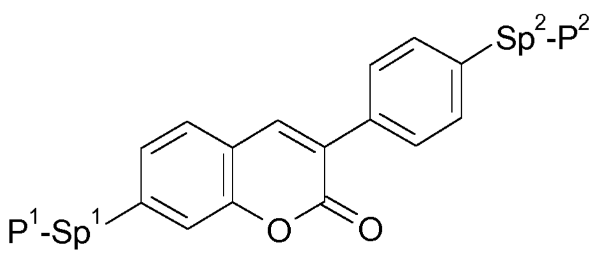

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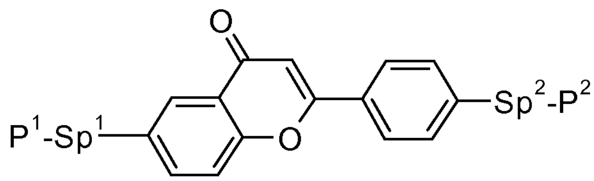

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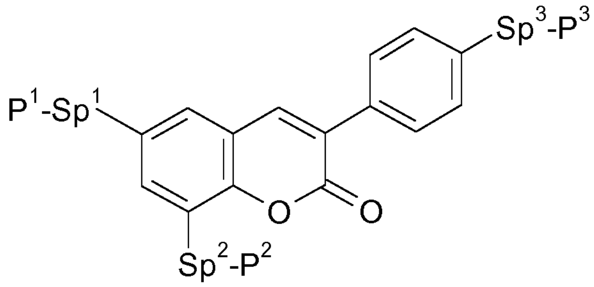

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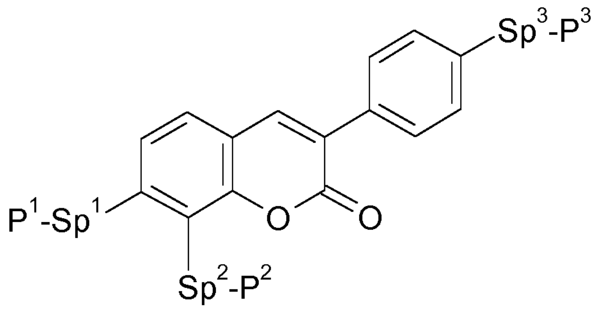

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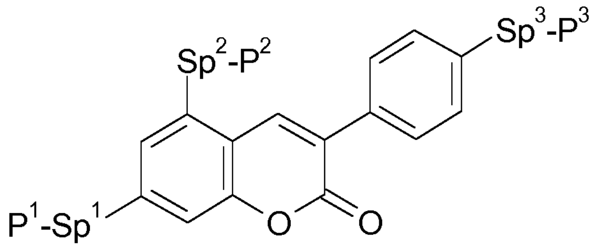

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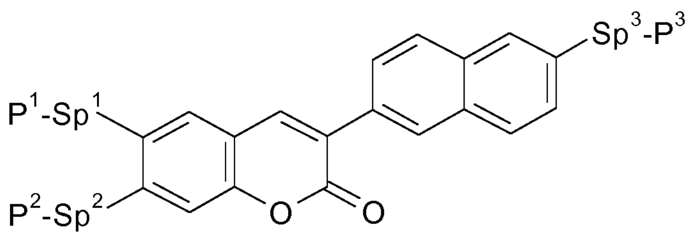

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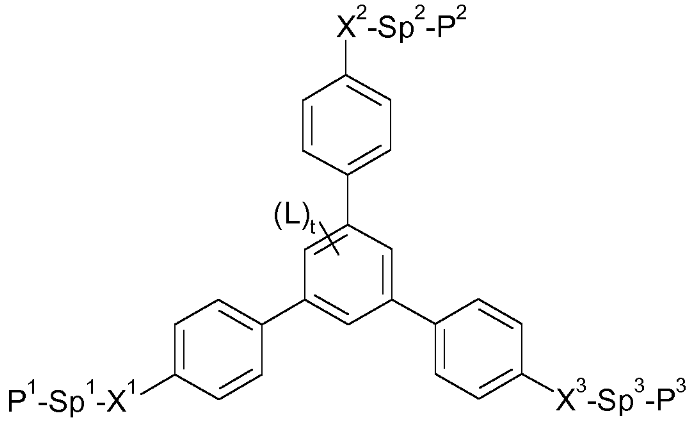

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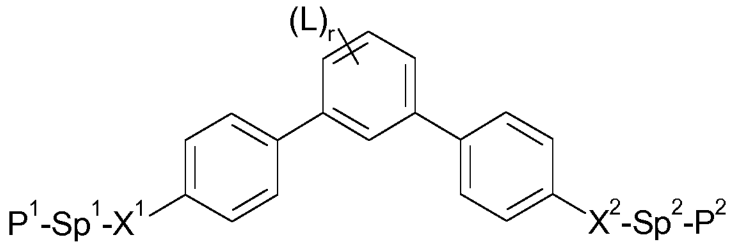

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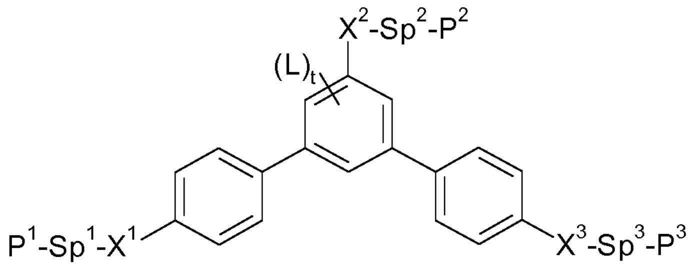

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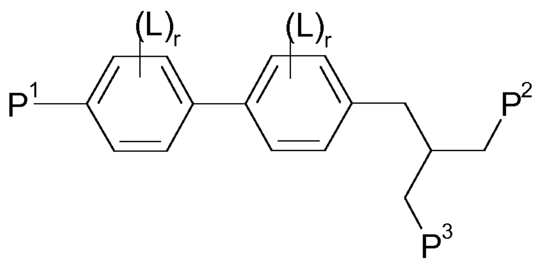

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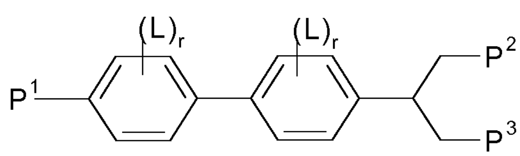

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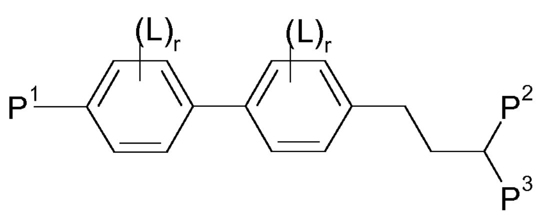

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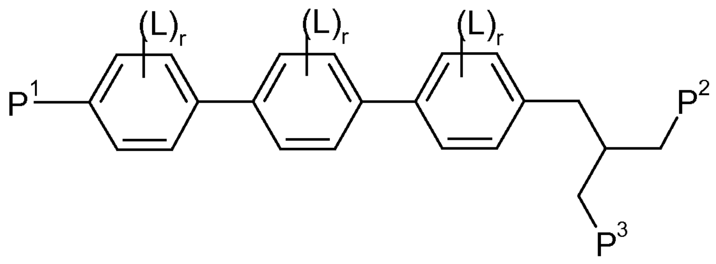

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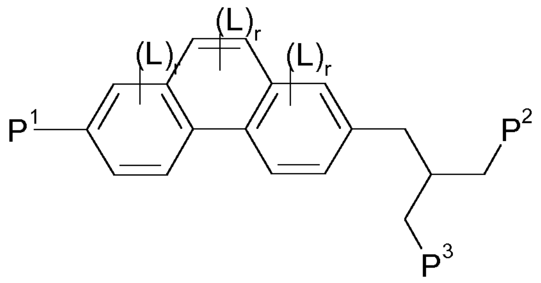

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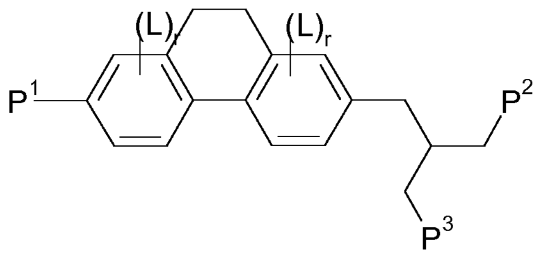

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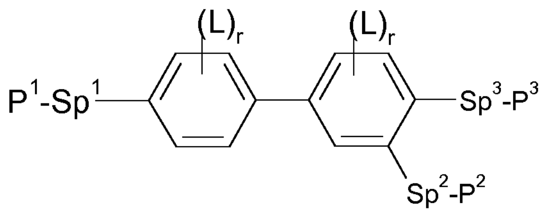

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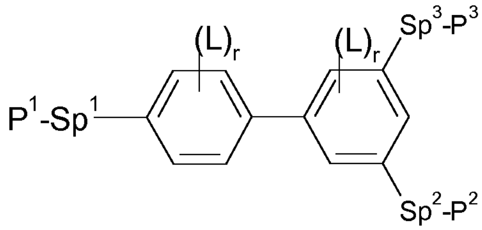


P31

wherein the individual radicals have the following meanings:

P^1 to P^3 each, independently of one another, denote a polymerizable group as defined for formula P, preferably an acrylate, methacrylate, fluoroacrylate, oxetane, vinyloxy or epoxide group,

Sp^1 to Sp^3 each, independently of one another, denote a single bond or a spacer group, preferably having one of the meanings indicated above and below for Sp^a, and particularly preferably $-(CH_2)_{p1}-$, $-(CH_2)_{p1}-O-$, $-(CH_2)_{p1}-CO-O-$ or $-(CH_2)_{p1}-O-CO-O-$, wherein p1 is an integer from 1 to 12, preferably 2 to 10, more preferably 3 to 9, and where the linking to the adjacent ring in the last-mentioned groups takes place via the O atom,

where, in addition, one or more of the radicals P^1-Sp^1- , P^2-Sp^2- and P^3-Sp^3- may denote a radical R^{aa}, with the proviso that at least one of the radicals P^1-Sp^1- , P^2-Sp^2- and P^3-Sp^3- present does not denote R^{aa},

R^{aa} denotes H, F, Cl, CN or straight-chain or branched alkyl having 1 to 25 C atoms, wherein, in addition, one or more non-adjacent CH_2 groups may each be replaced, independently of one another, by $C(R^0)=C(R^{00})-$, $-C\equiv C-$, $-N(R^0)-$, -O-, -S-, -CO-, -CO-O-, -O-CO-, -O-CO-O- in such a way that O and/or S atoms are not linked directly to one another, and wherein, in addition, one or more H atoms may be replaced by F, Cl, CN or P^1-Sp^1-, particularly preferably straight-chain or branched, optionally mono- or polyfluorinated alkyl, alkoxy, alkenyl, alkynyl, alkylcarbonyl, alkoxycarbonyl or alkylcarbonyloxy having 1 to 12 C atoms (where the alkenyl and alkynyl radicals have at least two C atoms and the branched radicals have at least three C atoms),

R^0, R^{00} each, independently of one another, denote H or alkyl having 1 to 12 C atoms,

R^y and R^z each, independently of one another, denote H, F, CH_3 or CF_3,

Z^{p1} denotes -O-, -CO-, $-C(R^yR^z)-$ or $-CF_2CF_2-$,

Z^{p2} and Z^{p3} each, independently of one another, denote -CO-O-, -O-CO-, $-CH_2O-$, $-OCH_2-$, $-CF_2O-$, $-OCF_2-$ or $-(CH_2)_{n3}-$, where n3 is 2, 3 or 4,

L on each occurrence, identically or differently, denotes F, Cl, CN, SCN, SF_5 or straight-chain or branched, optionally mono- or polyfluorinated alkyl, alkoxy, alkenyl, alkynyl, alkylcarbonyl, alkoxycarbonyl, alkylcarbonyloxy or alkoxycarbonyloxy having 1 to 12 C atoms, preferably F,

L' and L" each, independently of one another, denote H, F or Cl,

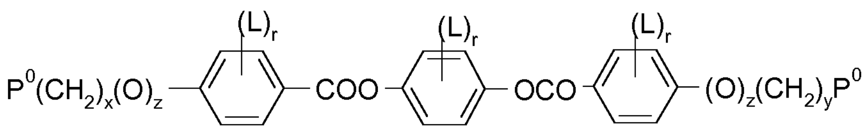
r denotes 0, 1, 2, 3 or 4,

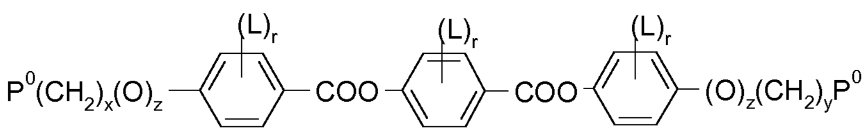
s denotes 0, 1, 2 or 3,

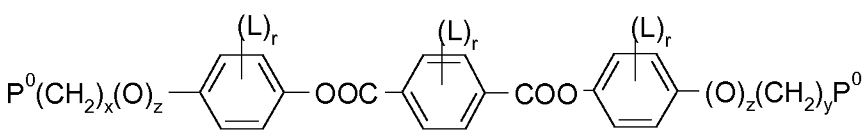
t denotes 0, 1 or 2, and

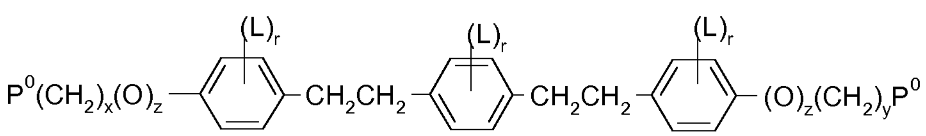
x denotes 0 or 1.

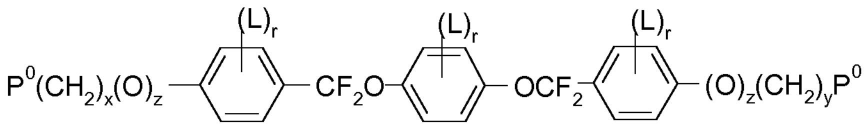
In a particularly preferred embodiment of the present invention the LC mixture comprises one or more compounds of formula P10-1 to P10-7.


P10-1

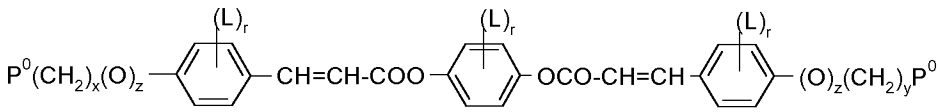

P10-2


P10-3

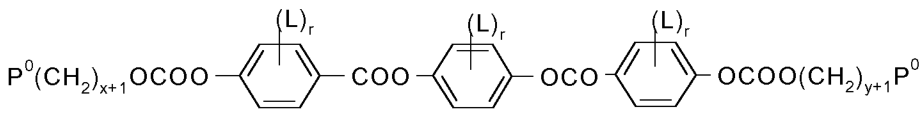

P10-4



P10-5



P10-6



P10-7

wherein

P^0	is, in case of multiple occurrence independently of one another, an acryl, methacryl, oxetane, epoxy, vinyl, heptadiene, vinyloxy, propenyl ether or styrene group,
L	has on each occurrence identically or differently one of the meanings given for L^1 in formula DRM,
r	is 0, 1, 2, 3 or 4,
x and y	are independently of each other identical or different integers from 1 to 12,
z	is each and independently 0 or 1.

