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(54) **Title:** BIREFRINGENT RM LENS

(57) **Abstract:** The invention relates to a birefringent RM lens obtainable from a polymerizable liquid crystalline medium consisting of - a polymerizable liquid crystalline component A, consisting of one or more polymerizable mesogenic compounds, and - a non-polymerizable component B, consisting of one or more non-polymerizable compounds and to the use of such birefringent RM lenses in electro optical devices, such as liquid crystal displays (LCDs) or other optical or electrooptical devices, for decorative or security applications.



WO 2014/090369 A1

## Birefringent RM Lens

### Field of invention

The invention relates to a birefringent RM lens obtainable from a polymerizable liquid crystalline medium consisting of

- a polymerizable liquid crystalline component A, consisting of one or more polymerizable mesogenic compounds, and
- a non-polymerizable component B, consisting of one or more non-polymerizable compounds.

Moreover, the invention relates to the use of such birefringent RM lenses in electro optical devices, such as liquid crystal displays (LCDs) or other optical or electrooptical devices, for decorative or security applications.

### BACKGROUND AND PRIOR ART

Polymerizable liquid crystals known as reactive mesogens (RM's) are widely known for their applications in viewing angle compensation films and thin film retarders in liquid crystal display (LCD) applications.

Recently such RMs have been suggested for the use in a patterned retarder in commercially available 3D LCD displays. In these applications the birefringent nature of the RM is used to alternate the polarization of light emitted from the front of the LCD.

For example in US2009073559 (A1) or WO2011078989 A1, it has also been reported that glass free autostereoscopic displays can be realized by combining an active LC panel as a polarization switch and a polarization sensitive lens made on the front of LCD's.

Such devices comprise an LCD panel for example of the active matrix type that acts as a spatial light modulator to produce the display image. The display panel has an orthogonal array of display pixels arranged in rows and columns. In practice, the display panel comprises about one thousand rows and several thousand columns of display pixels.

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5 The structure of the LCD panel is entirely conventional. In particular, the panel comprises a pair of spaced transparent glass substrates, between which for example an aligned twisted nematic or another liquid crystal medium is provided. The substrates carry patterns of transparent indium tin oxide (ITO) electrodes on their facing surfaces. Polarizing layers are also provided on the outer surfaces of the substrates.

10 Each display pixel comprises opposing electrodes on the substrates, with the intervening liquid crystalline medium there between. The shape and layout of the display pixels are determined by the shape and layout of the electrodes. The display pixels are regularly spaced from one another by gaps. Each display pixel is associated with a switching element, such as a thin film transistor (TFT) or thin film diode (TFD). The display pixels are operated to produce the display image by providing addressing signals to  
15 the switching elements, and those skilled in the art will know suitable addressing schemes.

20 The display panel is illuminated by a light source comprising, in this case, a planar backlight extending over the area of the display pixel array. Light from the light source is directed through the display panel, with the individual display pixels being driven to modulate the light and produce the display image.

25 The display device of prior art comprises a lenticular sheet, arranged over the front side of the display panel, which performs a view forming function. The lenticular sheet comprises a row of lens elements extending parallel to one another. The lens elements are in a form of plano-convex lenses, and they act as a light output directing means to provide different images, or views, from the display panel to the eyes of a user positioned in front of  
30 the display device.

In this connection, US 2007/109400 A1 discloses a birefringent lens structure comprising a birefringent lens array capable of directing light of a given polarization into a directional distribution, the birefringent lens  
35 comprises a solid birefringent material and an isotropic material having an interface having a refractive structure. A switchable liquid crystal layer

capable of rotating the polarization of light passing there through is arranged adjacent the first birefringent material. The interface between the birefringent material and the liquid crystal layer has an alignment microstructure providing alignment of the birefringent material and the liquid crystal layer. A pair of electrodes for applying an electric field to switch the liquid crystal is arranged with both the lens array and the switchable liquid crystal layer there between and a conductive material is incorporated in the lens array to reduce the voltage drop across the lens array. To reduce reflection, the interface between the birefringent material and the isotropic material has an interface having alignment microstructure providing alignment of the birefringent material, and the refractive index of the isotropic material is substantially equal to the extraordinary refractive index of the birefringent material.

JP2012-137616 A1 discloses a birefringent lens material for a stereoscopic image display which contains a reactive mesogenic compound having at least one or more polymerizable functional group, and a non-liquid crystal compound having at least one or more polymerizable functional group, and a manufacturing method of a birefringent lens for a stereoscopic image display using the birefringent lens material for the stereoscopic image display.

However, the use of non-mesogenic compounds or non-liquid crystalline materials in the lens material leads amongst other disadvantageously changes in the optical characteristics, to a drop of the birefringence.

If the birefringence of a suitable RM mixture is increased, the higher birefringence allows a higher radius of curvature (thinner lens) to be used for a given focal length. This phenomenon is well known to the skilled person and for example described in Hecht, E. (2002) Optics, 4th edn., "Geometrical optics" Chapter 5, page 158 et seqq.

In fact, modern applications require suitable high values for the birefringence in order to reduce the lens thickness and therefore the amount of materials and connected costs required to make such a lens. Moreover, the mixtures and/or the resulting lenses have to fulfil beside

suitable values for the birefringence a number of other requirements, which are amongst others,

- 5       - a good room temperature stability against crystallization before polymerization,
- an homogeneous planar alignment throughout the whole lens,
- high clearing points,
- suitable low yellowness index
- a good stability against thermal stress, e.g. heat or cold,
- 10      - a good stability against UV-light,
- a good durability in an environment where it is externally exposed,
- a good transmittance for VIS-light, and
- the method of its production has to be cost efficient and suitable for a mass production process.

15

In view of the prior art and the above-mentioned requirements on such materials, there is a considerable demand for new or alternative materials, which preferably do not show the drawbacks of the RM materials or mixtures of prior art or even if do so, to a less extend.

20

Surprisingly, the inventors have found that a birefringent RM lens as described and claimed hereinafter represents an excellent alternative to known birefringent RM lenses, which preferably improves one or more of the above-mentioned requirements or even more preferably fulfils all

25 above-mentioned requirements at the same time.

#### SUMMARY OF THE INVENTION

30

The invention relates RM lens obtainable from a polymerizable liquid crystalline medium consisting of

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- a polymerizable liquid crystalline component A consisting of one or more polymerizable mesogenic compounds,
- and a non-polymerizable component B consisting of one or more non-polymerizable compounds.

The invention further relates to a method of production of a birefringent RM lens as described above and below.

5 The invention further relates to the use of a birefringent RM lens as described above and below in liquid crystal displays (LCDs) or other optical or electrooptical devices.

10 The invention further relates to an electrooptical device, such as an LCD, comprising at least one birefringent RM lens as described above and below.

### TERMS AND DEFINITIONS

15 As used herein, the term "polymer" will be understood to mean a molecule that encompasses a backbone of one or more distinct types of repeating units (the smallest constitutional unit of the molecule) and is inclusive of the commonly known terms "oligomer", "copolymer", "homopolymer" and the like. Further, it will be understood that the term polymer is inclusive of, in addition to the polymer itself, residues from initiators, catalysts, and  
20 other elements attendant to the synthesis of such a polymer, where such residues are understood as not being covalently incorporated thereto. Further, such residues and other elements, while normally removed during post polymerization purification processes, are typically mixed or co-mingled with the polymer such that they generally remain with the polymer  
25 when it is transferred between vessels or between solvents or dispersion media.

30 The term "polymerization" means the chemical process to form a polymer by bonding together multiple polymerizable groups or polymer precursors (polymerizable compounds) containing such polymerizable groups.

35 The terms "film" and "layer" include rigid or flexible, self-supporting or freestanding films with mechanical stability, as well as coatings or layers on a supporting substrate or between two substrates.

The term "liquid crystal (LC)" relates to materials having liquid crystalline mesophases in some temperature ranges (thermotropic LCs) or in some concentration ranges in solutions (lyotropic LCs). They obligatorily contain mesogenic compounds.

5

The terms "mesogenic compound" and "liquid crystal compound" mean a compound comprising one or more calamitic (rod- or board/lath-shaped) or discotic (disk-shaped) mesogenic groups. The term "mesogenic group" means a group with the ability to induce liquid crystalline phase (or mesophase) behaviour.

10

The compounds comprising mesogenic groups do not necessarily have to exhibit a liquid-crystalline mesophase themselves. It is also possible that they show liquid-crystalline mesophases only in mixtures with other compounds, or when the mesogenic compounds or materials, or the mixtures thereof, are polymerized. This includes low-molecular-weight non-reactive liquid-crystalline compounds, reactive or polymerizable liquid-crystalline compounds, and liquid-crystalline polymers.

15

20

A calamitic mesogenic group is usually comprising a mesogenic core consisting of one or more aromatic or non-aromatic cyclic groups connected to each other directly or via linkage groups, optionally comprising terminal groups attached to the ends of the mesogenic core, and optionally comprising one or more lateral groups attached to the long side of the mesogenic core, wherein these terminal and lateral groups are usually selected e.g. from carbyl or hydrocarbyl groups, polar groups like halogen, nitro, hydroxy, etc., or polymerizable groups.

25

30

The term "reactive mesogen" means a polymerizable mesogenic or liquid crystal compound, preferably a monomeric compound. These compounds can be used as pure compounds or as mixtures of reactive mesogens with other compounds functioning as photoinitiators, inhibitors, surfactants, stabilizers, chain transfer agents, non-polymerizable compounds, etc.

35

Polymerizable compounds with one polymerizable group are also referred to as "monoreactive" compounds, compounds with two polymerizable

groups as "direactive" compounds, and compounds with more than two polymerizable groups as "multireactive" compounds. Compounds without a polymerizable group are also referred to as "non-reactive or non-polymerizable" compounds.

5

A "photo initiator" dissociates when exposed to the correct wavelength and the formed radicals will initiate polymerization of monomers.

10

Visible light is electromagnetic radiation that has wavelength in a range from about 400 nm to about 800 nm. Ultraviolet (UV) light is electromagnetic radiation with a wavelength in a range from about 200 nm to 400 nm.

15

The Irradiance ( $E_e$ ) or radiation power is defined as the power of electromagnetic radiation ( $d\theta$ ) per unit area ( $dA$ ) incident on a surface:

$$E_e = d\theta/dA.$$

20

The radiant exposure or radiation dose ( $H_e$ ), is as the irradiance or radiation power ( $E_e$ ) per time ( $t$ ):

$$H_e = E_e \cdot t.$$

25

All temperatures, such as, for example, the melting point  $T(C,N)$  or  $T(C,S)$ , the transition from the smectic (S) to the nematic (N) phase  $T(S,N)$  and the clearing point  $T(N,I)$  of the liquid crystals, are quoted in degrees Celsius.

All temperature differences are quoted in differential degrees.

30

The term "clearing point" means the temperature at which the transition between the mesophase with the highest temperature range and the isotropic phase occurs.

35

The term "alignment" or "orientation" relates to alignment (orientational 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 or RM 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.

5 The terms "uniform orientation" or "uniform alignment" of an liquid-crystalline or RM 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 or RM molecules are oriented substantially in the same direction. In other words, the lines of liquid-crystalline director are parallel.

10

Throughout this application, the alignment of liquid-crystalline or RM layers, unless stated otherwise, is uniform alignment.

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

20 The term "tilted orientation/alignment", for example in a layer of an liquid-crystalline or RM material, means that the long molecular axes (in case of calamitic compounds) or the short molecular axes (in case of discotic compounds) of the liquid-crystalline or RM molecules are oriented at an angle  $\theta$  ("tilt angle") between 0 and 90° relative to the plane of the layer.

25

In case of doubt the definitions as given in C. Tschierske, G. Pelzl and S. Diele, Angew. Chem. 2004, 116, 6340-6368 shall apply.

#### DETAILED DESCRIPTION

30 As mentioned above, the polymerizable liquid crystalline component A exclusively consists of at least one polymerizable mesogenic compound and are therefore the only polymerizable compounds present in the polymerizable liquid crystalline medium. The presence of other, e.g. non-mesogenic compounds is therefore excluded, which leads besides other  
35 favourable effects, e.g. to a significant increase of the birefringence.

The polymerizable liquid-crystalline component A consists of at least one polymerizable mesogenic compound, preferably of a mixture of two or more polymerizable mesogenic compound, for example 2 to 30 polymerizable mesogenic compounds.

5

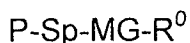
The polymerizable mesogenic compounds of the polymerizable liquid crystalline component A are preferably selected from calamitic or discotic compounds demonstrating thermotropic or lyotropic liquid crystallinity, very preferably calamitic compounds, or mixtures of one or more types of these compounds having liquid-crystalline mesophases in a certain temperature range. These materials typically have good optical properties, like reduced chromaticity, and can be easily and quickly aligned into the desired orientation. The liquid crystals can be small molecules (i.e. monomeric compounds) or liquid-crystalline oligomers.

10

15

In one embodiment, the polymerizable mesogenic compounds of the polymerizable liquid crystalline component A are preferably selected from one or more polymerizable mono-, di- or multireactive mesogenic compounds of formula I,

20



I

wherein

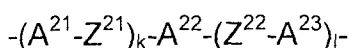
25

P is a polymerizable group, preferably an acryl, methacryl, vinyl, vinyloxy, propenyl ether, epoxy, oxetane or styrene group,

Sp is a spacer group or a single bond,

30

MG is a rod-shaped mesogenic group, which is preferably selected of formula M,



M

35

$A^{21}$  to  $A^{23}$  are in each occurrence independently of one another an aryl-, heteroaryl-, heterocyclic- or alicyclic group

optionally being substituted by one or more identical or different groups L, preferably 1,4-cyclohexylene or 1,4-phenylene, 1,4 pyridine, 1,4-pyrimidine, 2,5-thiophene, 2,6-dithieno[3,2-b:2',3'-d]thiophene, 2,7-fluorine, 2,6-naphtalene, 2,7-phenanthrene optionally being substituted by one or more identical or different groups L,

$Z^{21}$  and  $Z^{22}$  are in each occurrence independently from each other, -O-, -S-, -CO-, -COO-, -OCO-, -S-CO-, -CO-S-, -O-COO-, -CO-NR<sup>01</sup>-, -NR<sup>01</sup>-CO-, -NR<sup>01</sup>-CO-NR<sup>02</sup>-, -NR<sup>01</sup>-CO-O-, -O-CO-NR<sup>01</sup>-, -OCH<sub>2</sub>-, -CH<sub>2</sub>O-, -SCH<sub>2</sub>-, -CH<sub>2</sub>S-, -CF<sub>2</sub>O-, -OCF<sub>2</sub>-, -CF<sub>2</sub>S-, -SCF<sub>2</sub>-, -CH<sub>2</sub>CH<sub>2</sub>-, -(CH<sub>2</sub>)<sub>4</sub>-, -CF<sub>2</sub>CH<sub>2</sub>-, -CH<sub>2</sub>CF<sub>2</sub>-, -CF<sub>2</sub>CF<sub>2</sub>-, -CH=N-, -N=CH-, -N=N-, -CH=CR<sup>01</sup>-, -CY<sup>01</sup>=CY<sup>02</sup>-, -C≡C-, -CH=CH-COO-, -OCO-CH=CH-, or a single bond, preferably -COO-, -OCO-, -CO-O-, -O-CO-, -OCH<sub>2</sub>-, -CH<sub>2</sub>O-, -, -CH<sub>2</sub>CH<sub>2</sub>-, -(CH<sub>2</sub>)<sub>4</sub>-, -CF<sub>2</sub>CH<sub>2</sub>-, -CH<sub>2</sub>CF<sub>2</sub>-, -CF<sub>2</sub>CF<sub>2</sub>-, -C≡C-, -CH=CH-COO-, -OCO-CH=CH-, or a single bond,

L is, in case of multiple occurrence independently of one another, H, halogen, CN or optionally halogenated alkyl, alkoxy, alkylcarbonyl, alkoxycarbonyl, alkylcarbonyloxy or alkoxycarbonyloxy with 1 to 5 C atoms, preferably H, halogen or CN, alkyl or alkoxy with 1 to 5 C atoms,

R<sup>0</sup> is H, alkyl, alkoxy, thioalkyl, alkylcarbonyl, alkoxycarbonyl, alkylcarbonyloxy or alkoxycarbonyloxy with 1 to 20 C atoms more, preferably 1 to 15 C atoms which are optionally fluorinated, or is Y<sup>0</sup> or P-Sp-,

Y<sup>0</sup> is F, Cl, CN, NO<sub>2</sub>, OCH<sub>3</sub>, OCN, SCN, optionally fluorinated alkylcarbonyl, alkoxycarbonyl, alkylcarbonyloxy or alkoxycarbonyloxy with 1 to 4 C atoms, or mono- oligo- or polyfluorinated alkyl or alkoxy

- with 1 to 4 C atoms, preferably F, Cl, CN, NO<sub>2</sub>, OCH<sub>3</sub>, or mono- oligo- or polyfluorinated alkyl or alkoxy with 1 to 4 C atoms,
- 5      Y<sup>01</sup> and Y<sup>02</sup>      each, independently of one another, denote H, F, Cl or CN.
- 10      R<sup>01</sup> and R<sup>02</sup>      are independently of each other H, or straight chain or branched alkyl with 1 to 20 C-atoms, preferably 1 to 6 C- atoms, and
- 15      k and l      are each and independently 0, 1, 2, 3 or 4, preferably 0, 1 or 2, most preferably 1.
- 20      Above and below, "carbyl group" denotes a mono- or polyvalent organic group containing at least one carbon atom which 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.).
- 25      "Hydrocarbyl group" denotes a carbyl 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.
- 30      "Halogen" denotes F, Cl, Br or I.
- 35      A carbyl or hydrocarbyl group can be a saturated or unsaturated group. Unsaturated groups are, for example, aryl, alkenyl or alkynyl groups. A carbyl or hydrocarbyl group having more than 3 C atoms can be straight chain, branched and/or cyclic and may contain spiro links or condensed rings.
- Above and below, 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 there from. The term "heteroaryl" denotes "aryl" in accordance with the above definition containing one or more heteroatoms.

5 Preferred carbyl and hydrocarbyl 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.

10 Further preferred carbyl and hydrocarbyl groups are C<sub>1</sub>-C<sub>40</sub> alkyl, C<sub>2</sub>-C<sub>40</sub> alkenyl, C<sub>2</sub>-C<sub>40</sub> alkynyl, C<sub>3</sub>-C<sub>40</sub> allyl, C<sub>4</sub>-C<sub>40</sub> alkyldienyl, C<sub>4</sub>-C<sub>40</sub> polyenyl, C<sub>6</sub>-C<sub>40</sub> aryl, C<sub>6</sub>-C<sub>40</sub> alkylaryl, C<sub>6</sub>-C<sub>40</sub> arylalkyl, C<sub>6</sub>-C<sub>40</sub> alkylaryloxy, C<sub>6</sub>-C<sub>40</sub> arylalkyloxy, C<sub>2</sub>-C<sub>40</sub> heteroaryl, C<sub>4</sub>-C<sub>40</sub> cycloalkyl, C<sub>4</sub>-C<sub>40</sub> cycloalkenyl, etc.

15 Particular preference is given to C<sub>1</sub>-C<sub>22</sub> alkyl, C<sub>2</sub>-C<sub>22</sub> alkenyl, C<sub>2</sub>-C<sub>22</sub> alkynyl, C<sub>3</sub>-C<sub>22</sub> allyl, C<sub>4</sub>-C<sub>22</sub> alkyldienyl, C<sub>6</sub>-C<sub>12</sub> aryl, C<sub>6</sub>-C<sub>20</sub> arylalkyl and C<sub>2</sub>-C<sub>20</sub> heteroaryl.

20 Further preferred carbyl and hydrocarbyl 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 or more non-adjacent CH<sub>2</sub> groups may each be replaced, independently of one another, by -C(R<sup>x</sup>)=C(R<sup>x</sup>)-, -C≡C-, -N(R<sup>x</sup>)-, -O-, -S-, -CO-, -CO-O-, -O-CO-, -O-CO-O- in such a way that O and/or S

25 atoms are not linked directly to one another.

R<sup>x</sup> 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-, -O-CO-O-, and in which one or more H atoms may be replaced by fluorine,

30 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.

35 Preferred alkyl groups are, for example, methyl, ethyl, n-propyl, isopropyl, n-butyl, isobutyl, s-butyl, t-butyl, 2-methylbutyl, n-pentyl, s-pentyl, cyclo-

pentyl, n-hexyl, cyclohexyl, 2-ethylhexyl, n-heptyl, cycloheptyl, n-octyl, cyclooctyl, n-nonyl, n-decyl, n-undecyl, n-dodecyl, dodecanyl, trifluoromethyl, perfluoro-n-butyl, 2,2,2-trifluoroethyl, perfluorooctyl, perfluorohexyl, etc.

5

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

10

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

15

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-heptyloxy, n-octyloxy, n-nonyloxy, n-decyloxy, n-undecyloxy, n-dodecyloxy, etc.

20

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

25

Aryl and heteroaryl groups can be monocyclic or polycyclic, i.e. they can have one ring (such as, for example, phenyl) or two or more rings, which may also be fused (such as, for example, naphthyl) or covalently linked (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.

30

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.