The media according to the invention preferably comprise from 0.01 to 10%, particularly preferably from 0.05 to 5.0% and most preferably from 0.2 to 2% of one or more compounds of formula P according to the invention. The media preferably comprise one, two or three, more preferably one or two and most preferably one compound of the formula P according to the invention.

The polymerizable compounds of formula P are suitable for polymerisation with or without an initiator, whereby the latter is associated with considerable advantages, such as, for example, lower material costs and, in particular, reduced contamination of the LC medium by possible residual amounts of the initiator or degradation products thereof.

The polymerisation can thus also be carried out without addition of an initiator. The LC medium thus, in a preferred embodiment, comprises no polymerisation initiator.

The LC medium may also comprise one or more stabilisers. Suitable types and amounts of stabilisers are known to the person skilled in the art and are described in the literature. Particularly suitable are, for example, the commercially available stabilisers from the Irganox® series (BASF SE), such as, for example, Irganox® 1076. If stabilisers are employed, their proportion, based on the total amount of the RMs or the polymerizable component, is preferably 10 - 10,000 ppm, particularly preferably 50 - 1000 ppm.

By means of suitable additives, the liquid-crystalline phases of the present invention can be modified in such a way that they can be used in all types of liquid-crystal display element that have been disclosed hitherto. Additives of this type are known to the person skilled in the art and are described in detail in the literature (H. Kelker/ R. Hatz, Handbook of Liquid Crystals, Verlag Chemie, Weinheim, 1980).

The LC mixtures media are prepared in a manner conventional per se. In general, the components are dissolved in one another, preferably at elevated temperature.

The polymerizable compounds are polymerised and/or crosslinked with the application of an electrical field. Preferably before and/or during the polymerisation an electrical field, preferably an AC electrical field, is applied to the electrodes of the light modulation element.

Suitable and preferred electrical fields depend on the cross-over frequency of the applied liquid crystalline mixture and can be adjusted easily by the skilled person in the art.

Typically the applied electrical fields exhibit a voltage are in the range from 0.01 to 30 V, preferably from 0.1 to 20 V and more preferably in the range from 0.1 V to 10 V.

The polymerisation step can be carried out in one or more steps. If two or more polymerisations steps are applied, each subsequent polymerization step can be thereby performed under the same conditions as the polymerization step performed before or under different conditions, in view of temperature, utilized actinic radiation, time and irradiation atmosphere, etc.

In the polymerization step, the cell is exposed to actinic radiation that causes photopolymerization of the polymerizable functional groups of the polymerizable compounds contained in the cholesteric liquid crystal medium. Polymerisation is achieved for example by exposing the polymerizable material to heat or actinic radiation. Actinic radiation means irradiation with light, like UV light, IR light or visible light, irradiation with X-rays or gamma rays or irradiation with high-energy particles, such as ions or electrons. Preferably, polymerisation is carried out by UV irradiation. As a source for actinic radiation, for example a single UV lamp or a set of UV lamps can be used.

The utilized wavelength of the actinic radiation should not be too low, to avoid damage to the LC molecules of the medium, and should preferably be different from, very preferably higher than, the UV absorption maximum of the LC host mixture. On the other hand, the wavelength of the photo radiation should not be too high, to allow quick and complete UV photopolymerization of the polymerizable compounds, and should be not higher than, preferably the same as or lower than the UV absorption maximum of the polymerizable component.

Suitable wavelengths are preferably selected from wavelengths in the range from 250 to 450 nm, for example 400 nm or less, preferably 350 nm or less, more preferably 300 nm or less.

The irradiation or exposure time should be selected such that polymerisation is as complete as possible, but still not be too high to allow a smooth production process. In addition, the radiation intensity should be high enough to allow quick and complete polymerisation as possible, but should not be too high to avoid damage to the cholesteric liquid crystal medium.

The curing time depends, inter alia, on the reactivity of the polymerizable material, the thickness of the coated layer, the type of polymerisation initiator and the power of the UV lamp. The curing time is preferably ≤ 10 minutes, very preferably ≤ 5 minutes, and most preferably ≤ 1 minutes. In general, for mass production shorter curing times are preferred, such as approximately 60 seconds to 1 second.

A suitable UV radiation power is preferably in the range from 5 to 150 mWcm$^{-2,}$ more preferably in the range from 10 to 75 mWcm^{-2}, especially in the range from 25 to 60 mWcm^{-2}, and in particular 45 to 55 mWcm^{-2}.

Polymerisation is preferably performed under an inert gas atmosphere, preferably in under a nitrogen atmosphere, but also polymerisation in air is possible.

Polymerisation is preferably performed at a temperature in the range from -10°C to +70°C, more preferably 0°C to +50°C, even more preferably +15°C to +40°C.

In a preferred embodiment, the light modulation element can additionally be annealed after the polymerisation, preferably at a temperature above 20°C and below 140°C, more preferably above 40°C and below 130°C and most preferably above 70°C and below 120°C, in order to reach full conversion of the monomers and in order to achieve an optimum stability

The invention further relates to a light modulation element obtainable from a process as described above and below.

The light modulation element according to the invention preferably can be electrically switched between a boundary state A and a boundary state B.

The light modulation element preferably has the boundary state A with a transmission T_A when no electrical field is applied, the so called “off state” and preferably has another boundary state B when an electric field is applied, the so called “on state”, whereby $T_A > T_B$.

Typically, the applied electric field for the switching has frequency is in the range from 0.1Hz to approximately 10000MHz, more preferably in the range from approximately 1Hz to approximately 1000MHz, and even more preferably in the range from approximately 10Hz to approximately 1000MHz.

The required applied electric field strength is mainly dependent on the electrode gap and the modulus of $\Delta\varepsilon$ of the LC mixture. The applied electric field strengths are typically lower than approximately 50 V/µm^{-1}, preferably lower than approximately 30 V/µm^{-1} and more preferably lower than approximately 25 V/µm^{-1}. In particular, the applied electric field strengths are in the range from 1 V/µm^{-1} to 20V/µm^{-1}.

Preferably, the applied driving voltage or operation voltage to switch the light modulation element should be as low as possible. Typically, the applied driving voltage is in the range from 2 V to approximately 200 V, more preferably in the range from approximately 3 V to approximately 100 V, and even more preferably in the range from approximately 5 V to approximately 50 V.

The transmission change is governed by the strength of the applied field. With more field applied to the system, the degree of transmission increases.

The light modulation element of the present invention can be used in diverse types of optical and electro-optical devices. Accordingly, the present invention is also directed to the use of the light modulation element as described above in an optical or electro-optical device and to an optical or electro-optical device comprising the light modulation element according to the present invention.

Said optical and electro optical devices include, without limitation electro-optical displays, liquid crystal displays (LCDs), non-linear optic (NLO) devices, optical information storage devices, light shutters and Smart Windows, privacy windows, virtual reality devices and augmented reality devices.

The present invention also relates to electro-optical liquid-crystal display elements containing a liquid-crystalline medium as described above and below, which is preferably homogeneously aligned. In a preferred embodiment the liquid crystal display is of the IPS or FFS mode.

It will be appreciated that many of the features described above, particularly of the preferred embodiments, are inventive in their own right and not just as part of an embodiment of the present invention. Independent protection may be sought for these features in addition to, or alternative to any invention presently claimed.

It will be appreciated that variations to the foregoing embodiments of the invention can be made while still falling within the scope of the invention. Alternative features serving the same, equivalent or similar purpose may replace each feature disclosed in this specification, unless stated otherwise. Thus, unless stated otherwise, each feature disclosed is one example only of a generic series of equivalent or similar features.

All the features disclosed in this specification may be combined in any combination, except combinations where at least some of such features and/or steps are mutually exclusive. The preferred features of the invention are applicable to all aspects of the invention and may be used in any combination. Likewise, features described in non-essential combinations may be used separately (not in combination).

The parameter ranges indicated in this application all include the limit values including the maximum permissible errors as known by the expert. The different upper and lower limit values indicated for various ranges of properties in combination with one another give rise to additional preferred ranges.

Further combinations of the embodiments and variants of the invention in accordance with the description arise from the claims.

The invention is explained in greater detail below with reference to working examples, but without intending to be restricted thereby. The person skilled in the art will be able to glean from the examples working details that are not given in detail in the general description, generalise them in accordance with general expert knowledge and apply them to a specific problem.

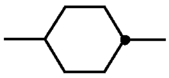
Besides the usual and well-known abbreviations, the following abbreviations are used: C: crystalline phase; N: nematic phase; Sm: smectic phase; I: isotropic phase. The numbers between these symbols show the transition temperatures of the substance concerned.
Temperature data are in °C, unless indicated otherwise.

Physical, physicochemical or electro-optical parameters are determined by generally known methods, as described, inter alia, in the brochure "Merck Liquid Crystals - Licristal® - Physical Properties of Liquid Crystals – Description of the Measurement Methods", 1998, Merck KGaA, Darmstadt.

The compounds used in the present invention are prepared by methods known per se, as described in the literature (for example in the standard works, such as Houben-Weyl, Methoden der organischen Chemie [Methods of Organic Chemistry], Georg-Thieme-Verlag, Stuttgart), to be precise under reaction conditions which are known and suitable for the said reactions. Use can also be made here of variants known per se, which are not mentioned here in greater detail.

In the present invention and especially in the following examples, the structures of the mesogenic compounds are indicated by means of abbreviations, also called acronyms. In these acronyms, the chemical formulae are abbreviated as follows using Tables A to C below. All groups C_nH_{2n+1}, C_mH_{2m+1} and C_lH_{2l+1} or C_nH_{2n-1}, C_mH_{2m-1} and C_lH_{2l-1} denote straight-chain alkyl or alkenyl, preferably 1E-alkenyl, each having n, m and l C atoms respectively. Table A lists the codes used for the ring elements of the core structures of the compounds, while Table B shows the linking groups. Table C gives the meanings of the codes for the left-hand or right-hand end groups. 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			
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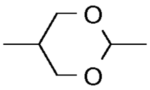
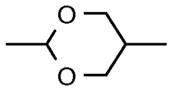
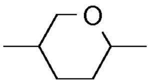
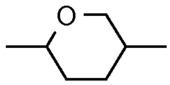
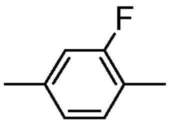
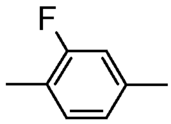
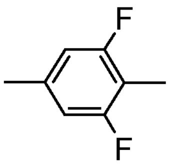
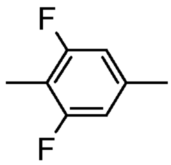
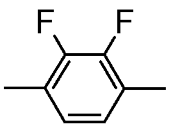
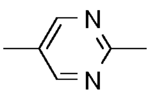
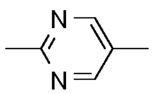
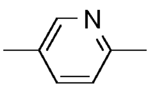
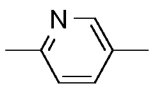
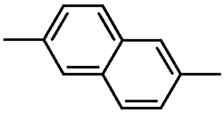
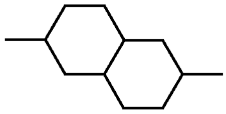
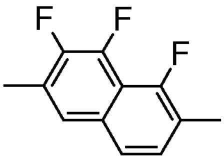
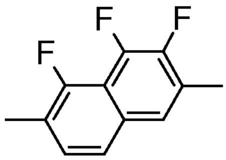
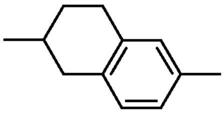
D		**DI**	
A		**AI**	
G		**GI**	
U		**UI**	
Y			
M		**MI**	
N		**NI**	

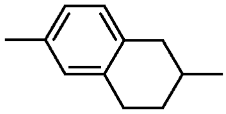
Np 

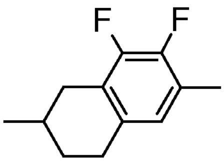
dH 

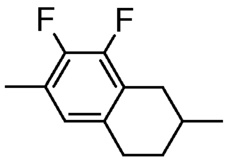
N3f 

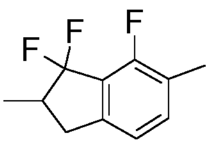
N3fl 

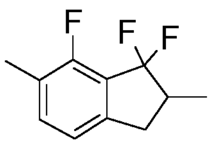
tH 

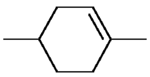
tHl 

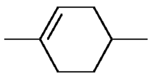
tH2f 

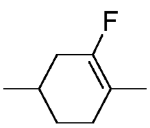
tH2fl 

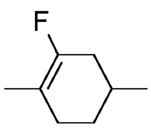
K 

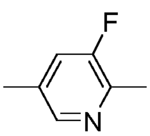
Kl 

L 

Ll 

F 

Fl 

Nf 

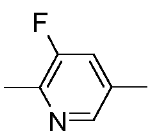
Nfl 

Table B: Linking groups

E	$-CH_2CH_2-$	**Z**	-CO-O-
V	-CH=CH-	**ZI**	-O-CO-
X	-CF=CH-	**O**	$-CH_2-O-$
XI	-CH=CF-	**OI**	$-O-CH_2-$
B	-CF=CF-	**Q**	$-CF_2-O-$
T	-C≡C-	**QI**	$-O-CF_2-$
W	$-CF_2CF_2-$	**T**	-C≡C-

Table C: End groups

Left-hand side		**Right-hand side**	
	Use alone		
-n-	$C_nH_{2n+1}-$	**-n**	$--C_nH_{2n+1}$
-nO-	$C_nH_{2n+1}-O-$	**-nO**	$-O-C_nH_{2n+1}$
-V-	$CH_2=CH-$	**-V**	$-CH=CH_2$
-nV-	$C_nH_{2n+1}-CH=CH-$	**-nV**	$-C_nH_{2n}-CH=CH_2$
-Vn-	$CH_2=CH- C_nH_{2n+1}-$	**-Vn**	$-CH=CH-C_nH_{2n+1}$
-nVm-	$C_nH_{2n+1}-CH=CH-C_mH_{2m}-$	**-nVm**	$-C_nH_{2n}-CH=CH-C_mH_{2m+1}$
-N-	N≡C-	**-N**	-C≡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_2H-	**-D**	$-CF_2H$
-T-	CF_3-	**-T**	$-CF_3$
-MO-	CFH_2O -	**-OM**	$-OCFH_2$
-DO-	CF_2HO -	**-OD**	$-OCF_2H$
-TO-	CF_3O -	**-OT**	$-OCF_3$

-FXO-	CF_2=CH-O-	**-OXF**	-O-CH=CF_2
-A-	H-C≡C-	**-A**	-C≡C-H
-nA-	C_nH_{2n+1}-C≡C-	**-An**	-C≡C-C_nH_{2n+1}
-NA-	N≡C-C≡C-	**-AN**	-C≡C-C≡N

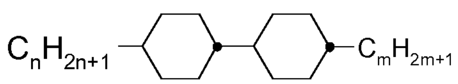
Use together with one another and with others

-...A...-	-C≡-	**-...A...**	-C≡-
-...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-

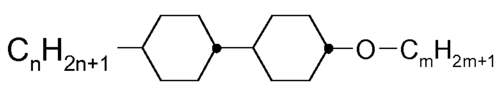
wherein n and m each denote integers, and the three dots "..." are placeholders for other abbreviations from this table.

The following table shows illustrative structures together with their respective abbreviations. These are shown in order to illustrate the meaning of the rules for the abbreviations. They furthermore represent compounds which are preferably used.

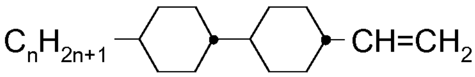
<u>Table D: Illustrative structures</u>



CC-n-m



CC-n-Om



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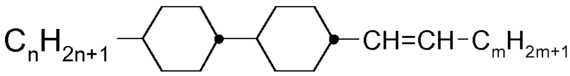

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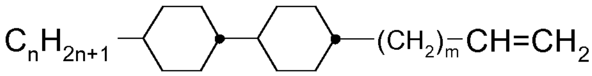

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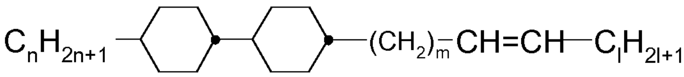

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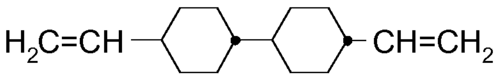

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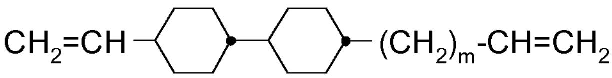

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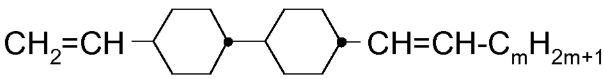

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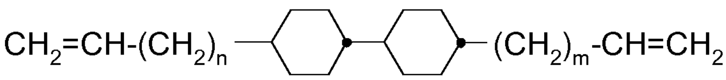

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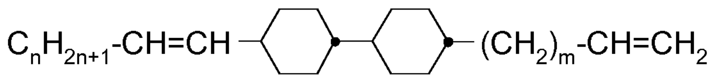

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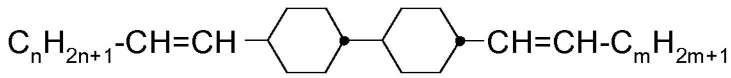

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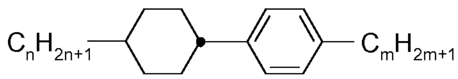

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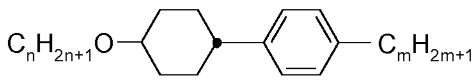

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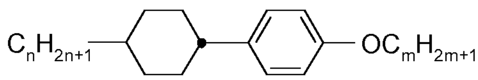

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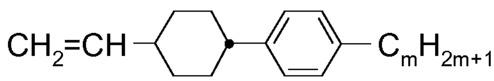

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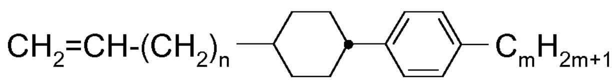

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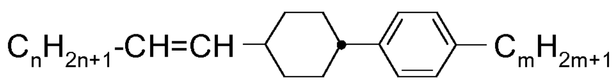

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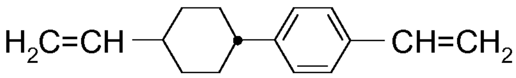

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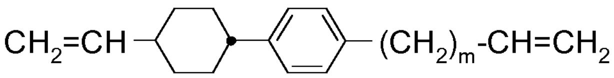

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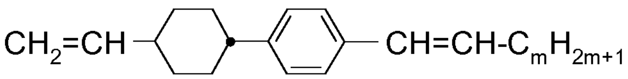

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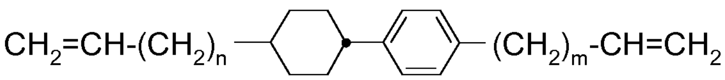

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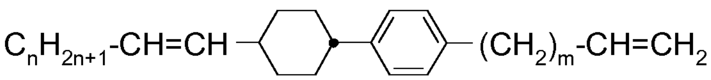

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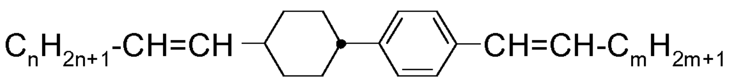

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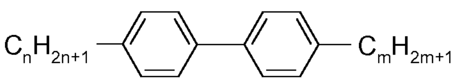

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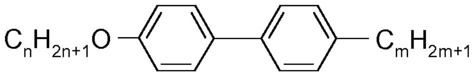

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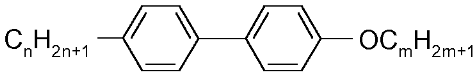

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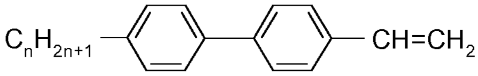

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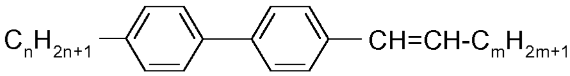

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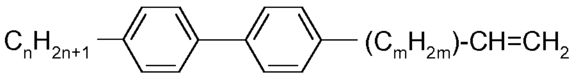

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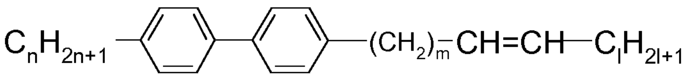

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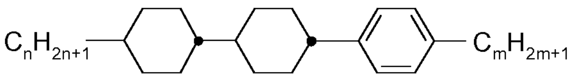

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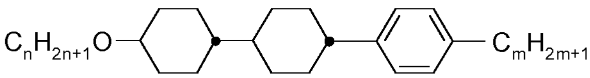

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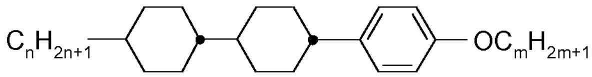

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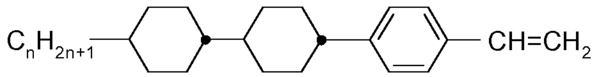

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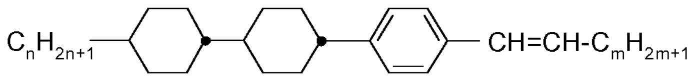

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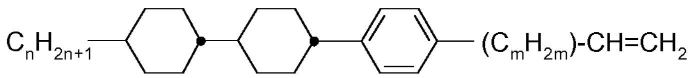

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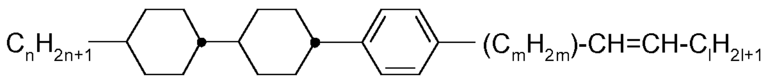

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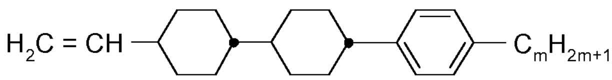

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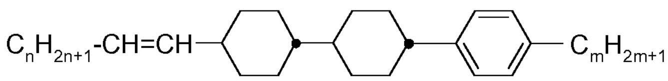

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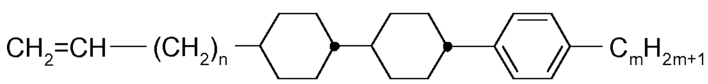

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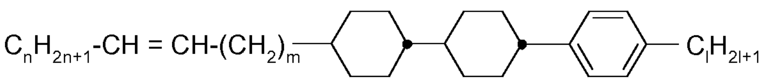

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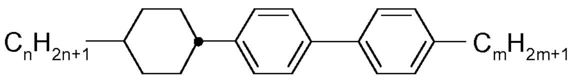

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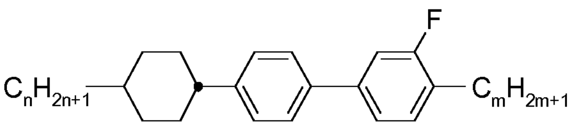

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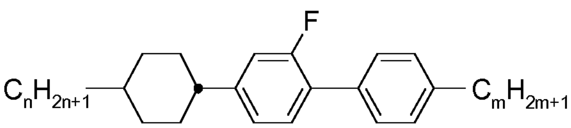

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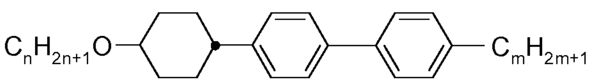

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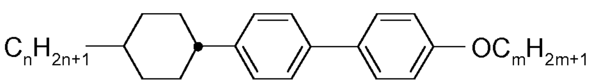

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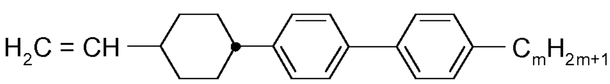

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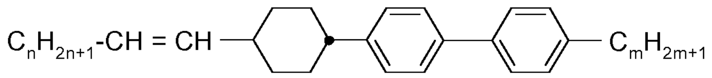

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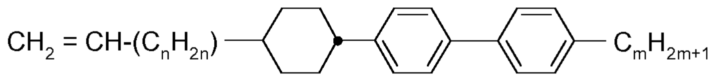

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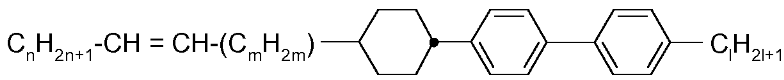

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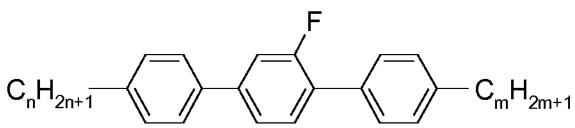

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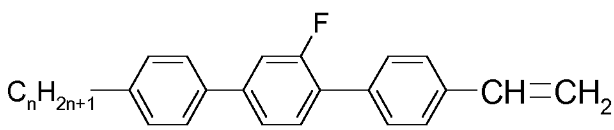

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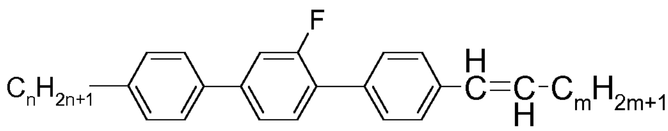

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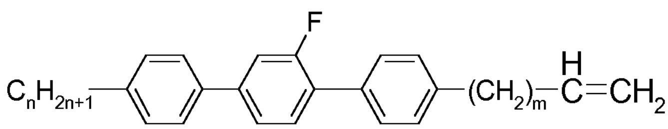

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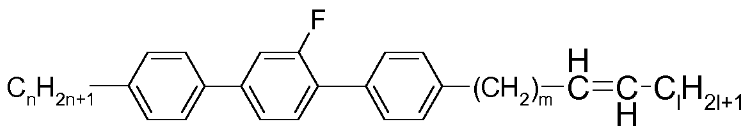

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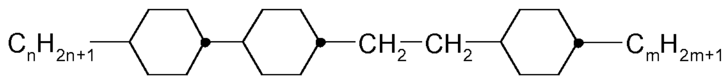

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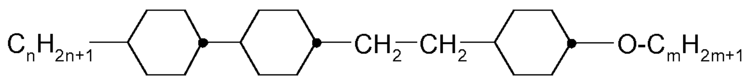

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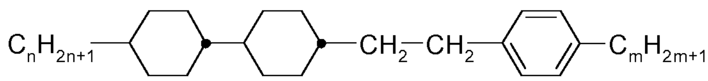

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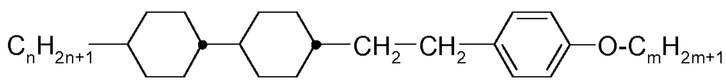

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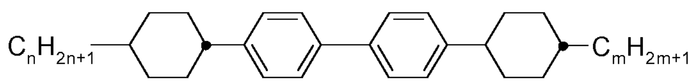

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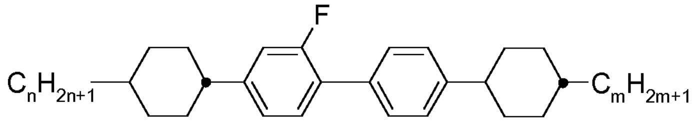

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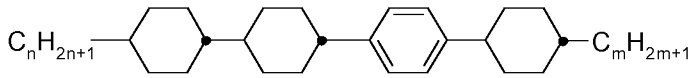

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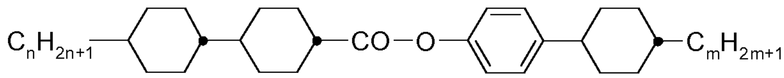

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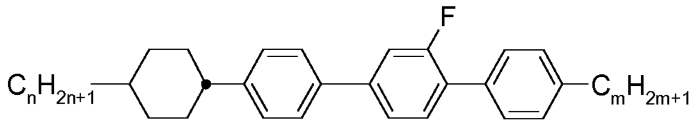

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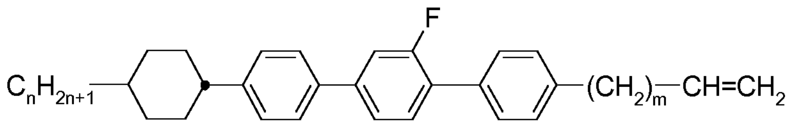

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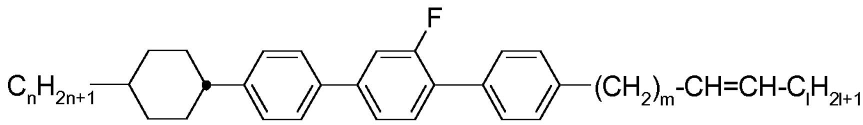

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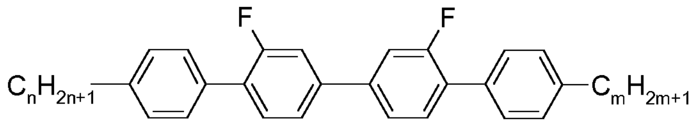

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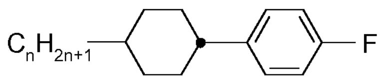

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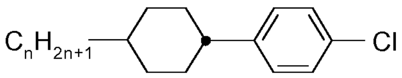

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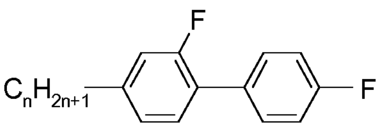

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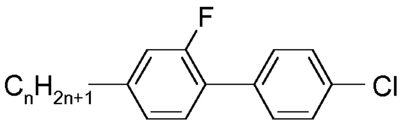

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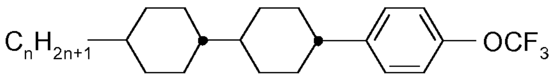

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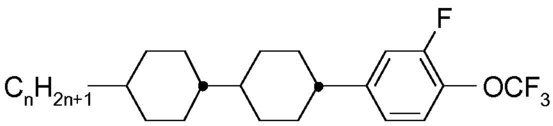

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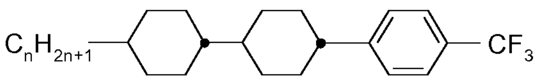

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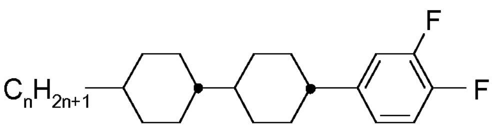