35

Preferred aryl groups are, for example, phenyl, biphenyl, terphenyl, [1,1':3',1'']terphenyl-2'-yl, naphthyl, anthracene, binaphthyl, phenanthrene, pyrene, dihydropyrene, chrysene, perylene, tetracene, pentacene, benzo-pyrene, fluorene, indene, indenofluorene, spirobifluorene, etc.

5

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, iso-indole, indolizine, indazole, benzimidazole, benzotriazole, purine, naphth-imidazole, phenanthrimidazole, pyridimidazole, pyrazinimidazole, quinoxal-  
15 linimidazole, 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, isobenzothiophene, dibenzothiophene, benzothiadiazothiophene, or combinations of these groups. The heteroaryl groups may also be substituted  
20 by alkyl, alkoxy, thioalkyl, fluorine, fluoroalkyl or further aryl or heteroaryl groups.

25

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

30

The (non-aromatic) alicyclic and heterocyclic groups can be monocyclic, i.e. contain only one ring (such as, for example, cyclohexane), or poly-cyclic, i.e. contain a plurality of rings (such as, for example, decahydro-

35

- naphthalene 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-
- 5 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<sub>2</sub> groups may be replaced by -O- and/or -S-.
- 10 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
- 15 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, carbyl and hydrocarbyl radicals optionally have one or
- 20 more substituents, which are preferably selected from the group comprising silyl, sulfo, sulfonyl, formyl, amine, imine, nitrile, mercapto, nitro, halogen, C<sub>1-12</sub> alkyl, C<sub>6-12</sub> aryl, C<sub>1-12</sub> alkoxy, hydroxyl, or combinations of these groups.
- 25 Preferred substituents are, for example, solubility-promoting groups, such as alkyl or alkoxy, electron-withdrawing groups, such as fluorine, nitro or nitrile, or substituents for increasing the glass transition temperature (T<sub>g</sub>) in the polymer, in particular bulky groups, such as, for example, t-butyl or optionally substituted aryl groups.
- 30 Preferred substituents, also referred to as "L" below, are, for example, F, Cl, Br, I, OH, -CN, -NO<sub>2</sub>, -NCO, -NCS, -OCN, -SCN, -C(=O)N(R<sup>x</sup>)<sub>2</sub>, -C(=O)Y<sup>1</sup>, -C(=O)R<sup>x</sup>, -C(=O)OR<sup>x</sup>, -N(R<sup>x</sup>)<sub>2</sub>, in which R<sup>x</sup> has the above-mentioned meaning, and Y<sup>1</sup> denotes halogen, optionally substituted silyl,
- 35 optionally substituted aryl or heteroaryl having 4 to 40, preferably 4 to 20 ring atoms, and straight-chain or branched alkyl, alkenyl, alkynyl, alkoxy,



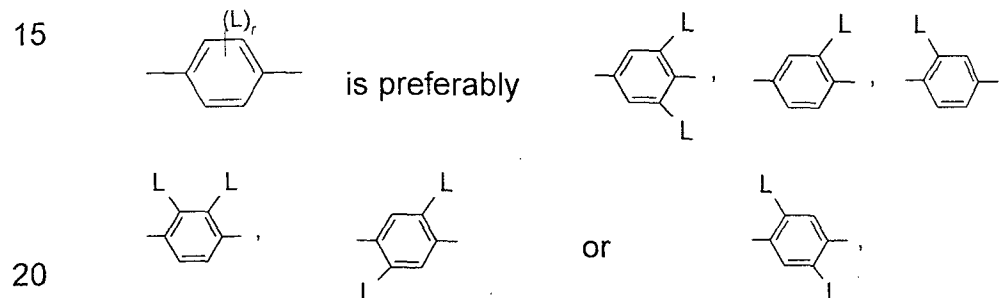
- 16 -

alkylcarbonyl, alkoxycarbonyl, alkylcarbonyloxy or alkoxycarbonyloxy having 1 to 25 C atoms, in which one or more H atoms may optionally be replaced by F or Cl.

- 5 "Substituted silyl or aryl" preferably means substituted by halogen, -CN,  $R^0$ , -OR<sup>0</sup>, -CO-R<sup>0</sup>, -CO-O-R<sup>0</sup>, -O-CO-R<sup>0</sup> or -O-CO-O-R<sup>0</sup>, in which R<sup>0</sup> has the above-mentioned meaning.

- 10 Particularly preferred substituents L are, for example, F, Cl, CN, NO<sub>2</sub>, CH<sub>3</sub>, C<sub>2</sub>H<sub>5</sub>, OCH<sub>3</sub>, OC<sub>2</sub>H<sub>5</sub>, COCH<sub>3</sub>, COC<sub>2</sub>H<sub>5</sub>, COOCH<sub>3</sub>, COOC<sub>2</sub>H<sub>5</sub>, CF<sub>3</sub>, OCF<sub>3</sub>, OCHF<sub>2</sub>, OC<sub>2</sub>F<sub>5</sub>, furthermore phenyl.

In the formula shown above and below, a substituted phenylene ring

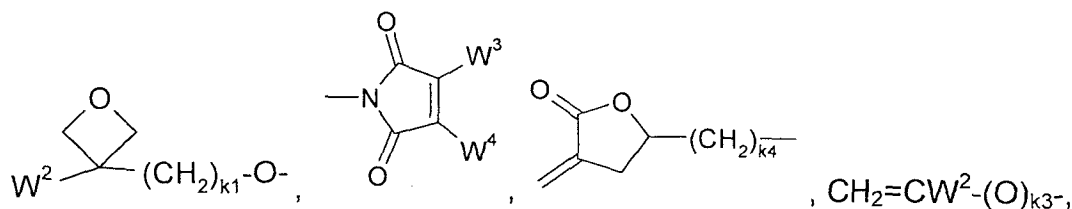


- in which L has, on each occurrence identically or differently, one of the meanings given above and below, and is preferably F, Cl, CN, NO<sub>2</sub>, CH<sub>3</sub>, C<sub>2</sub>H<sub>5</sub>, C(CH<sub>3</sub>)<sub>3</sub>, CH(CH<sub>3</sub>)<sub>2</sub>, CH<sub>2</sub>CH(CH<sub>3</sub>)C<sub>2</sub>H<sub>5</sub>, OCH<sub>3</sub>, OC<sub>2</sub>H<sub>5</sub>, COCH<sub>3</sub>, COC<sub>2</sub>H<sub>5</sub>, COOCH<sub>3</sub>, COOC<sub>2</sub>H<sub>5</sub>, CF<sub>3</sub>, OCF<sub>3</sub>, OCHF<sub>2</sub>, OC<sub>2</sub>F<sub>5</sub> or P-Sp-, very preferably F, Cl, CN, CH<sub>3</sub>, C<sub>2</sub>H<sub>5</sub>, OCH<sub>3</sub>, COCH<sub>3</sub>, OCF<sub>3</sub> or P-Sp-, most preferably F, Cl, CH<sub>3</sub>, OCH<sub>3</sub>, COCH<sub>3</sub> or OCF<sub>3</sub>.

- 30 The polymerizable group P is preferably selected from groups containing a C=C double bond or C≡C triple bond, and groups which are suitable for polymerization with ring opening, such as, for example, oxetane or epoxide groups.



- 35 Very preferably the polymerizable group P is selected from the group consisting of CH<sub>2</sub>=CW<sup>1</sup>-COO-, CH<sub>2</sub>=CW<sup>1</sup>-CO-,  $W^2HC \begin{array}{c} \diagup O \diagdown \\ \text{---} \end{array} CH-$ ,

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5  $CW^1=CH-CO-(O)_{k_3}-$ ,  $CW^1=CH-CO-NH-$ ,  $CH_2=CW^1-CO-NH-$ ,  $CH_3-CH=CH-O-$ ,  $(CH_2=CH)_2CH-OCO-$ ,  $(CH_2=CH-CH_2)_2CH-OCO-$ ,  $(CH_2=CH)_2CH-O-$ ,  $(CH_2=CH-CH_2)_2N-$ ,  $(CH_2=CH-CH_2)_2N-CO-$ ,  $CH_2=CW^1-CO-NH-$ ,  $CH_2=CH-(COO)_{k_1}-Phe-(O)_{k_2}-$ ,  $CH_2=CH-(CO)_{k_1}-Phe-(O)_{k_2}-$ ,  $Phe-CH=CH-$ , 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, 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.

20 Particularly preferred groups P are  $CH_2=CH-COO-$ ,  $CH_2=C(CH_3)-COO-$ ,  $CH_2=CF-COO-$ ,  $CH_2=CH-$ ,  $CH_2=CH-O-$ ,  $(CH_2=CH)_2CH-OCO-$ ,

25  $(CH_2=CH)_2CH-O-$ ,  $W^2HC$    $CH-$  and  $W^2$    $(CH_2)_{k_1}-O-$ , in particular vinyloxy, acrylate, methacrylate, fluoroacrylate, chloroacrylate, oxetane and epoxide, most preferably acrylate or methacrylate.

30 In a further preferred embodiment of the invention, the all 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:

35  $-X-alkyl-CHP^1-CH_2-CH_2P^2$

I\*a

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	$-X\text{-alkyl-C}(\text{CH}_2\text{P}^1)(\text{CH}_2\text{P}^2)\text{-CH}_2\text{P}^3$	I*b
	$-X\text{-alkyl-CHP}^1\text{CHP}^2\text{-CH}_2\text{P}^3$	I*c
5	$-X\text{-alkyl-C}(\text{CH}_2\text{P}^1)(\text{CH}_2\text{P}^2)\text{-C}_{aa}\text{H}_{2aa+1}$	I*d
	$-X\text{-alkyl-CHP}^1\text{-CH}_2\text{P}^2$	I*e
	$-X\text{-alkyl-CHP}^1\text{P}^2$	I*f
10	$-X\text{-alkyl-CP}^1\text{P}^2\text{-C}_{aa}\text{H}_{2aa+1}$	I*g
	$-X\text{-alkyl-C}(\text{CH}_2\text{P}^1)(\text{CH}_2\text{P}^2)\text{-CH}_2\text{OCH}_2\text{-C}(\text{CH}_2\text{P}^3)(\text{CH}_2\text{P}^4)\text{CH}_2\text{P}^5$	I*h
15	$-X\text{-alkyl-CH}((\text{CH}_2)_{aa}\text{P}^1)((\text{CH}_2)_{bb}\text{P}^2)$	I*i
	$-X\text{-alkyl-CHP}^1\text{CHP}^2\text{-C}_{aa}\text{H}_{2aa+1}$	I*k

in which

20

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<sub>2</sub> groups may each be replaced, independently of one another, by -C(R<sup>x</sup>)=C(R<sup>x</sup>)-, -C≡C-, -N(R<sup>x</sup>)-, -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<sup>x</sup> has the above-mentioned meaning and preferably denotes R<sup>0</sup> as defined above,

25

30 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

35 P<sup>1-5</sup> each, independently of one another, have one of the meanings indicated above for P.

Preferred spacer groups Sp are selected from the formula Sp'-X', so that the radical "P-Sp-" conforms to the formula "P-Sp'-X'-", where

- 5      Sp'      denotes alkylene having 1 to 20, preferably 1 to 12 C atoms, which is optionally mono- or polysubstituted by F, Cl, Br, I or CN and in which, in addition, one or more non-adjacent CH<sub>2</sub> groups may each be replaced, independently of one another, by -O-, -S-, -NH-, -NR<sup>01</sup>-,
- 10      -SiR<sup>01</sup>R<sup>02</sup>-, -CO-, -COO-, -OCO-, -OCO-O-, -S-CO-, -CO-S-, -NR<sup>01</sup>-CO-O-, -O-CO-NR<sup>01</sup>-, -NR<sup>01</sup>-CO-NR<sup>01</sup>-, -CH=CH- or -C≡C- in such a way that O and/or S atoms are not linked directly to one another,
- 15      X'      denotes -O-, -S-, -CO-, -COO-, -OCO-, -O-COO-, -CO-NR<sup>01</sup>-, -NR<sup>01</sup>-CO-, -NR<sup>01</sup>-CO-NR<sup>01</sup>-, -OCH<sub>2</sub>-, -CH<sub>2</sub>O-, -SCH<sub>2</sub>-, -CH<sub>2</sub>S-, -CF<sub>2</sub>O-, -OCF<sub>2</sub>-, -CF<sub>2</sub>S-, -SCF<sub>2</sub>-, -CF<sub>2</sub>CH<sub>2</sub>-, -CH<sub>2</sub>CF<sub>2</sub>-, -CF<sub>2</sub>CF<sub>2</sub>-, -CH=N-, -N=CH-, -N=N-, -CH=CR<sup>01</sup>-, -CY<sup>01</sup>=CY<sup>02</sup>-, -C≡C-,
- 20      -CH=CH-COO-, -OCO-CH=CH- or a single bond,
- R<sup>01</sup> and R<sup>02</sup>      each, independently of one another, denote H or alkyl having 1 to 12 C atoms, and
- 25      Y<sup>01</sup> and Y<sup>02</sup>      each, independently of one another, denote H, F, Cl or CN.
- X'      is preferably -O-, -S-, -CO-, -COO-, -OCO-, -O-COO-, -CO-NR<sup>01</sup>-, -NR<sup>01</sup>-CO-, -NR<sup>01</sup>-CO-NR<sup>01</sup>- or a single
- 30      bond.

Typical spacer groups Sp' are, for example, -(CH<sub>2</sub>)<sub>p1</sub>-, -(CH<sub>2</sub>CH<sub>2</sub>O)<sub>q1</sub>-CH<sub>2</sub>CH<sub>2</sub>-, -CH<sub>2</sub>CH<sub>2</sub>-S-CH<sub>2</sub>CH<sub>2</sub>-, -CH<sub>2</sub>CH<sub>2</sub>-NH-CH<sub>2</sub>CH<sub>2</sub>- or -(SiR<sup>01</sup>R<sup>02</sup>-O)<sub>p1</sub>-, in which p<sub>1</sub> is an integer from 1 to 12, q<sub>1</sub> is an integer

35      from 1 to 3, and R<sup>01</sup> and R<sup>02</sup> have the above-mentioned meanings.

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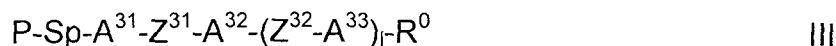
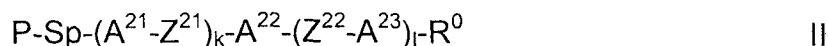
Particularly preferred groups -X'-Sp'- are -(CH<sub>2</sub>)<sub>p1</sub>-, -O-(CH<sub>2</sub>)<sub>p1</sub>-,  
-OCO-(CH<sub>2</sub>)<sub>p1</sub>-, -OCOO-(CH<sub>2</sub>)<sub>p1</sub>-.

5 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.

10

In another embodiment, the polymerizable liquid crystalline component A comprises at least one polymerizable mono-, di- or multireactive mesogenic compound selected of formula II, and at least one polymerizable mono-, di- or multireactive mesogenic compound selected of formula III,

15



20

wherein

P is a polymerizable group, preferably an acryl, methacryl, vinyl, vinyloxy, propenyl ether, epoxy, oxetane or styrene group,

25

Sp is a spacer group or a single bond,

A<sup>21</sup> to A<sup>33</sup> are in each occurrence independently of one another an aryl-, heteroaryl-, heterocyclic- or alicyclic group optionally being substituted by one or more identical or different groups L, preferably 1,4-cyclohexylene or 1,4-phenylene, 1,4 pyridine, 1,4-pyrimidine, 2,5-thiophene, 2,6-dithieno[3,2-b:2',3'-d]thiophene, 2,7- fluorine, 2,6-naphtalene, 2,7-phenanthrene optionally being substituted by one or more identical or different groups L,

35

- $Z^{21}$  and  $Z^{22}$  are in each occurrence independently from each other,  
 -O-, -S-, -CO-, -COO-, -OCO-, -S-CO-, -CO-S-,  
 -O-COO-, -CO-NR<sup>01</sup>-, -NR<sup>01</sup>-CO-, -NR<sup>01</sup>-CO-NR<sup>02</sup>,  
 5 -NR<sup>01</sup>-CO-O-, -O-CO-NR<sup>01</sup>-, -OCH<sub>2</sub>-, -CH<sub>2</sub>O-, -SCH<sub>2</sub>-,  
 -CH<sub>2</sub>S-, -CF<sub>2</sub>O-, -OCF<sub>2</sub>-, -CF<sub>2</sub>S-, -SCF<sub>2</sub>-, -CH<sub>2</sub>CH<sub>2</sub>-,  
 -(CH<sub>2</sub>)<sub>4</sub>-, -CF<sub>2</sub>CH<sub>2</sub>-, -CH<sub>2</sub>CF<sub>2</sub>-, -CF<sub>2</sub>CF<sub>2</sub>-, or a single  
 bond, preferably -COO-, -OCO-, -CO-O-, -O-CO-,  
 -OCH<sub>2</sub>-, -CH<sub>2</sub>O-, -CH<sub>2</sub>CH<sub>2</sub>-, -(CH<sub>2</sub>)<sub>4</sub>-, -CF<sub>2</sub>CH<sub>2</sub>-,  
 10 -CH<sub>2</sub>CF<sub>2</sub>-, -CF<sub>2</sub>CF<sub>2</sub>-, or a single bond,
- $Z^{31}$  and  $Z^{32}$  are in each occurrence independently from each other  
 -CH=N-, -N=CH-, -N=N-, -CH=CR<sup>01</sup>-, -CY<sup>01</sup>=CY<sup>02</sup>-,  
 -C≡C-, -CH=CH-COO-, -OCO-CH=CH-, and if  $l > 0$ , one  
 15 of  $Z^{31}$  and  $Z^{32}$  can also denote -O-, -S-, -CO-, -COO-,  
 -OCO-, -S-CO-, -CO-S-, -O-COO-, -CO-NR<sup>01</sup>-,  
 -NR<sup>01</sup>-CO-, -NR<sup>01</sup>-CO-NR<sup>02</sup>-, -NR<sup>01</sup>-CO-O-,  
 -O-CO-NR<sup>01</sup>-, -OCH<sub>2</sub>-, -CH<sub>2</sub>O-, -SCH<sub>2</sub>-, -CH<sub>2</sub>S-,  
 -CF<sub>2</sub>O-, -OCF<sub>2</sub>-, -CF<sub>2</sub>S-, -SCF<sub>2</sub>-, -CH<sub>2</sub>CH<sub>2</sub>-, -(CH<sub>2</sub>)<sub>4</sub>-,  
 20 -CF<sub>2</sub>CH<sub>2</sub>-, -CH<sub>2</sub>CF<sub>2</sub>-, -CF<sub>2</sub>CF<sub>2</sub>-, or a single bond,
- L is, in case of multiple occurrence independently of one  
 another, H, halogen, CN or optionally halogenated alkyl,  
 alkoxy, alkylcarbonyl, alkoxycarbonyl, alkylcarbonyloxy  
 25 or alkoxycarbonyloxy with 1 to 5 C atoms, preferably H,  
 halogen or CN, alkyl or alkoxy with 1 to 5 C atoms,
- $R^0$  is H, alkyl, alkoxy, thioalkyl, alkylcarbonyl,  
 alkoxycarbonyl, alkylcarbonyloxy or alkoxycarbonyloxy  
 30 with 1 to 20 C atoms more, preferably 1 to 15 C atoms  
 which are optionally fluorinated, or is  $Y^0$  or P-Sp-,
- $Y^0$  is F, Cl, CN, NO<sub>2</sub>, OCH<sub>3</sub>, OCN, SCN, optionally  
 fluorinated alkylcarbonyl, alkoxycarbonyl, alkylcarbonyl-  
 35 oxy or alkoxycarbonyloxy with 1 to 4 C atoms, or mono-  
 oligo- or polyfluorinated alkyl or alkoxy with 1 to 4 C

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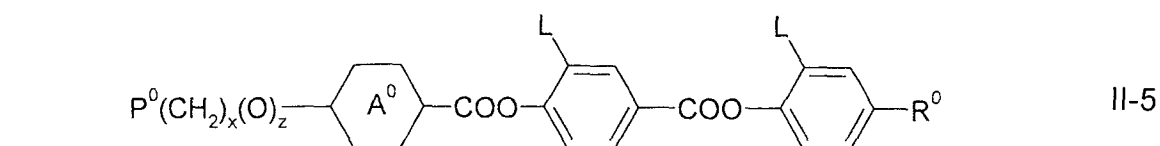
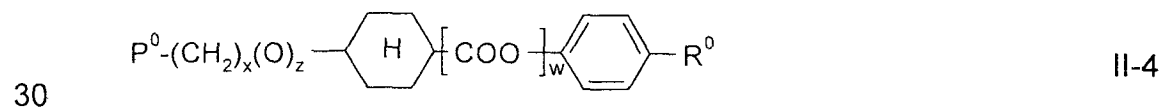
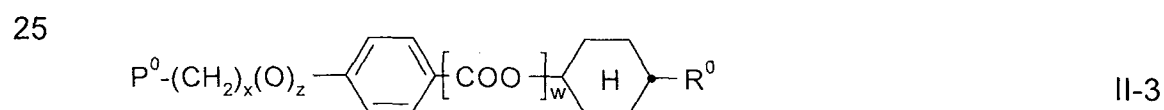
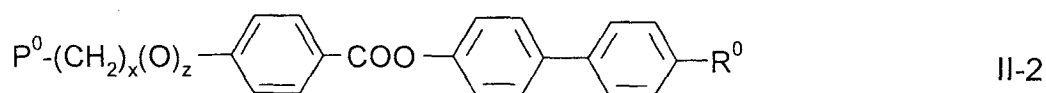
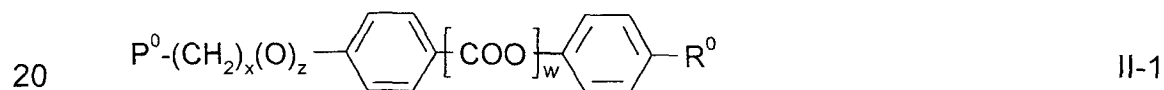
atoms, preferably F, Cl, CN, NO<sub>2</sub>, OCH<sub>3</sub>, or mono-oligo- or polyfluorinated alkyl or alkoxy with 1 to 4 C atoms,