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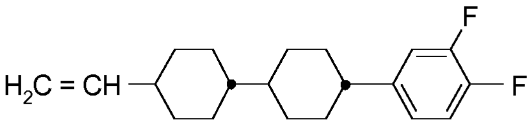

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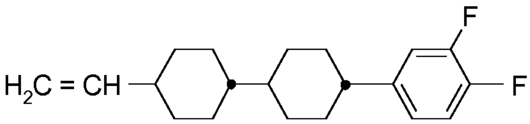

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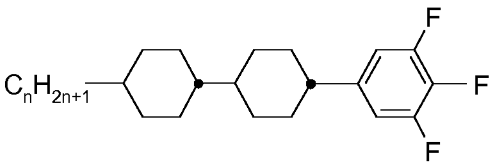

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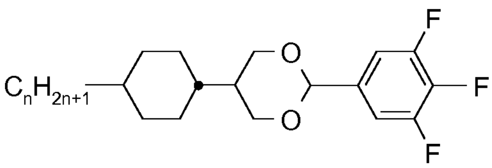

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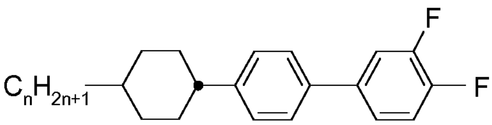

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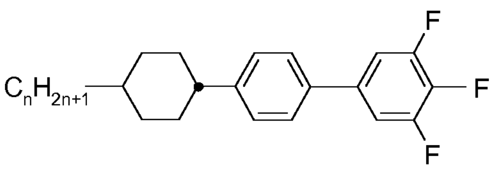

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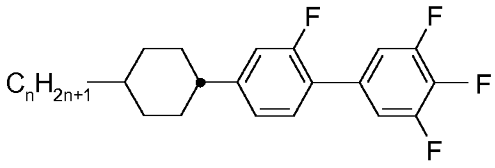

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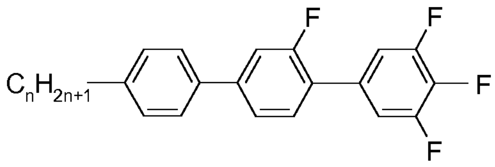

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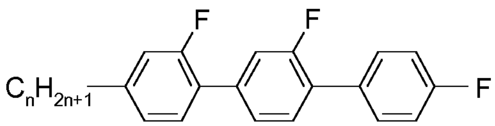

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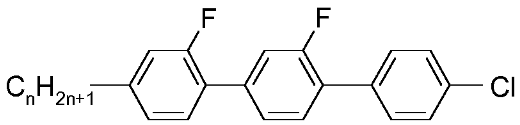

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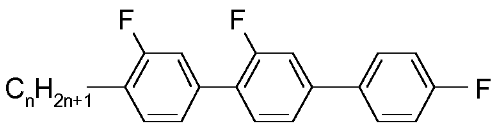

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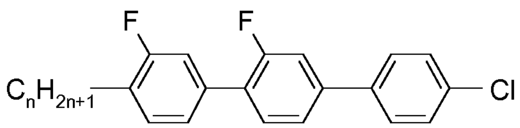

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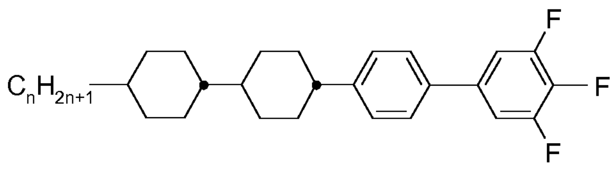

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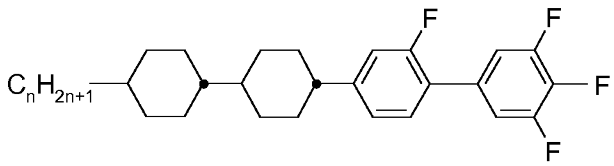

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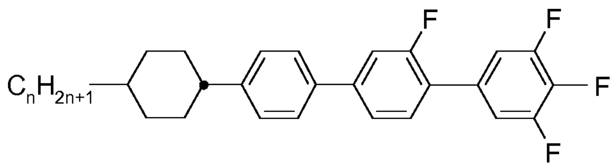

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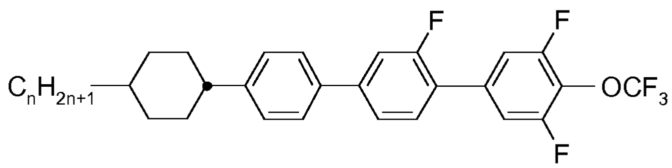

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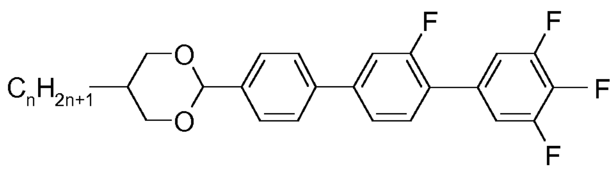

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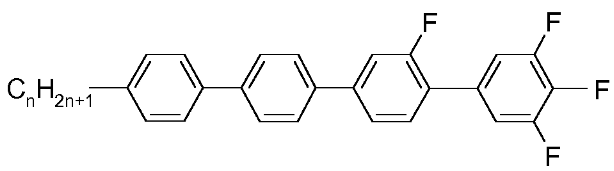

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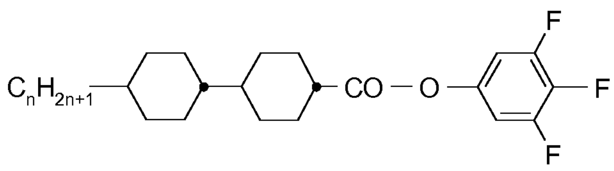

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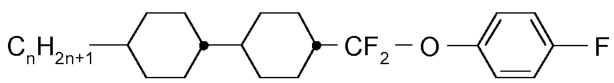

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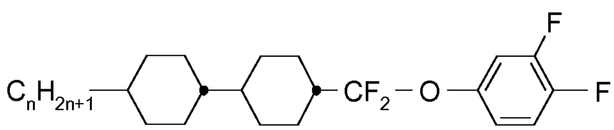

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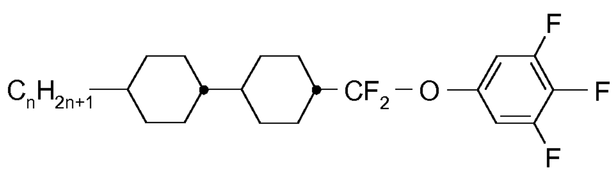

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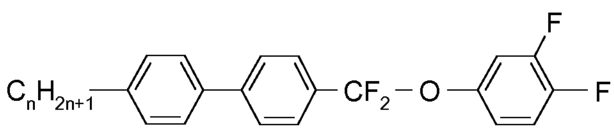

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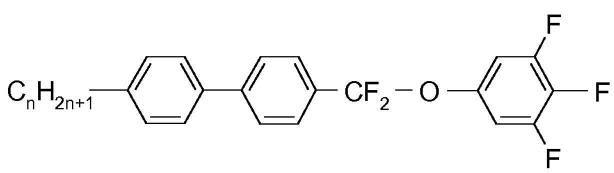

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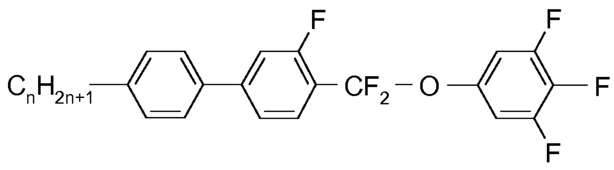

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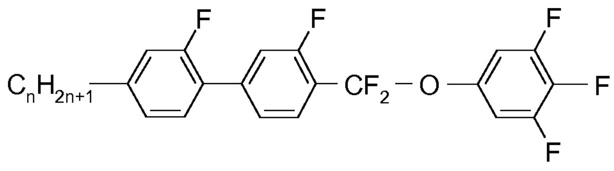

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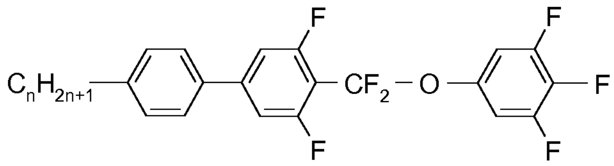

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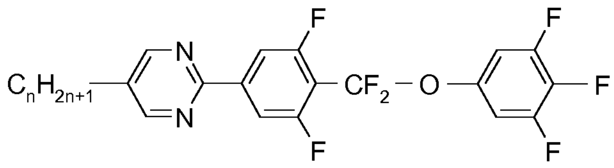

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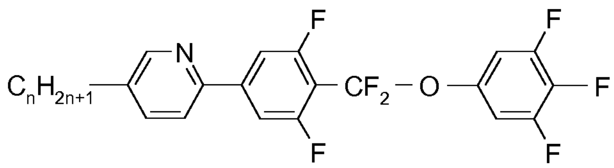

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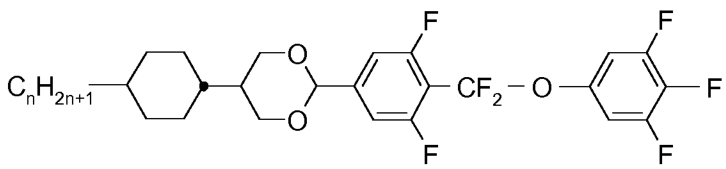

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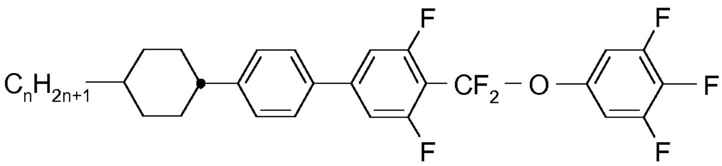

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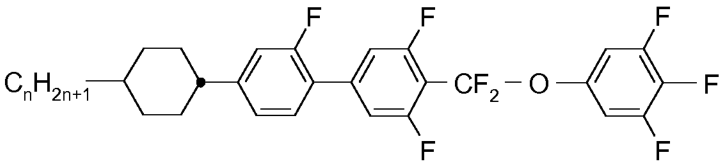

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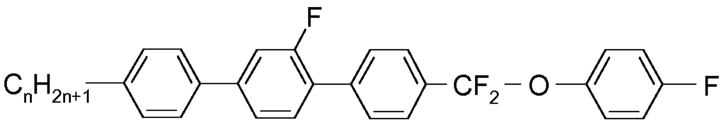
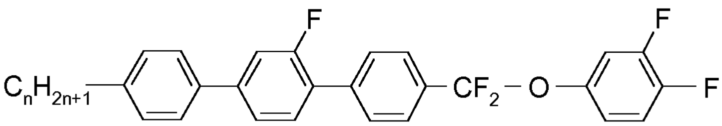


PGPQP-n-F



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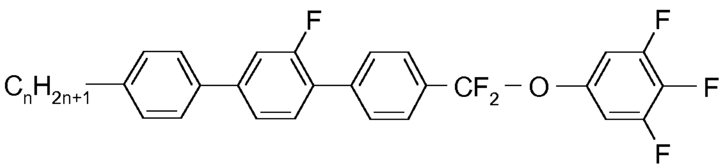

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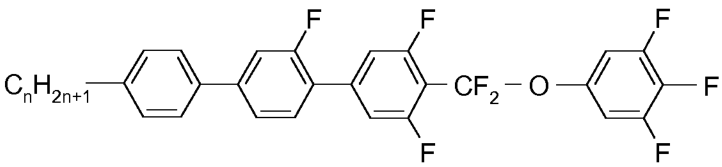

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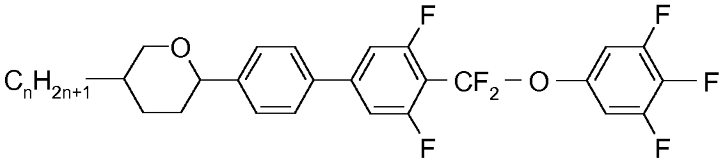
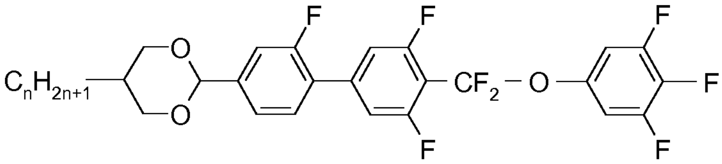
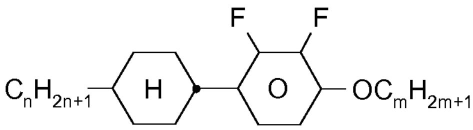


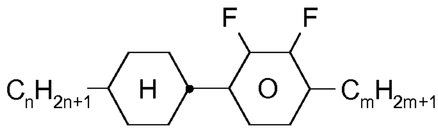
APUQU-n-F



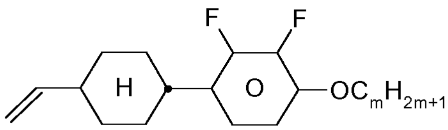
DGUQU-n-F



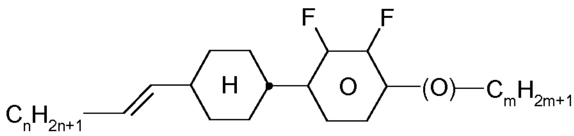
CY-n-Om



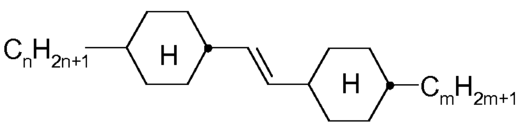
CY-n-m



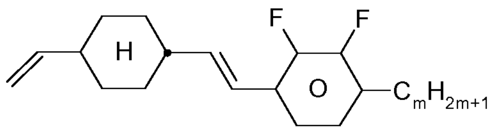
CY-V-Om



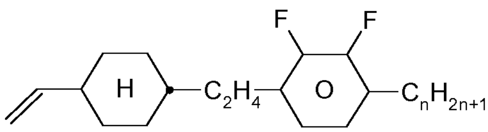
CY-nV-(O)m



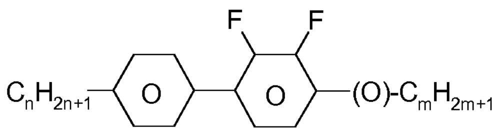
CVC-n-m



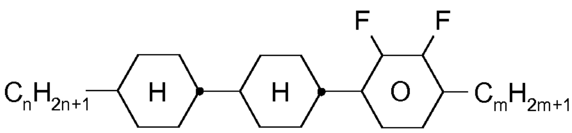
CVY-V-m



CEY-V-m



PY-n-(O)m



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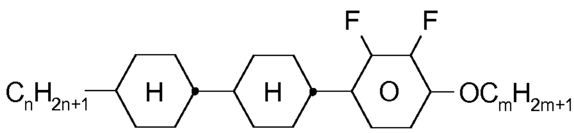
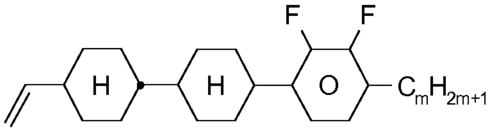
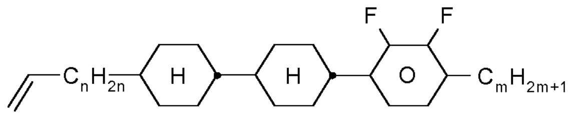