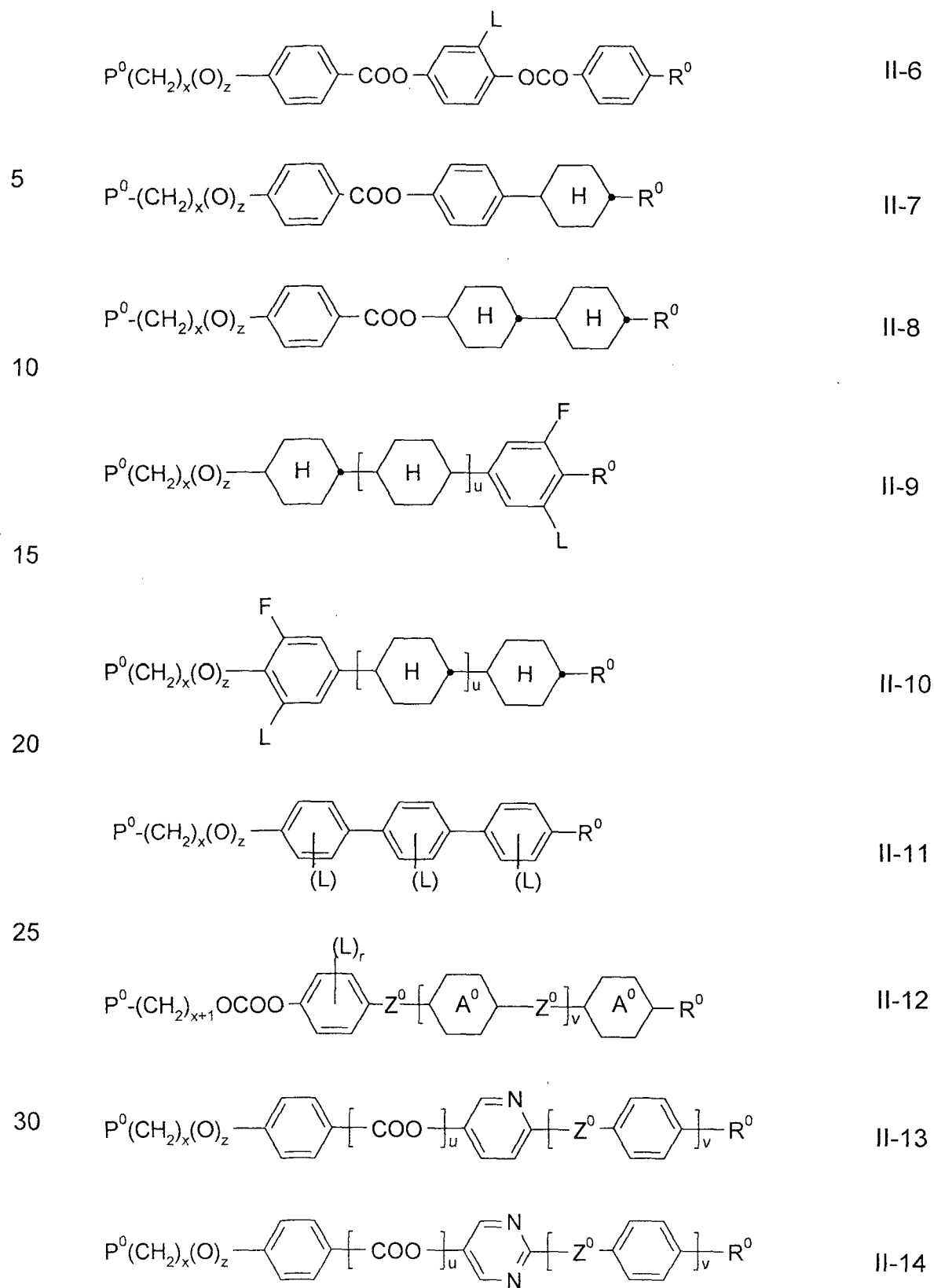
5      Y<sup>01</sup> and Y<sup>02</sup> ; each, independently of one another, denote H, F, Cl or CN.

10      R<sup>01</sup> and R<sup>02</sup> are independently of each other H, or straight chain or branched alkyl with 1 to 20 C-atoms, preferably 1 to 6 C- atoms, and

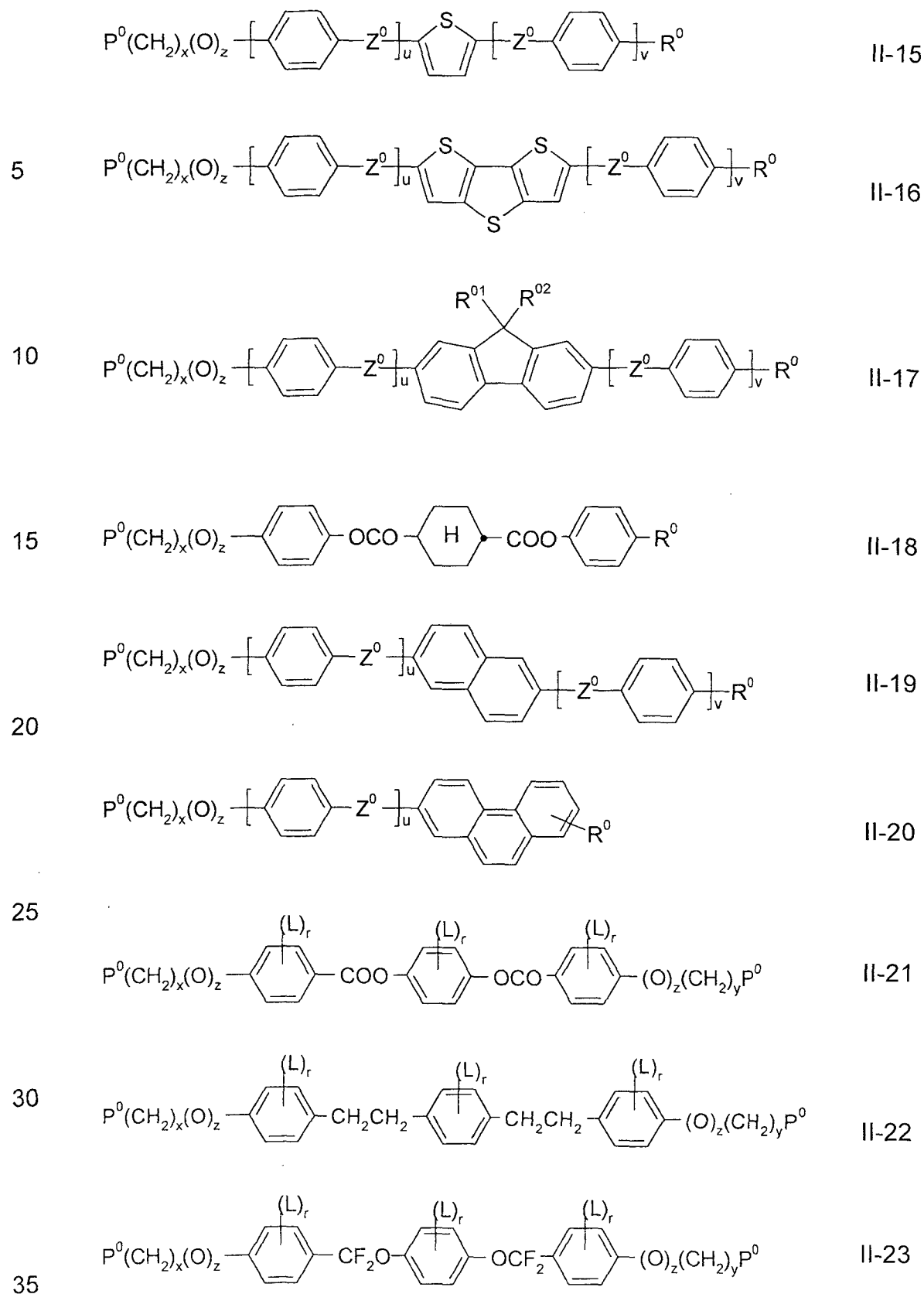
k and l are each and independently 0, 1, 2, 3 or 4, preferably 0, 1 or 2, most preferably 1.

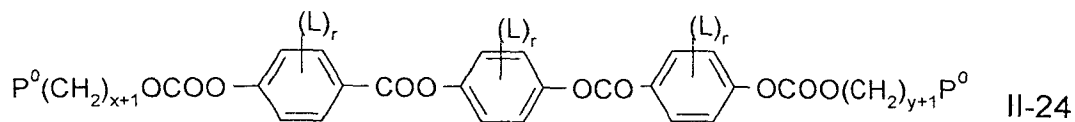
15      Preferably, the polymerizable liquid crystalline component A comprises at least one polymerizable mono-, di- or multireactive mesogenic compound selected of formulae II-1 to II-27,



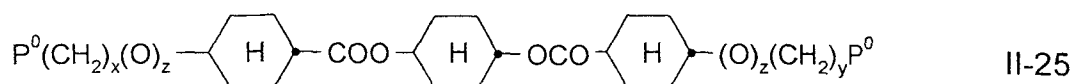




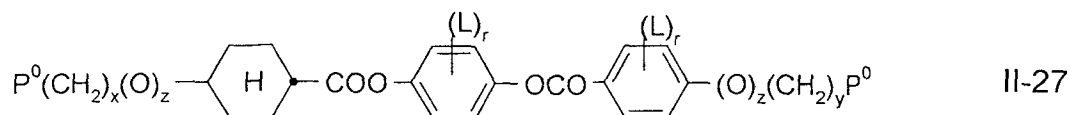
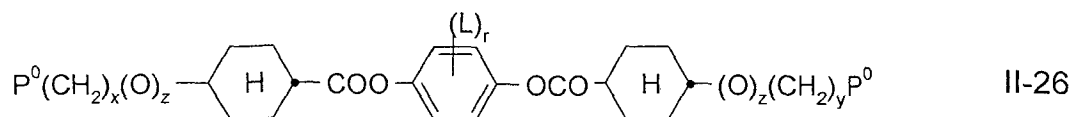