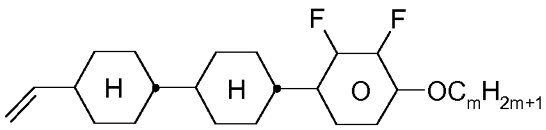
CCY-n-Om



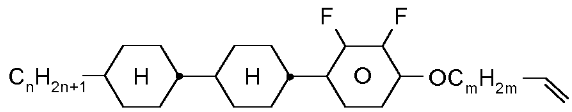
CCY-V-m



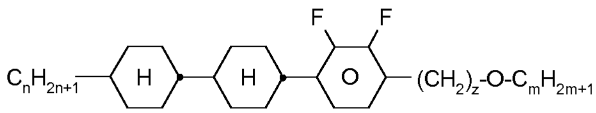
CCY-Vn-m



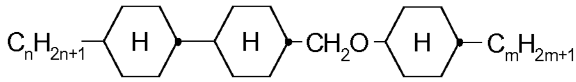
CCY-V-Om



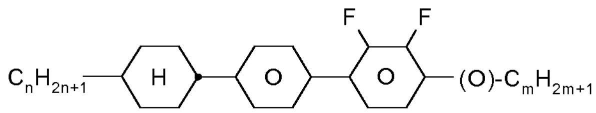
CCY-n-OmV



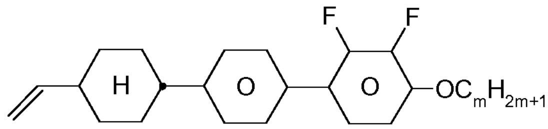
CCY-n-zOm



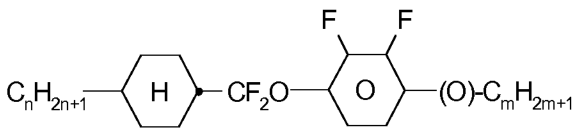
CCOC-n-m



CPY-n-(O)m



CPY-V-Om



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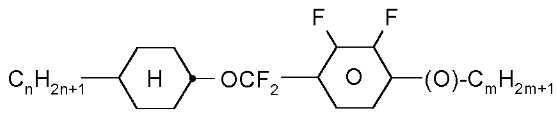
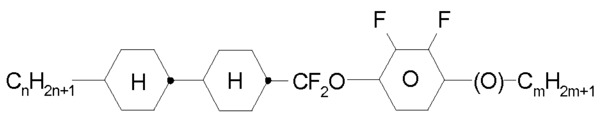
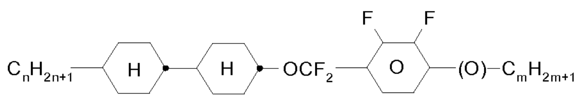


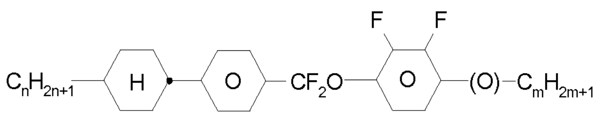
CQIY-n-(O)m



CCQY-n-(O)m



CCQIY-n-(O)m



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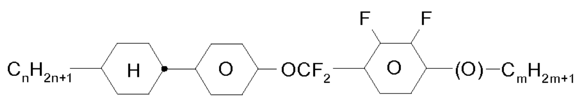
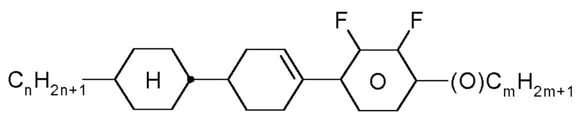
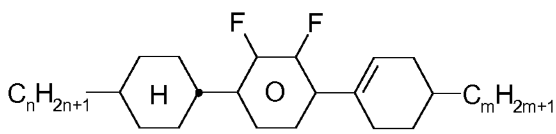
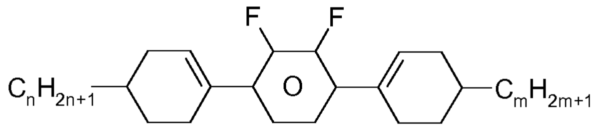


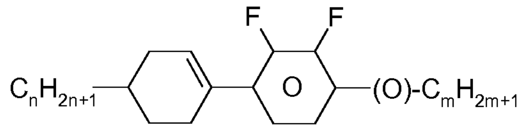
CPQIY-n-Om



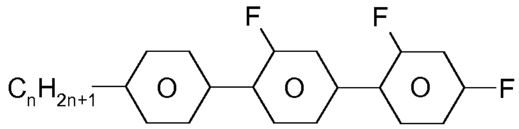


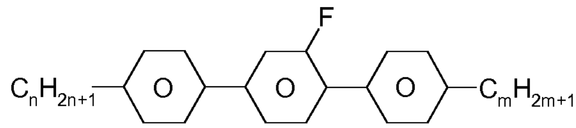
CLY-n-(O)m **CYLI-n-m**



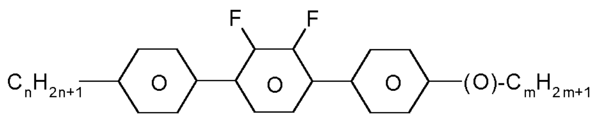


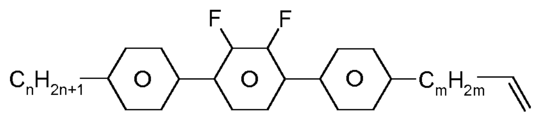
LYLI-n-m **LY-n-(O)m**



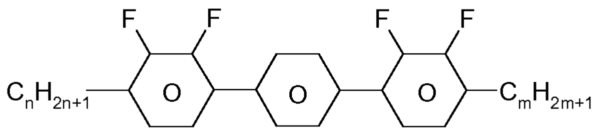


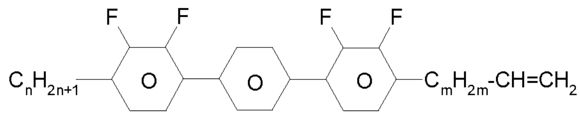
PGIGI-n-F **PGP-n-m**



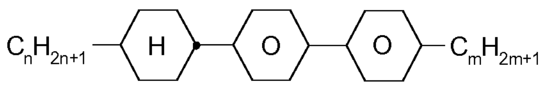


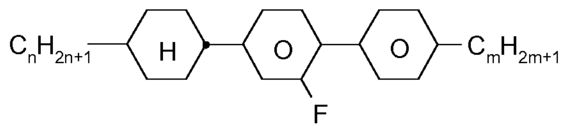
PYP-n-(O)m **PYP-n-mV**



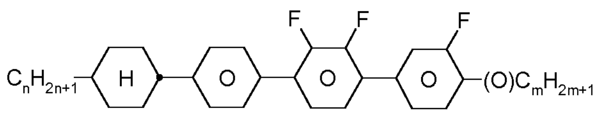


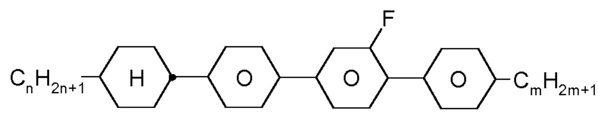
YPY-n-m **YPY-n-mV**



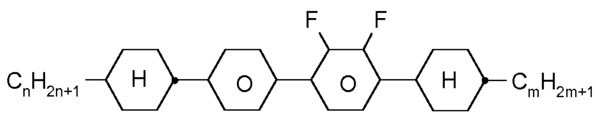


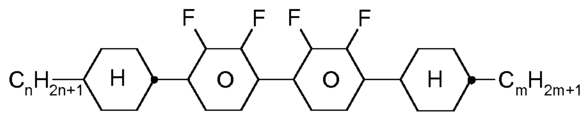
BCH-nm **BCH-nmF**



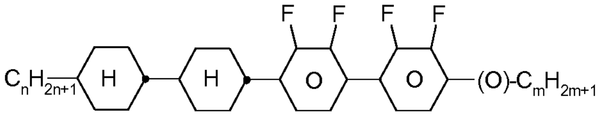


CPYP-n-(O)m **CPGP-n-m**

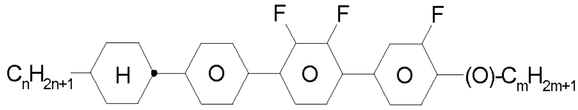




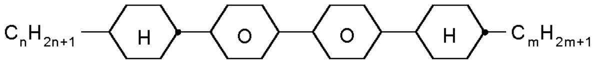
CPYC-n-m **CYYC-n-m**



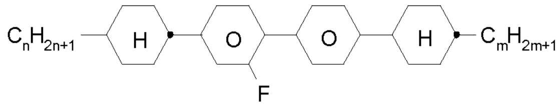
CCYY-n-m



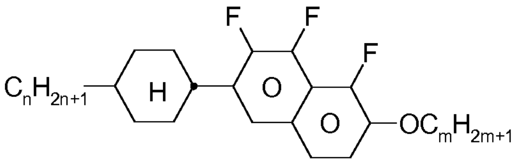
CPYG-n-(O)m



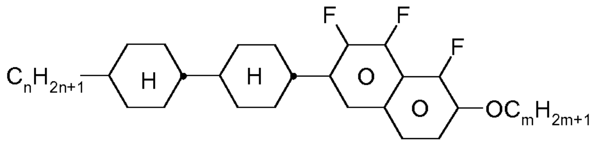
CBC-nm



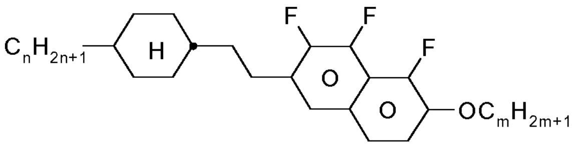
CBC-nmF



CNap-n-Om



CCNap-n-Om



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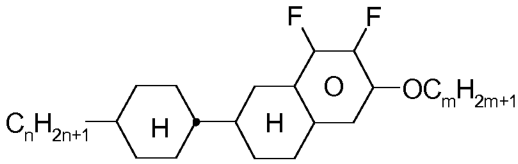
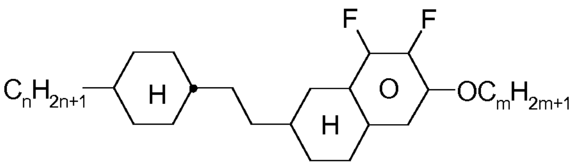
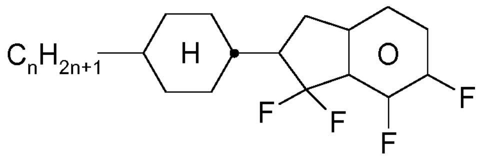


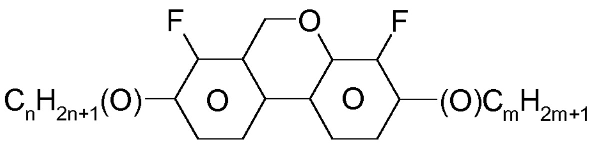
CTNap-n-Om



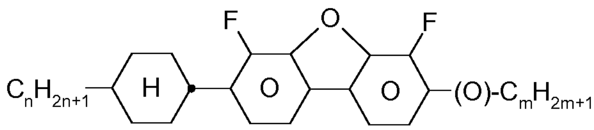
CETNap-n-Om



CK-n-F



DFDBC-n(O)-(O)m



C-DFDBF-n-(O)m

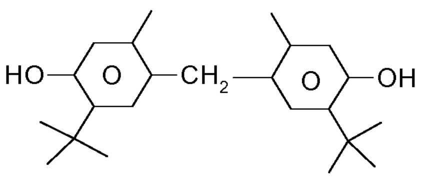
wherein n, m and l preferably, independently of one another, denote 1 to 7.

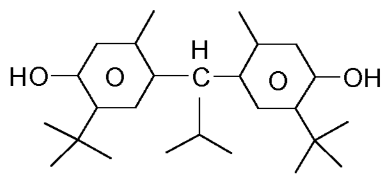
The following table, Table E, shows illustrative compounds which can be used as additional stabilisers in the mesogenic media according to the present invention.

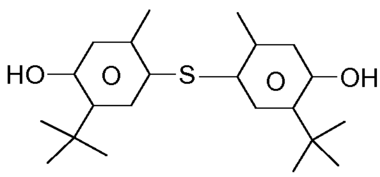
Table E

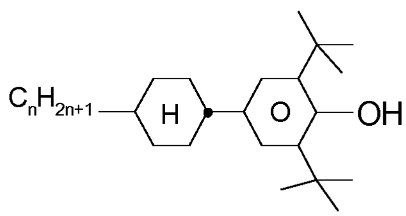
Table E shows possible stabilisers which can be added to the LC media according to the invention.

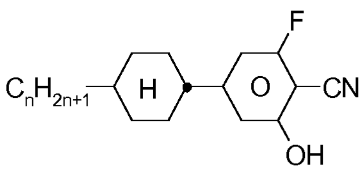
(n here denotes an integer from 1 to 12, preferably 1, 2, 3, 4, 5, 6, 7 or 8, terminal methyl groups are not shown).