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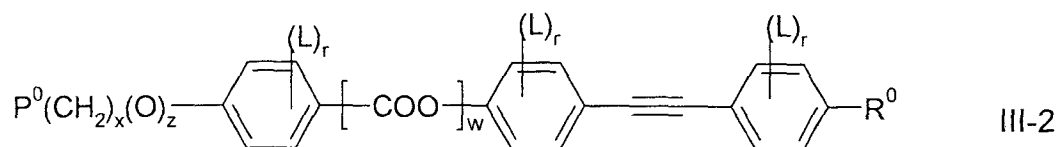
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and at least one polymerizable mono-, di- or multireactive mesogenic compounds selected of formula III-1 to III-12,

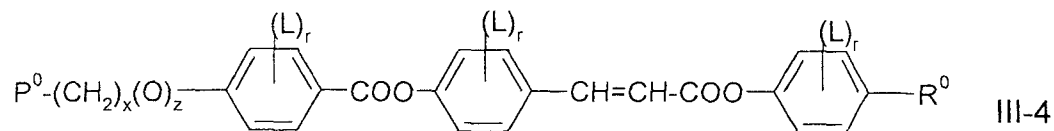
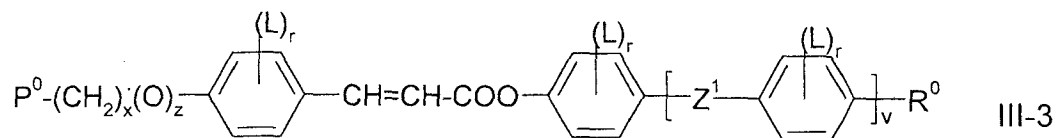
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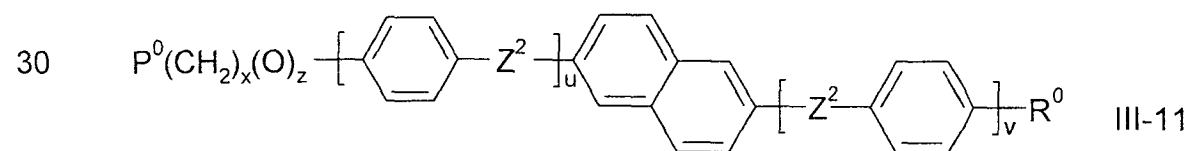
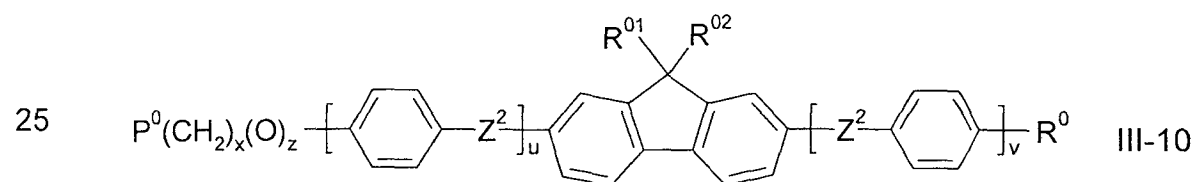
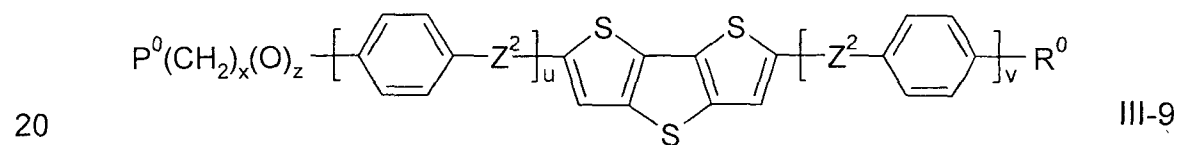
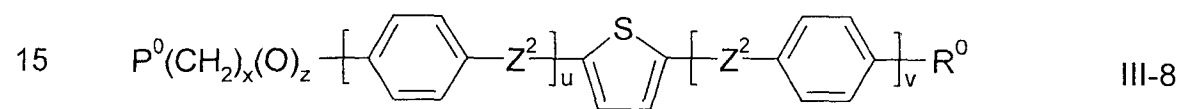
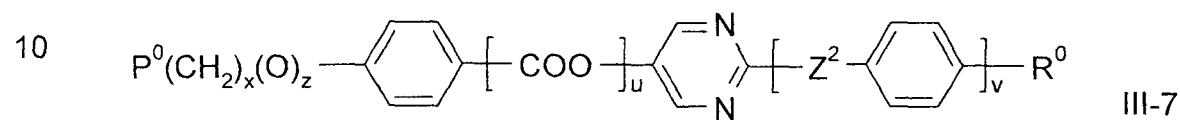
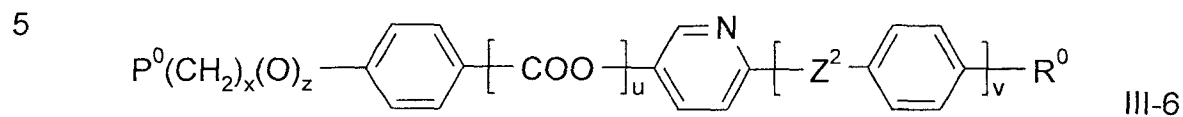
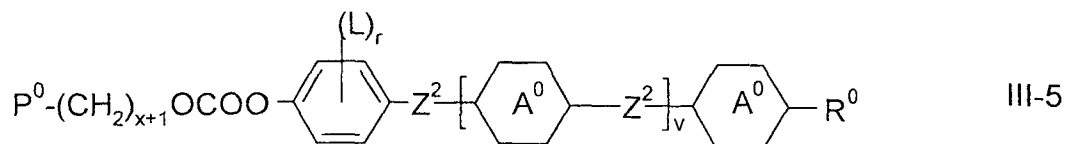
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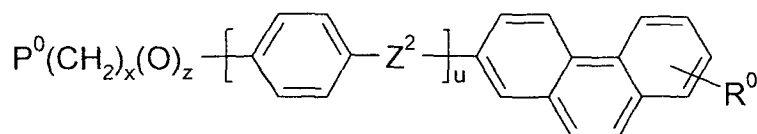
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III-12

5 wherein

$P^0$  is, in case of multiple occurrences independently of one another, a polymerizable group, preferably an acryl, methacryl, oxetane, epoxy, vinyl, vinyloxy, propenyl ether or styrene group,

$A^0$  is, in case of multiple occurrences independently of one another, 1,4-phenylene that is optionally substituted with 1, 2, 3 or 4 groups L, or trans-1,4-cyclohexylene,

$Z^0$  is, in case of multiple occurrences independently of one another, -COO-, -OCO-, -CH<sub>2</sub>CH<sub>2</sub>-, or a single bond,

$Z^1$  is in each occurrence independently from each other -O-, -S-, -CO-, -COO-, -OCO-, -S-CO-, -CO-S-, -O-COO-, -CO-NR<sup>01</sup>-, -NR<sup>01</sup>-CO-, -NR<sup>01</sup>-CO-NR<sup>02</sup>-, -NR<sup>01</sup>-CO-O-, -O-CO-NR<sup>01</sup>-, -OCH<sub>2</sub>-, -CH<sub>2</sub>O-, -SCH<sub>2</sub>-, -CH<sub>2</sub>S-, -CF<sub>2</sub>O-, -OCF<sub>2</sub>-, -CF<sub>2</sub>S-, -SCF<sub>2</sub>-, -CH<sub>2</sub>CH<sub>2</sub>-, -(CH<sub>2</sub>)<sub>4</sub>-, -CF<sub>2</sub>CH<sub>2</sub>-, -CH<sub>2</sub>CF<sub>2</sub>-, -CF<sub>2</sub>CF<sub>2</sub>-, -CH=N-, -N=CH-, -N=N-, -CH=CR<sup>01</sup>-, Y<sup>01</sup>=CY<sup>02</sup>-, -C≡C-, -CH=CH-COO-, -OCO-CH=CH-, or a single bond,

$Z^2$  is -CH=N-, -N=CH-, -N=N-, -CH=CR<sup>01</sup>-, -CY<sup>01</sup>=CY<sup>02</sup>-, -C≡C-, -CH=CH-COO-, -OCO-CH=CH-, and if present at least twice, at least one of  $Z^1$  can also denote -O-, -S-, -O-, -COO-, -OCO-, -S-CO-, -CO-S-, -O-COO-, -CO-NR<sup>01</sup>-, -NR<sup>01</sup>-CO-, -NR<sup>01</sup>-CO-NR<sup>02</sup>-, -NR<sup>01</sup>-CO-O-, -O-CO-NR<sup>01</sup>-, -OCH<sub>2</sub>-, -CH<sub>2</sub>O-, -SCH<sub>2</sub>-, -CH<sub>2</sub>S-, -CF<sub>2</sub>O-, -OCF<sub>2</sub>-, -CF<sub>2</sub>S-, -SCF<sub>2</sub>-, -CH<sub>2</sub>CH<sub>2</sub>-, -(CH<sub>2</sub>)<sub>4</sub>-, -CF<sub>2</sub>CH<sub>2</sub>-, -CH<sub>2</sub>CF<sub>2</sub>-, -CF<sub>2</sub>CF<sub>2</sub>-, or a single bond,

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

u and v are independently of each other 0, 1 or 2,

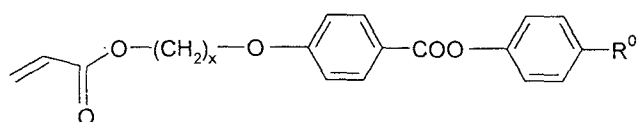
w is 0 or 1,

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

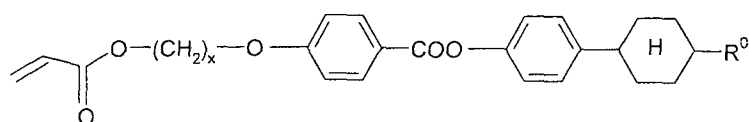
z is 0 or 1, with z being 0 if the adjacent x or y is 0, and

the parameter  $R^0$ ,  $Y^0$ ,  $R^{01}$ ,  $R^{02}$  and L have the same meanings as given above in formula I. wherein

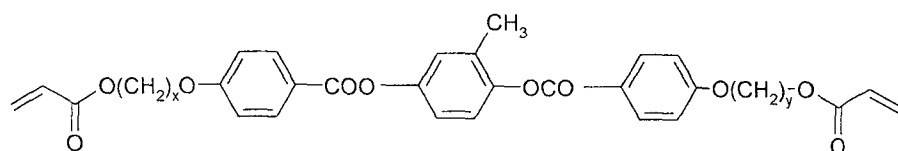
More preferably, the polymerizable liquid crystalline component A comprises at least one polymerizable mono-, di- or multireactive mesogenic compound selected formula IIa to IIc,