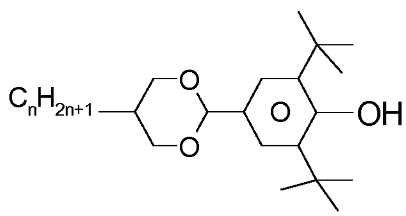


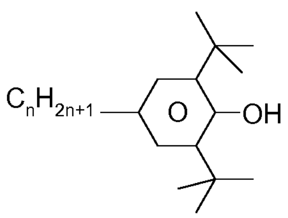


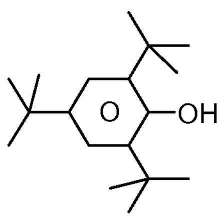


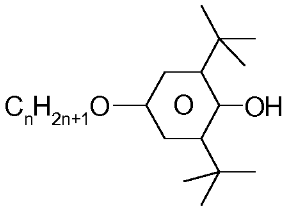


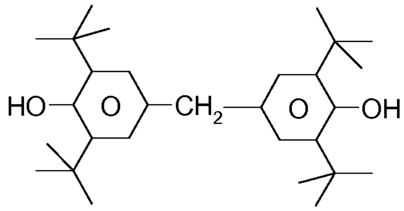


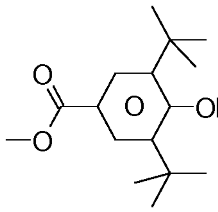


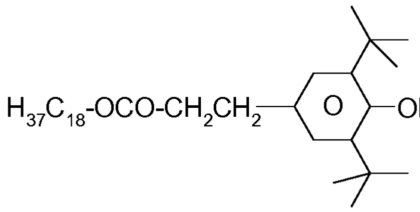


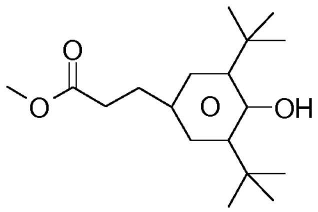


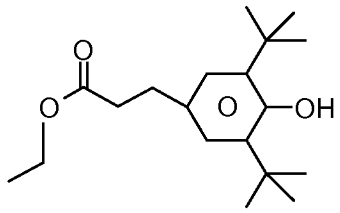

C$_n$H$_{2n+1}$O
O
OH

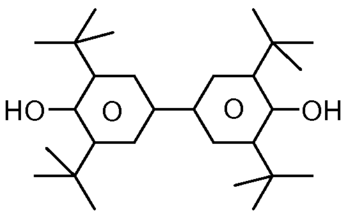

HO
O
CH$_2$
O
OH

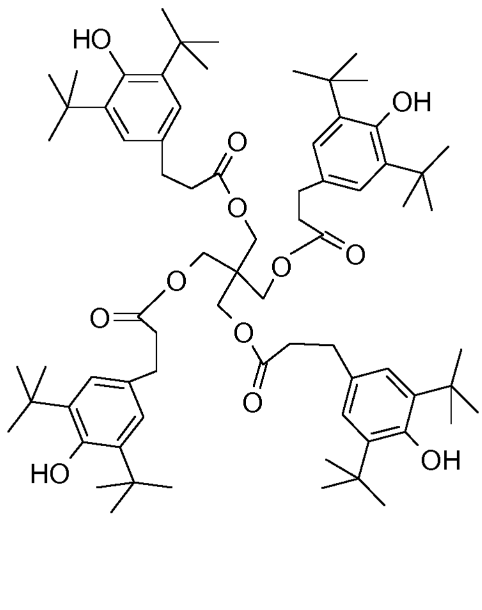

O
O
O
OH

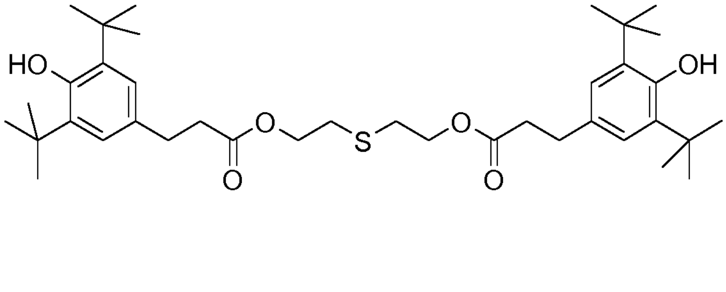

H$_{37}$C$_{18}$-OCO-CH$_2$CH$_2$
O
OH

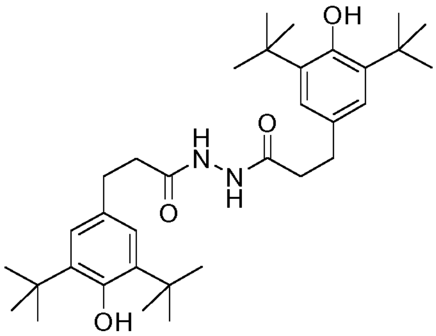

O
O
O
OH

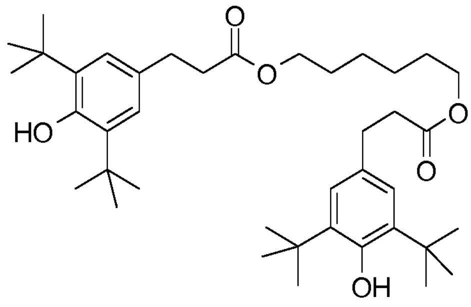

O
O
O
OH

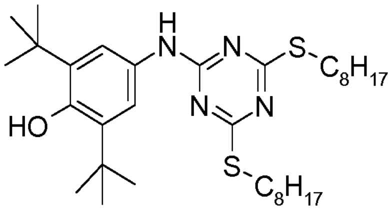

HO
O
O
OH

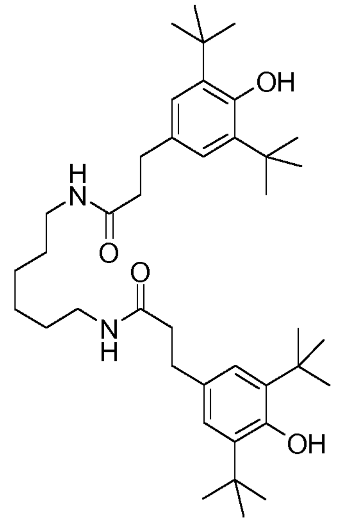

HO
OH
O
O
O
O
O
O
O
O
HO
OH

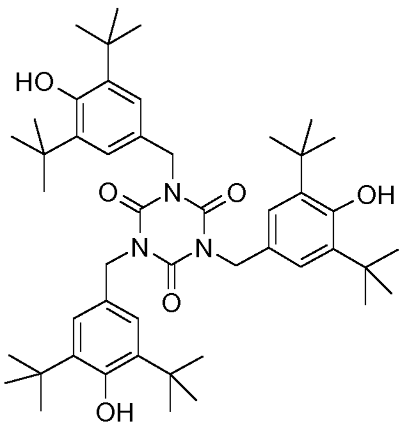

HO
O
S
O
OH
O
O

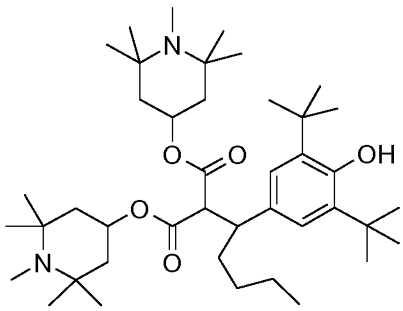


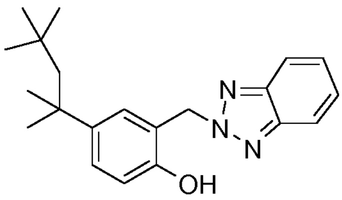


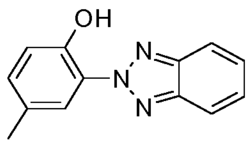


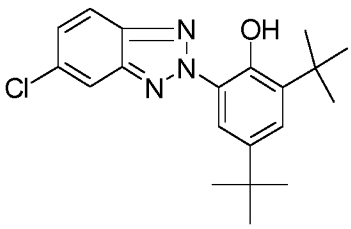


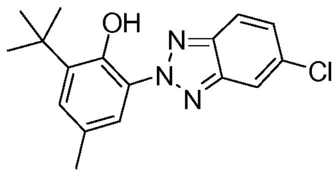


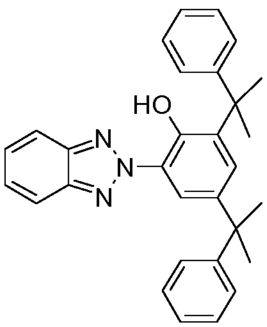


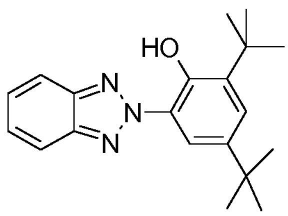

N
N
N
OH

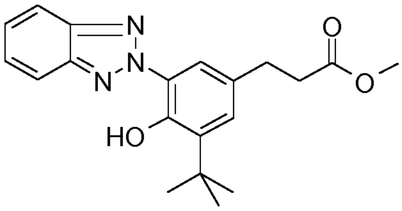

OH
N
N
N

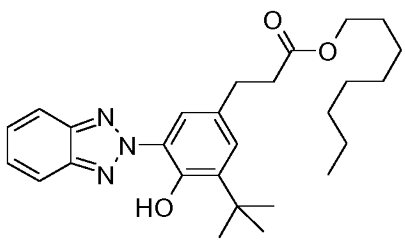

N
OH
Cl
N
N

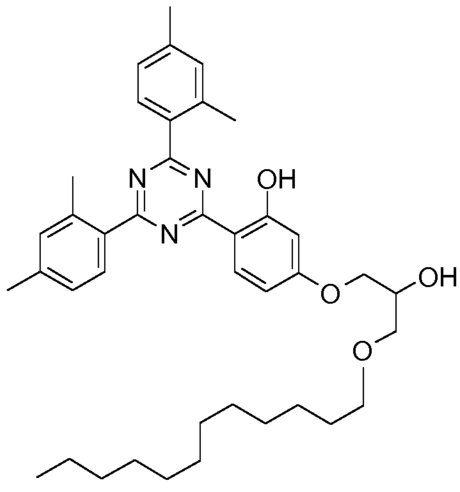

OH
N
N
N
Cl

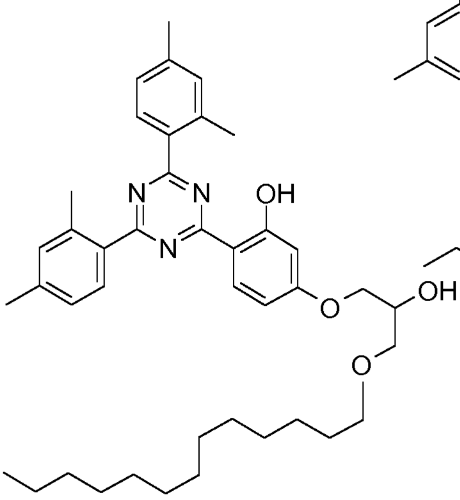

HO
N
N
N

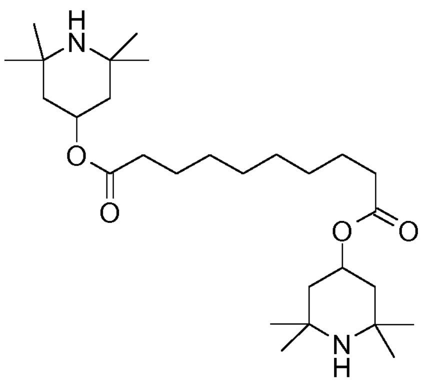

HO
N
N
N

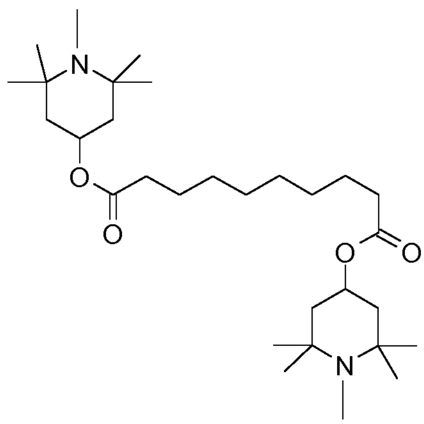

N
N
N
O
O
HO

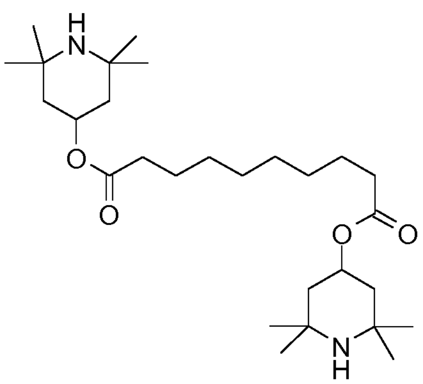

O
O
N
N
N
HO

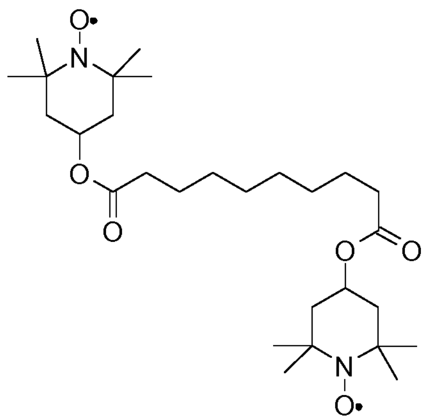


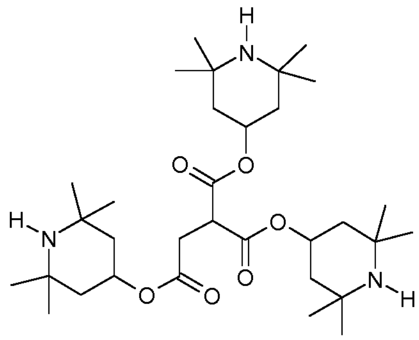


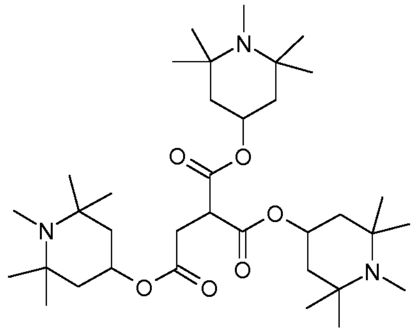


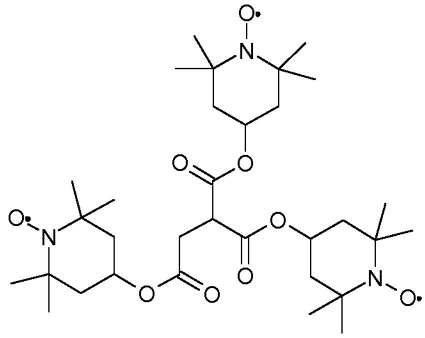


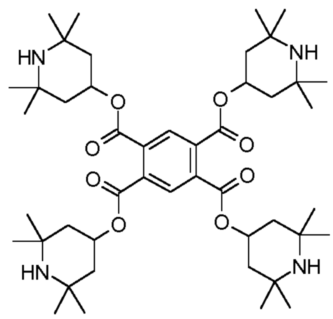


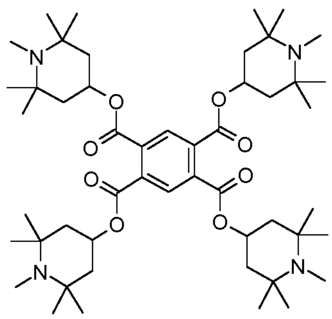


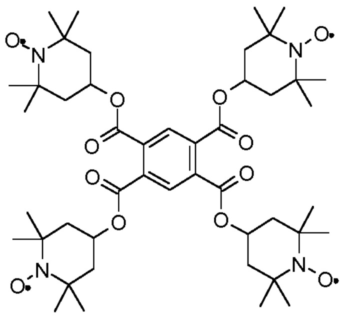


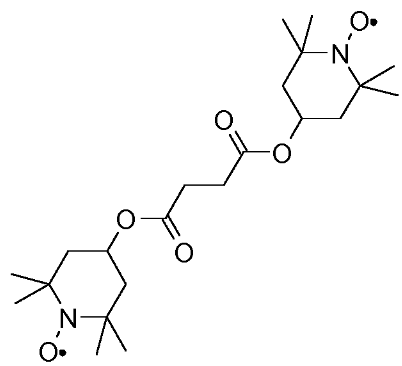


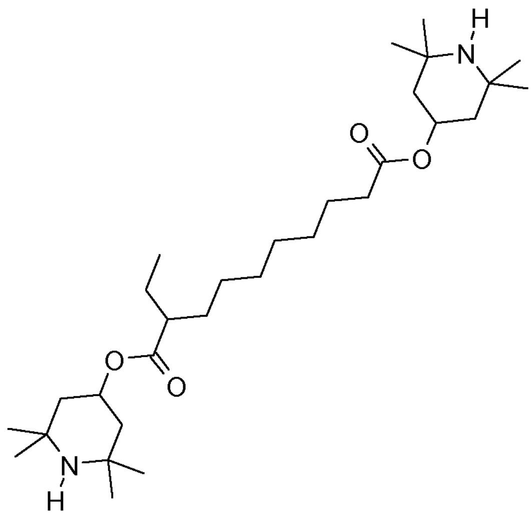


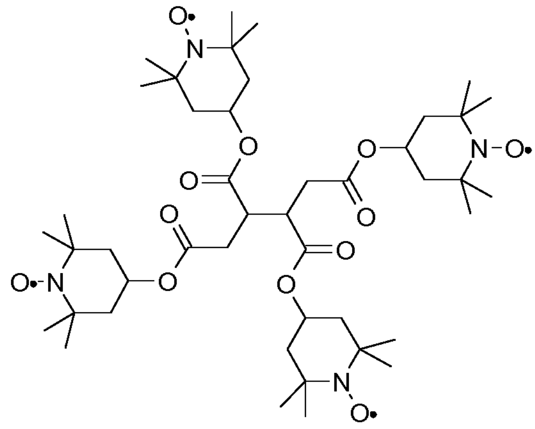












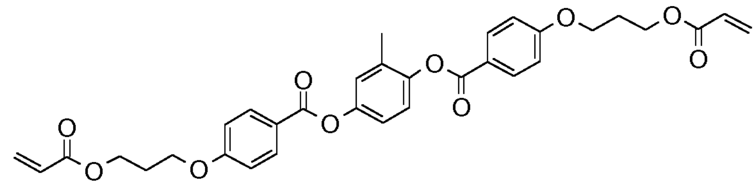
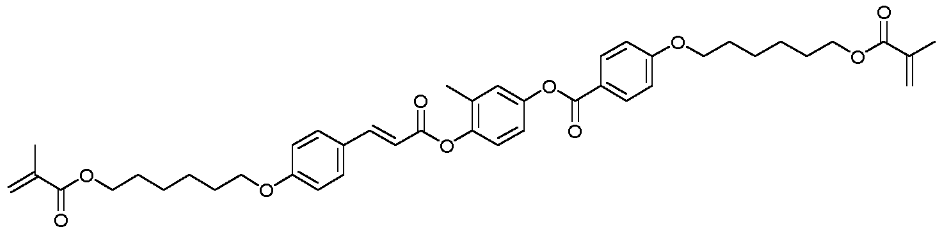
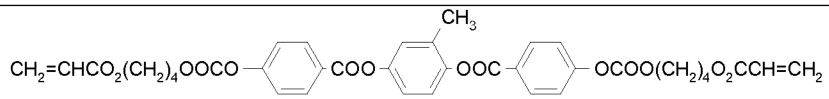
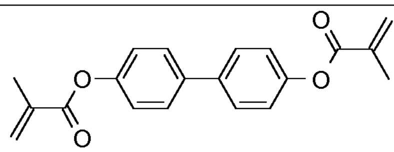
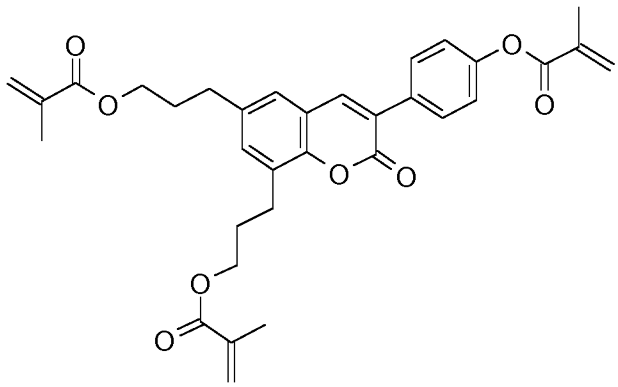
The LC media preferably comprise 0 to 10% by weight, in particular 1 ppm to 5% by weight, particularly preferably 1 ppm to 1% by weight, of stabilisers.

Hereinafter, the present invention is described in more detail and specifically with reference to the Examples, which however are not intended to limit the present invention.

Examples

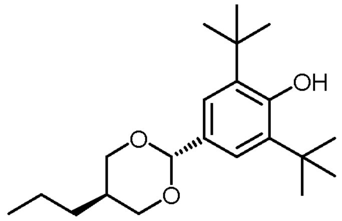
Hereinafter, the present invention is described in more detail and specifically with reference to the Examples, which however are not intended to limit the present invention.

Utilized polymerizable liquid crystalline compounds

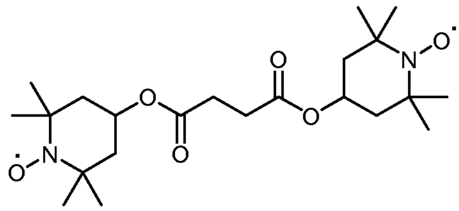
RM-1	
RM-2	
RM-3	
RM-4	
RM-5	

Dual frequency liquid crystal mixtures

The nematic LC host mixture N-1 to N-3 are prepared as indicated in the following tables and the following stabilzers are added after preparation:



0.04



0.010 to 0.020

N-1:

APUQU-2-F	6.0	cl.p. [°C]:	80.8
APUQU-3-F	8.0	Δn [589 nm, 20°C]:	0.1125
CC-3-V	26.0	n_e [589 nm, 20°C]:	1.6002
CCP-V-1	14.0	n_o [589 nm, 20°C]:	1.4877
CCP-V2-1	12.0	Δε [1 kHz, 20°C]:	10.5
DGUQU-4-F	5.0	$\varepsilon_{\parallel}$ [1 kHz, 20°C]:	15.6
DPGU-4-F	5.0	$\varepsilon_{\perp}$ [1 kHz, 20°C]:	5.1
PGP-2-2V	4.5	K_1 [pN, 20°C]:	12.3
PGUQU-3-F	5.0	K_3 [pN, 20°C]:	13.5
PGUQU-4-F	3.0		
PPGU-3-F	0.5		
Y-4O-O4	11.0		
Σ	100.0		

N-2:

APUQU-2-F	5.5	cl.p. [°C]:	80.1
APUQU-3-F	7.0	Δn [589 nm, 20°C]:	0.1120
B-2O-O5	4.0	n_e [589 nm, 20°C]:	1.5969
CC-3-V	23.5	n_o [589 nm, 20°C]:	1.4849
CC-3-V1	4.0	Δε [1 kHz, 20°C]:	8.0
CCP-3-1	3.5	$\varepsilon_{\parallel}$ [1 kHz, 20°C]:	14.1
CCP-30CF3	3.0	$\varepsilon_{\perp}$ [1 kHz, 20°C]:	6.1
CCP-V-1	14.0	K_1 [pN, 20°C]:	13.1
CDUQU-3-F	4.0	K_3 [pN, 20°C]:	13.6
DGUQU-4-F	4.0		
DPGU-4-F	4.0		
PGUQU-3-F	3.0		
PPGU-3-F	1.5		
PY-3-O2	9.5		
Y-4O-O4	5.0		
CCY-3-O2	4.5		
Σ	100.0		

N-3:

APUQU-2-F	4.5	cl.p. [°C]:	80.4
APUQU-3-F	5.5	Δn [589 nm, 20°C]:	0.1109
B-2O-O5	4.0	n_e [589 nm, 20°C]:	1.5915
CC-3-V	22.0	n_o [589 nm, 20°C]:	1.4806
CC-3-V1	5.0	Δε [1 kHz, 20°C]:	5.8
CCP-30CF3	8.0	$\varepsilon_{\parallel}$ [1 kHz, 20°C]:	13.4
CCP-V-1	4.0	$\varepsilon_{\perp}$ [1 kHz, 20°C]:	7.6
CCY-3-O2	5.0	K_1 [pN, 20°C]:	12.7
CDUQU-3-F	5.0	K_3 [pN, 20°C]:	13.6
CPY-2-O2	8.0		
CPY-3-O2	8.0		
DGUQU-4-F	5.0		
DPGU-4-F	4.0		
PPGU-3-F	0.5		
PY-3-O2	3.5		
Y-4O-O4	8.0		
Σ	100.0		

Working examples

LC mixtures M-1 to M-9 are prepared from mixtures N-1 to N-3 and RM-1 to RM-5 according to the compositions given in the following table.

Mixture example	**Host Mixture**	**c [%] of Host Mixture**	**Reactive Mesogen**	
			Compound	**c [%]**
M-1	N-1	99.00	RM-1	1.00
M-2	N-1	99.00	RM-2	1.00
M-3	N-1	99.00	RM-3	1.00
M-4	N-1	99.00	RM-4	1.00
M-5	N-1	99.00	RM-5	1.00
M-6	N-2	99.00	RM-1	1.00
M-7	N-2	99.00	RM-2	1.00

M-8	N-3	99.00	RM-1	1.00
M-9	N-3	99.00	RM-2	1.00

Test cells

Typically, the display cells are made with Corning AF glass of 0.7mm thickness using 6.4 µm spacer beads and XN-1500T sealant.

For measurement of electro-optics 3 µm thick PI-free IPS cells are made of substrates commercially available from SD-tech and constructed into cells using ITO electrodes having 5µm electrode spacing and a 3µm electrode width.

The cells are assembled by hand and then cured using a Omnicure 2000 Mercury lamp with with 35 mW/cm^2 the irradiation power is thereby measured by an Opsytec UV pad-e spectroradiometer.

The selected LC mixtures are capillary filled using capillary action at room temp., annealed for 1 h at 100°C.

After applying an electric field to the electrodes having a frequency of 1 MHz the cells ar irradiated at a temperature with UV light (35 mW/cm^2). The cells are then cooled to room temperature.

The cells can be switched from boundary state A to boundary state B by applying an electrical field to the electrodes.

Alignment quality

The alignment quality is studied between crossed polarisers on a light box.

Example	**Alignment quality**
M-1	++
M-2	++
M-3	++
M-4	++
M-5	++
M-6	++
M-7	++
M-8	++
M-9	++

Alignment quality: (++) excellent, (+) good, (o) acceptable, (-) poor

Excellent uniform planar alignment is achieved with all mixtures.

VHR measurements

Next, the VHR is studied using Toyo LCM-1 LC Material Characteristics Measurement System. The measurement of the VHR is carried out as described in T. Jacob, U. Finkenzeller in "Merck Liquid Crystals - Physical Properties of Liquid Crystals", 1997.

Example	**VHR**[%]
M-1	28.6
M-2	26.5
M-3	46.0
M-4	32.9

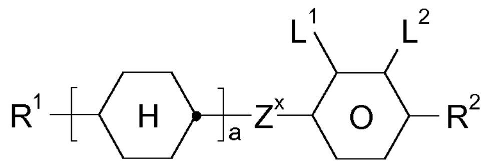
Patent Claims

1. Process for the fabrication of a light modulation element, preferably operated in the IPS/FFS mode, comprising at least the steps of:
   e) providing a first substrate which includes a pixel electrode and a common electrode for generating an electric field substantially parallel to a surface of the first substrate in the pixel region;
   f) providing a second substrate, the second substrate being disposed opposite to the first substrate;
   g) interposing a dual frequency liquid crystal mixture that additionally comprises one or one or more polymerizable liquid crystalline compounds;
   h) applying an electric field to the liquid crystal mixture having a frequency in the range of from 0.01Hz to 1500 kHz and subsequently irradiating the liquid crystal mixture with actinic radiation.

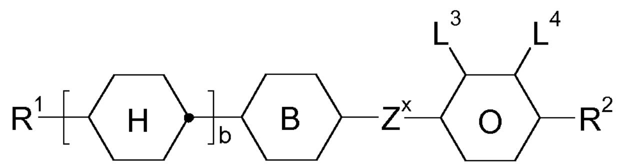
2. Process according to claim 1, characterized in that the value of $\Delta\varepsilon$, at 1 kHz and 20 °C of the liquid crystal medium is in the range from 1.0 to 20.0.

3. Process according to at least one of claims 1 or 2, characterized in that the value of $\Delta\varepsilon$, at 100 kHz, 500 kHz or 1000 kHz and 20 °C of the liquid crystal medium is less than 0.

4. Process according to one or more of claims 1 or 3, characterised in that the LC host mixture comprises one or more compounds selected from the following formulae:



CY

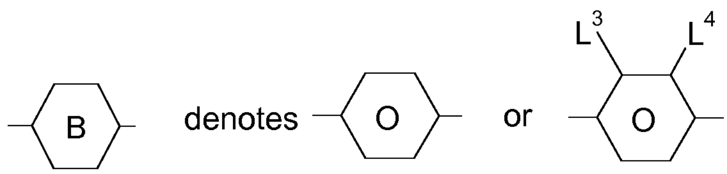


PY

wherein

a is 1 or 2,

b is 0 or 1,

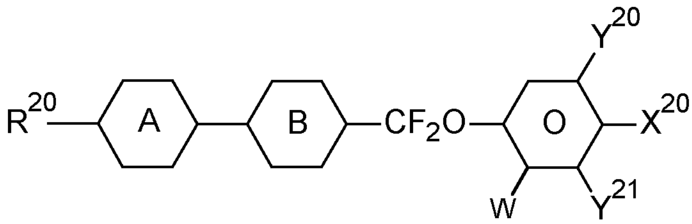


R^1 and R^2 each, independently of one another, denote alkyl having 1 to 12 C atoms, where, in addition, one or two non-adjacent CH_2 groups may be replaced by -O-, -CH=CH-, -CO-, -O-CO- or -CO-O- in such a way that O atoms are not linked directly to one another,

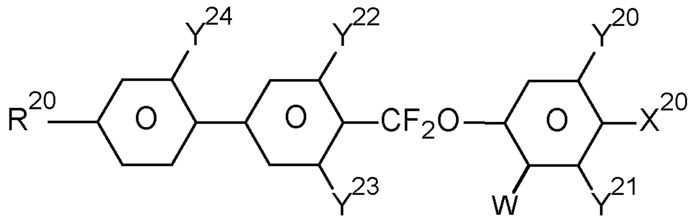
Z^x denotes -CH=CH- , $-CH_2O-$, $-OCH_2-$, $-CF_2O-$, $-OCF_2-$, -O-, $-CH_2-$, $-CH_2CH_2-$ or a single bond,

L^{1-4} each, independently of one another, denote F, Cl, OCF_3, CF_3, CH_3, CH_2F, CHF_2.