IIa



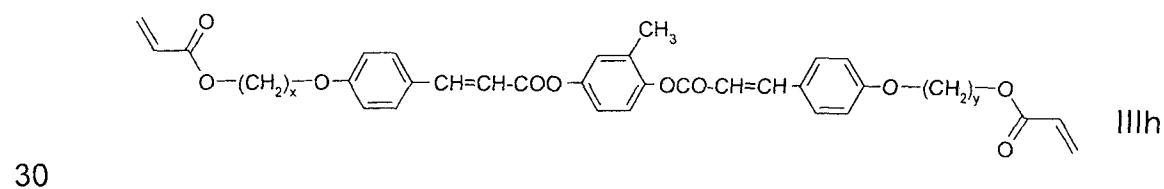
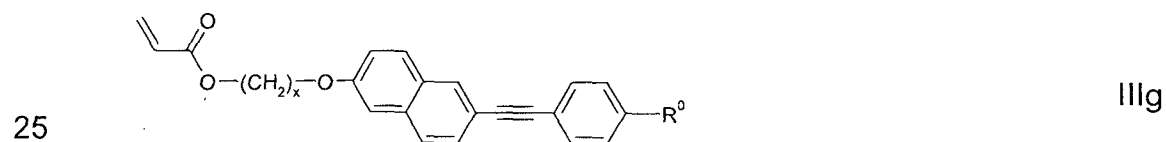
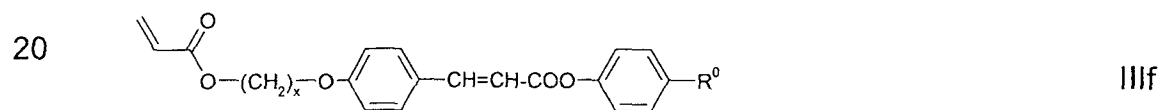
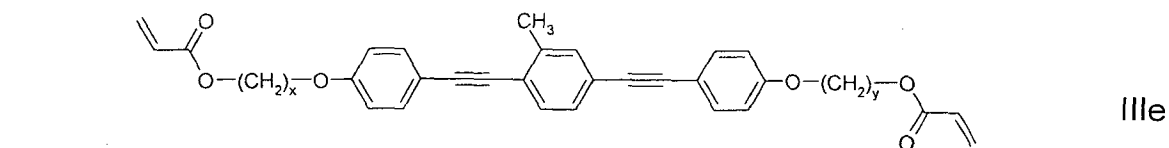
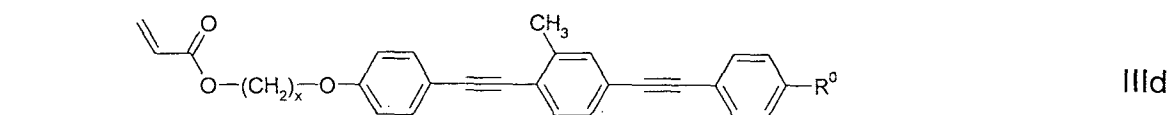
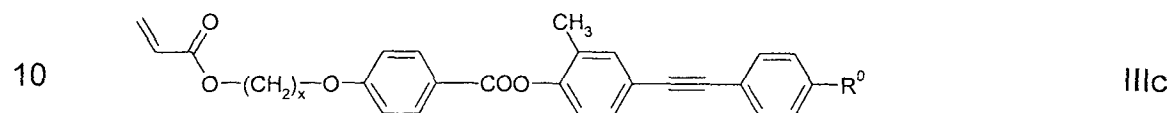
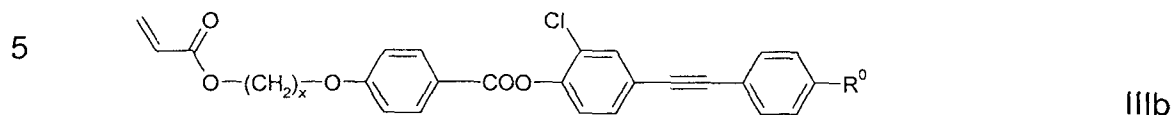
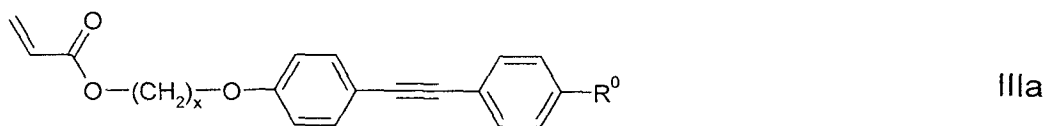
IIb



IIc

and at least one polymerizable mesogenic compound of the following formulae IIIa to IIIh,

- 29 -



wherein the parameter  $R^0$  has the same meaning as given above in formula I, x and y are independently of each other integers from 1 to 12.

35 Especially preferably the polymerizable mesogenic compounds of the polymerizable liquid crystalline component A are selected from at least

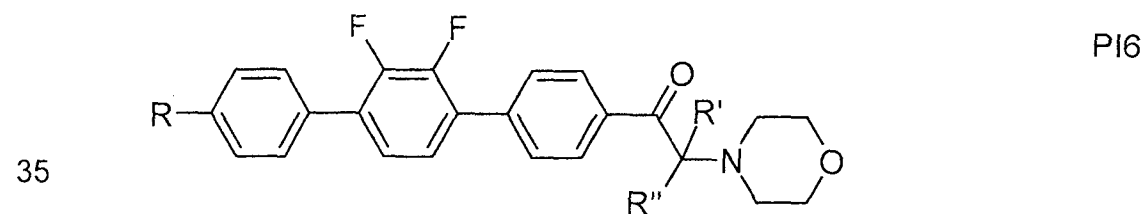
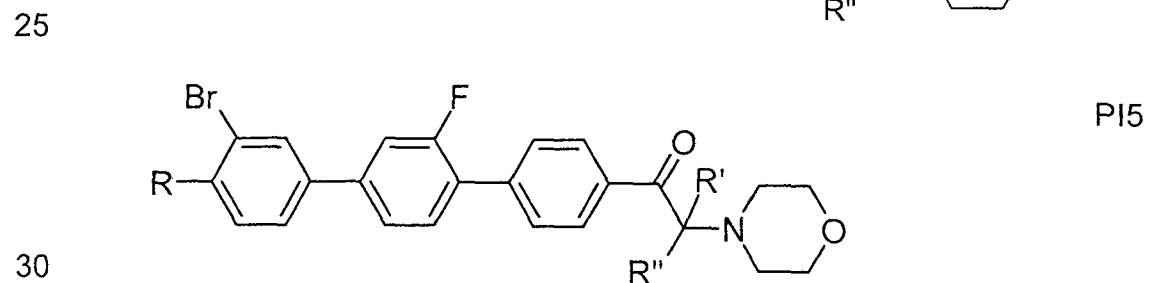
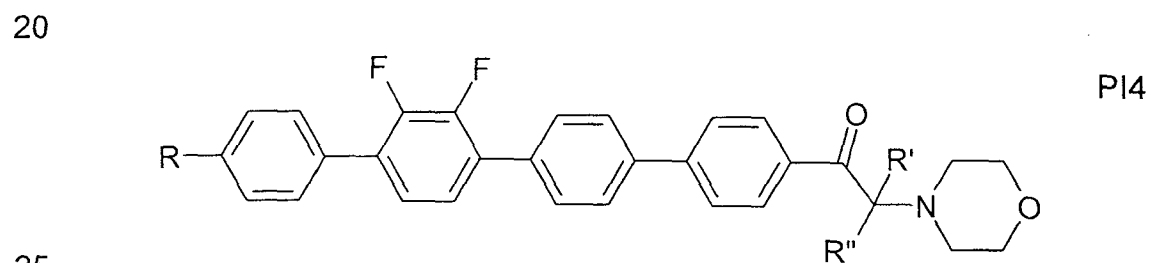
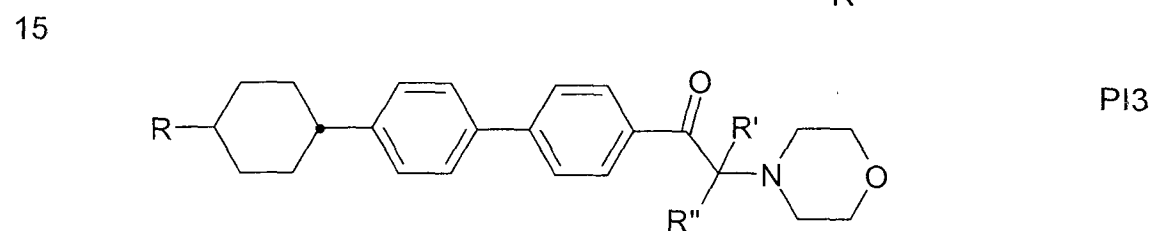
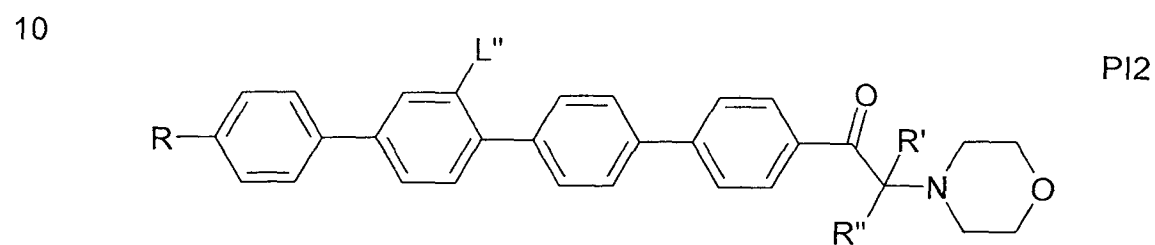
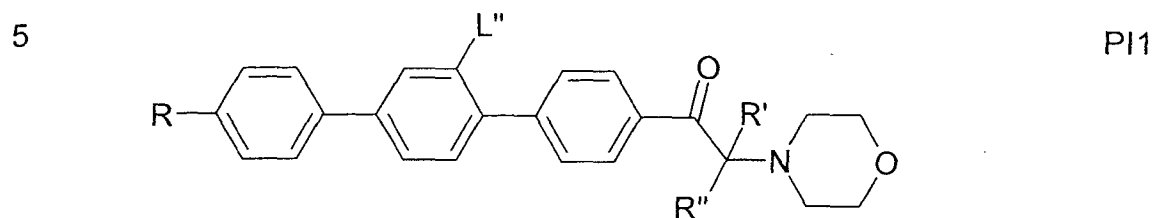
one compound of formulae IIa to IIc and at least one compound selected from the formulae IIIa to IIIe and IIlg.

5 In a preferred embodiment, the non-polymerizable component B comprises one or more stabilizers or inhibitors to prevent undesired spontaneous polymerization, preferably in an amount of 0 to 0.1 % by weight of the total medium, very preferably 0 to 0.2 % by weight of the total medium, for example selected from the commercially available Irganox® series (Ciba AG), like Irganox 1076.