5. Process according to one or more of claims 1 to 4, characterised in that the LC mixture comprises one or more compounds selected from the group consisting of the compounds of the formulae II and III,

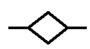
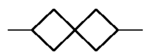


II



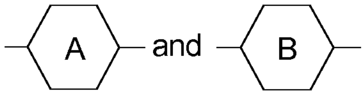
III

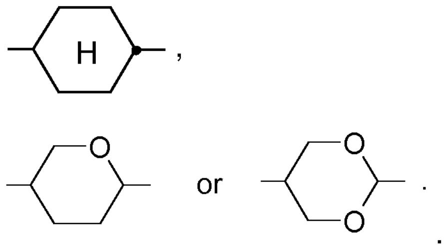
wherein

R^{20} each, identically or differently, denote a halogenated or unsubstituted alkyl or alkoxy radical having 1 to 15 C atoms, where, in addition, one or more CH_2 groups in these radicals may each be replaced, independently of one another, by -C≡C-, $-CF_2O-$, -CH=CH-, , , -O-, -CO-O- or -O-CO- in such a way that O atoms are not linked directly to one another,

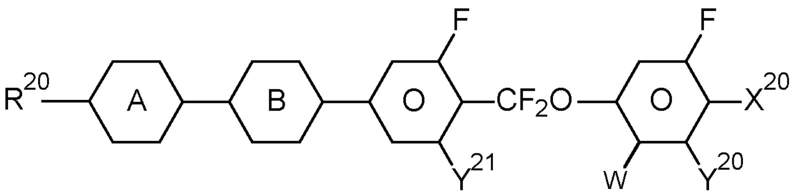
X^{20} each, identically or differently, denote F, Cl, CN, SF_5, SCN, NCS, a halogenated alkyl radical, a halogenated alkenyl radical, a halogenated alkoxy radical or a halogenated alkenyloxy radical, each having up to 6 C atoms, and

Y^{20-24} each, identically or differently, denote H or F, W denotes H or methyl,

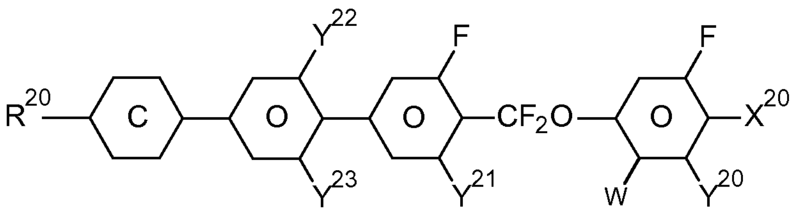
 each, identically or differently, denote



6. Process according to one or more of claims 1 to 5, characterised in that it comprises one or more compounds selected from the group consisting of compounds of formulae XI and XII

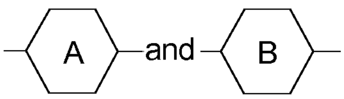


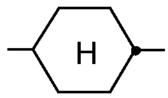
XI

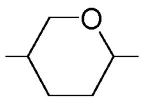
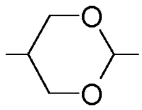


XII

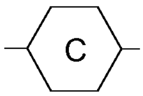
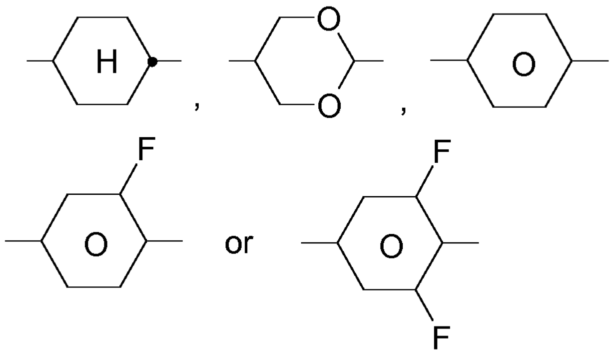
wherein R^{20}, X^{20}, W and Y^{20-23} have the meanings indicated in formula III in claim 16, and

 each, independently of one another, denote

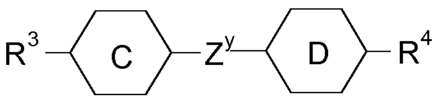
 ,

 or 

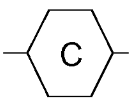
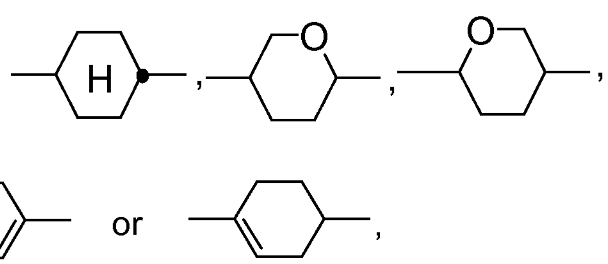
and

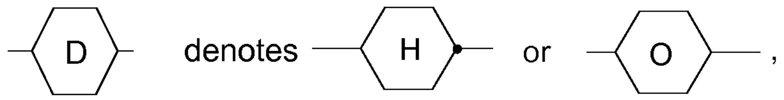
 denotes 

7. Process according to one or more of claims 1 to 6, characterised in that the LC host mixture comprises one or more compounds of the following formula:

 ZK

in which the individual radicals have the following meanings:

 denotes 



R[3] and R[4] each, independently of one another, denote alkyl having 1 to 12 C atoms, in which, in addition, one or two non-adjacent CH_2 groups may be replaced by -O-, -CH=CH-, -CO-, -O-CO- or -CO-O- in such a way that O atoms are not linked directly to one another,

Z^y denotes $-CH_2CH_2-$, -CH=CH-, $-CF_2O-$, $-OCF_2-$, $-CH_2O-$, $-OCH_2-$, -CO-O-, -O-CO-, $-C_2F_4-$, -CF=CF-, -CH=CH-CH_2O- or a single bond.

8. Process according to one or more of claims 1 to 7, characterized in that one or more polymerizable liquid crystalline compounds are selected from compounds of formula P

$$P^a\text{-}(Sp^a)_{s1}\text{-}A^2\text{-}(Z^1\text{-}A^1)_{n2}\text{-}(Sp^b)_{s2}\text{-}P^b \qquad \text{P}$$

wherein

P^a, P^b each, independently of one another, denote a polymerisable group,

Sp^a, Sp^b on each occurrence, identically or differently, denote a spacer group,

s1, s2 each, independently of one another, are 0 or 1,

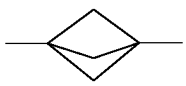
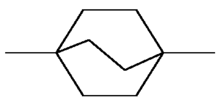
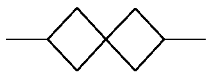
A^1, A^2 each, independently of one another, denote a radical selected from the following groups:

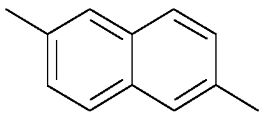
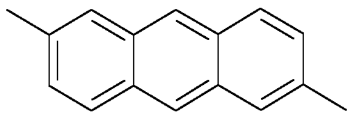
a) the group consisting of trans-1,4-cyclohexylene, 1,4-cyclohexenylene and 4,4´-bicyclohexylene, wherein, in addition, one or more non-adjacent CH_2 groups may be replaced by -O- and/or -S- and wherein, in addition, one or more H atoms may be replaced by F,

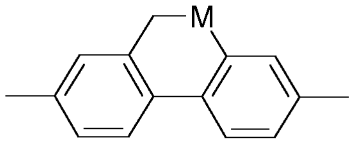
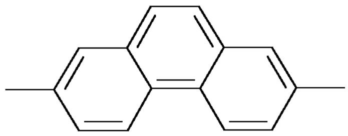
b) the group consisting of 1,4-phenylene and 1,3-phenylene, wherein, in addition, one or two CH groups may be replaced by N and wherein, in addition, one or more H atoms may be replaced by L,

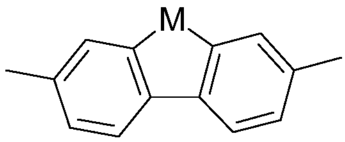
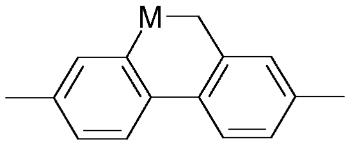
c) the group consisting of tetrahydropyran-2,5-diyl, 1,3-dioxane-2,5-diyl, tetrahydrofuran-2,5-diyl, cyclobutane-1,3-diyl, piperidine-1,4-diyl, thiophene-2,5-diyl and selenophene-2,5-diyl, each of which may also be mono- or polysubstituted by L,

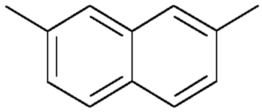
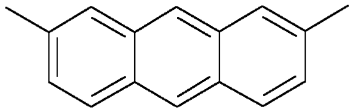
d) the group consisting of saturated, partially unsaturated or fully unsaturated, and optionally substituted, polycyclic radicals having 5 to 20 cyclic C atoms, one or more of which may, in addition, be replaced by heteroatoms, that are selected from:

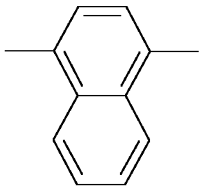
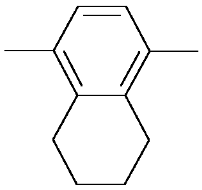
 ,   ,

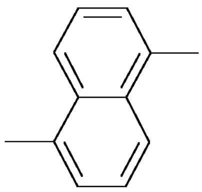
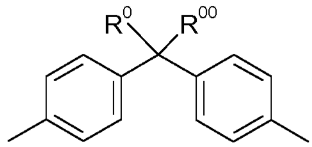
 ,  ,

 ,  ,

 ,  ,

 ,  ,

 ,  ,

 , 

where, in addition, one or more H atoms in these radicals may be replaced by L, and/or one or more double bonds may be replaced by single bonds, and/or one or more CH groups may be replaced by N,

n2 is 0, 1, 2 or 3,

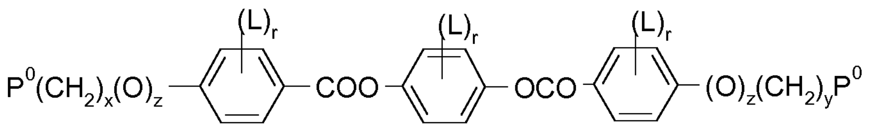
Z^1 in each case, independently of one another, denotes -CO-O-, -O-CO-, $-CH_2O-$, $-OCH_2-$, $-CF_2O-$, $-OCF_2-$, or $-(CH_2)_n-$, where n is 2, 3 or 4, -O-, -CO-, $-C(R^0R^{00})-$, $-CH_2CF_2-$, $-CF_2CF_2-$ or a single bond, L on each occurrence, identically or differently, denotes F, Cl, CN, SCN, SF_5 or straight-chain or branched, in each case optionally fluorinated, alkyl, alkoxy, alkylcarbonyl, alkoxycarbonyl, alkylcarbonyloxy or alkoxycarbonyloxy having up to 12 C atoms,

R^0, R^{00} each, independently of one another, denote H, F or straight-chain or branched alkyl having 1 to 12 C atoms, wherein, in addition, one or more H atoms may be replaced by F,

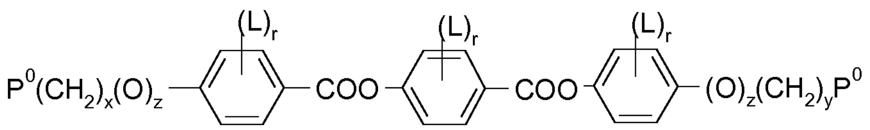
M denotes -O-, -S-, $-CH_2-$, $-CHY^1-$ or $-CY^1Y^2-$, and

Y^1 and Y^2 each, independently of one another, have one of the meanings indicated above for R^0 or denote Cl or CN.

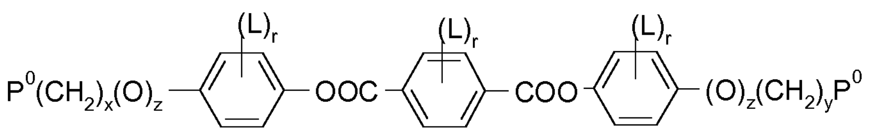
9. Process according to one or more of claims 1 to 8, characterized in that one or more polymerizable liquid crystalline compounds are selected from the following formulae,



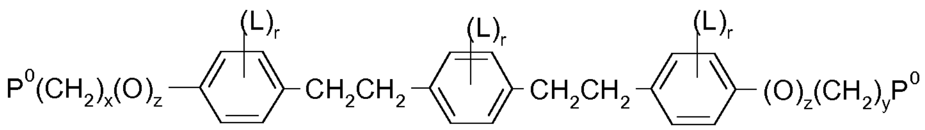
P10-1



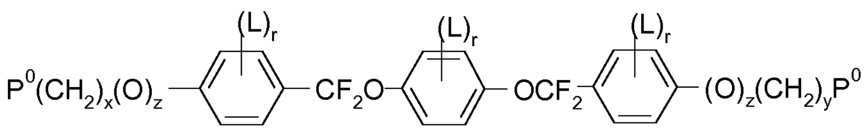
P10-2



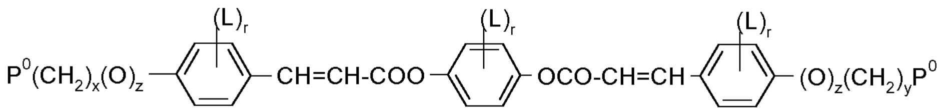
P10-3



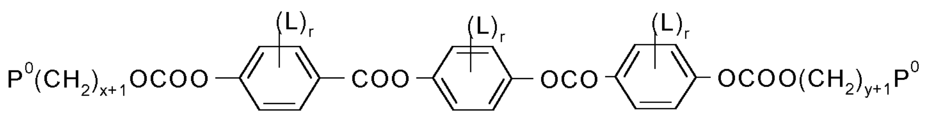
P10-4



P10-5



P10-6



P10-7

wherein

P^0 is, in case of multiple occurrence independently of one another, an acryl, methacryl, oxetane, epoxy, vinyl, heptadiene, vinyloxy, propenyl ether or styrene group,

L has on each occurrence identically or differently one of the meanings given for L^1 in formula DRM,

r is 0, 1, 2, 3 or 4,

x and y are independently of each other 0 or identical or different integers from 1 to 12,

z is each and independently, 0 or 1, with z being 0 if the adjacent x or y is 0.

10. Process according to one or more of claims 1 to 9, characterized in that the amount of one or more polymerizable liquid crystalline compounds in the liquid crystalline mixture is in the range from 0.2 to 2% by weight.

11. Process according to one or more of claims 1 to 10, characterized in that the applied electric field to the liquid crystal mixture has a frequency in the range of from 100 Hz to 1200 kHz.

12. Light modulation element obtainable from a process according to one or more of claims 1 to 10.

13. Use of a light modulation element according to claim 12 in an electrooptical device

14. Electrooptical device comprising a light modulation element according to claim 12.

15. Electrooptical device according to claim 14 characterized in that it is an IPS or FFS display.

INTERNATIONAL SEARCH REPORT

International application No
PCT/EP2019/072667

A. CLASSIFICATION OF SUBJECT MATTER
INV. G02F1/1343 G02F1/139
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)
G02F

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 A	US 2013/314656 A1 (MA XIAOLONG [CN] ET AL) 28 November 2013 (2013-11-28) figures 1,3,4 and the associated text passages	1-3, 11-15 4-10
A	US 2012/140133 A1 (CHOI SU SOEK [GB] ET AL) 7 June 2012 (2012-06-07) the whole document	1-15
A	US 2009/290078 A1 (YANG DENG-KE [US] ET AL) 26 November 2009 (2009-11-26) the whole document	1-15

☐ Further documents are listed in the continuation of Box C.

☒ See patent family annex.

* Special categories of cited documents :

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"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

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"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	Date of mailing of the international search report
30 September 2019	02/12/2019

Name and mailing address of the ISA/	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Fax: (+31-70) 340-3016	Lüssem, Georg

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No
PCT/EP2019/072667

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 2013314656 A1	28-11-2013	NONE	
US 2012140133 A1	07-06-2012	CN 102460290 A	16-05-2012
		EP 2438485 A1	11-04-2012
		KR 20120031270 A	02-04-2012
		US 2012140133 A1	07-06-2012
		WO 2010139995 A1	09-12-2010
US 2009290078 A1	26-11-2009	US 2009290078 A1	26-11-2009
		WO 2009151716 A2	17-12-2009