10 Polymerization of the polymerizable liquid crystalline medium is preferably carried out in the presence of a polymerization initiator. For this purpose the non-polymerizable component (B) preferably comprises one or more initiators. For example, when polymerizing by means of UV light, a  
15 photoinitiator can be used that decomposes under UV irradiation to produce free radicals or ions that start the polymerization reaction. For polymerizing acrylate or methacrylate groups preferably, a radical photoinitiator is used. For polymerizing vinyl, epoxide, or oxetane groups preferably, a cationic photoinitiator is used. It is also possible to use a  
20 thermal polymerization initiator that decomposes when heated to produce free radicals or ions that start the polymerization. Suitable for free-radical polymerization are, for example, the commercially available photoinitiators Irgacure651®, Irgacure184®, Irgacure907®, Irgacure369® or Darocure1173® (Ciba AG). If an initiator is employed, its proportion is  
25 preferably 0.001 to 5% by weight of the total medium, particularly preferably 0.001 to 1% by weight of the total medium. A typical cationic photoinitiator is for example UVI 6974 (Union Carbide).

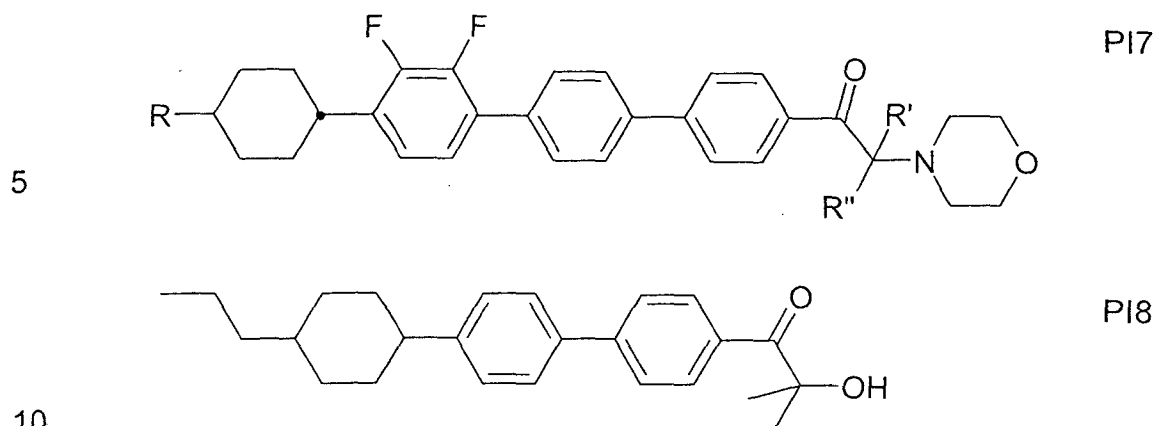
30 Alternatively, component B can also comprise a dichroic or liquid crystalline photoinitiator as disclosed for example in EP 1 388 538 A1. As with the common photo initiators, a "dichroic photo initiator" dissociates when exposed to the correct wavelength and the formed radicals will initiate polymerization of monomers. The dichroic photo initiator has the property that the light absorption is dependent on the molecular orientation  
35 of the molecule. The dichroic photo initiators selectively dissociate when aligned with the electric field vector of the incoming light.

Very preferred dichroic photoinitiators of component B are selected from the group consisting of the following formulae:



35





wherein L" is H or F, R is alkyl or alkoxy with 1 to 12 C-atoms, and R' and R" are selected from alkyl or alkoxy with 1 to 6 C-atoms, very preferably from methyl, ethyl or propyl.

The concentration of the polymerization initiator in the polymerizable liquid crystalline medium is preferably from 0.01 to 10 % by weight of the total medium, very preferably from 0.05 to 6 % by weight of the total medium.

Further preferred is a component B comprising one or more surfactants, which promote a specific surface alignment of the LIQUID CRYSTALLINE molecules. Suitable surfactants are described for example in J. Cognard, Mol.Cryst.Liq.Cryst. **78**, Supplement 1, 1-77 (1981). Preferred aligning agents for planar alignment are for example non-ionic surfactants, preferably fluorocarbon surfactants such as the commercially available Fluorad FC-171® (from 3M Co.) or Zonyl FSN® (from DuPont), multiblock surfactants as described in GB 2 383 040 or polymerizable surfactants as described in EP 1 256 617 A1.

The non-polymerizable component may also comprises one or more dyes having an absorption maximum adjusted to the wavelength of the radiation used for polymerization, in particular UV dyes like e.g. 4,4'-azoxy anisole or Tinuvin® dyes (from Ciba AG).

Said non-polymerizable component B can additionally comprise one or more additional components like for example catalysts, sensitizers,

stabilizers, inhibitors, chain-transfer agents, lubricating agents, wetting agents, dispersing agents, hydrophobing agents, adhesive agents, flow improvers, defoaming agents, deaerators, diluents, reactive diluents, auxiliaries, colourants or pigments.

5

As mentioned above, a suitable polymerizable liquid crystalline medium for a birefringent RM lens according to the present invention consists of several compounds, preferably of 2 to 30, more preferably of 3 to 20 and most preferably of 4 to 10 compounds. These compounds are mixed in conventional way. As a rule, the required amount of the compound used in the smaller amount is dissolved in the compound used in the greater amount. In case the temperature is above the clearing point of the compound used in the higher concentration, it is particularly easy to observe completion of the process of dissolution. It is, however, also possible to prepare the media by other conventional ways, e.g. using so-called pre-mixtures, which can be e.g. homologous or eutectic mixtures of compounds or using so-called multi-bottle-systems, the constituents of which are ready to use mixtures themselves.

20

Preferably the amount of the polymerizable liquid-crystalline component A in the medium is more than 95 % by weight of the total medium, more preferably more than 97% by weight of the total medium and even more preferably more than 98% by weight of the total medium.

25

Preferably, the amount of the non-polymerizable component B is less than 5 % by weight of the total medium, more preferably less than 3% by weight of the total medium and even more preferably less than 2% by weight of the total medium.

30

The polymerizable liquid-crystalline component A preferably comprises

- one or more compounds of formula I in a total concentration of more than 95 % by weight of the total medium, more preferably more than 97% by weight of the total medium and even more preferably more than 98% by weight of the total medium, preferably these compounds are selected from the group

35

of the sub formulae II-1, II-6, II-7, II-27, III-1, III-2, III-3 and III-11,  
and

the non-polymerizable component B preferably comprises

5

- one or more non-polymerizable compounds in a total concentration of less than 5 % by weight of the total medium, more preferably less than 3% by weight of the total medium and even more preferably less than 2% by weight of the total medium, preferably these compounds are selected from selected from stabilizers alignment additives, surfactants and photoinitiators.

10

More preferably, the polymerizable liquid-crystalline component A preferably comprises

15

- preferably one, two, three or more monoreactive mesogenic compounds, preferably selected from formulae II-1, II-6, II-7 III-1, III-2, III-3 and III-1, preferably in concentration in the range from 5 to 50% by weight of the total medium, more preferably 10 to 40 % by weight of the total medium, even more preferably 15 to 30 % by weight of the total medium, and

20

- preferably one, two, three or more direactive mesogenic compounds, preferably in concentration in the range from 1 to 90% by weight of the total medium, more preferably 5 to 80 % by weight of the total medium, even more preferably 10 to 70 % by weight of the total medium, and

25

- optionally one, two, three or more multireactive mesogenic compounds, preferably selected from formula II-27, preferably in concentration in the range from 0 to 25% by weight of the total medium, more preferably 0 to 20 % by weight of the total medium, even more preferably 0 to 10 % by weight of the total medium, and

30

35

the non-polymerizable component B preferably comprises

- 5 - one or more non-polymerizable compounds in a total concentration of less than 5 % by weight of the total medium, more preferably less than 3% by weight of the total medium and even more preferably less than 2% by weight of the total medium, preferably these compounds are selected from stabilizers alignment additives, surfactants and photoinitiators.

Even more preferably, the polymerizable liquid-crystalline component A  
10 preferably comprises,

- one or more compounds of formula IIa, in particular wherein R<sup>0</sup> denotes alkoxy or CN, and x is 6, preferably in concentration in the range from 10 to 60% by weight of the total medium, in particular 15-50 % by weight of the total medium, and

- one or more compounds of formula IIc, in particular wherein x and y denotes each both 3 or both 6, preferably in concentration in the range from 5 to 60 % by weight of the total medium, in particular 10-50 % by weight of the total medium, and

- 25 - at least one compound selected from the group of compounds of formulae IIIa to IIIh, preferably in concentration in the range from 1 to 60% by weight of the total medium, in particular 1 to 30% by weight of the total medium, and

the non-polymerizable component B preferably comprises

- 30 - one or more stabilizers, preferably selected from the commercially available Irganox® series (Ciba AG), like Irganox 1076, preferably in an amount of 0 to 0.1 % by weight of the total medium, very preferably 0 to 0.2 % by weight of the total medium, and

- 35        -                    one or more photoinitiators, preferably selected from  
the commercially available photoinitiators Irgacure651®, Irga-

cure184®, Irgacure907®, Irgacure369® or Darocure1173® (Ciba AG), preferably in an amount of 0.001 to 5% by weight of the total medium, particularly preferably 0.001 to 1% by weight of the total medium.

5

The general methods for the preparation of birefringent RM lens according to this invention are known to the ordinary expert and can be performed for example as described in JP2012-137616 A1.

10

In a preferred embodiment, a method of production comprises the steps of

- filling a melt of the polymerizable liquid crystalline medium into a plano-convex lens mould at elevated temperature,
- annealing the polymerizable liquid crystalline medium in the mould at elevated temperature,
- 15 - cooling the mould,
- curing of the polymerizable liquid crystalline medium,
- and
- optionally removing the mould.

20

In another preferred embodiment, the method comprises the steps of

- providing a layer of a melt of the polymerizable liquid crystalline medium onto a substrate at room temperature or elevated temperature,
- providing an inverse lens mould on top of the coated polymerizable liquid crystalline medium,
- 25 - annealing the polymerizable liquid crystalline medium in the mould at elevated temperature,
- cooling the mould,
- curing of the polymerizable liquid crystalline medium,
- 30 and
- optionally removing the mould.

35

The substrate used for the birefringent RM lens the present invention can be any substrate as usually used for liquid crystal devices, displays, optical parts, and optical films. It is not limited to any specific substrates as long as it has enough heat resistance to endure the heating after coating the

melted birefringent RM lens material of the present invention or the heating during the liquid crystal device manufacturing.

5 Examples of such substrates, which also can be the material of choice for the lens mould, are a glass substrate, metal substrate, ceramic substrate, and plastic substrate. Particularly when the substrate is the organic material, the examples of substrate materials are cellulose derivatives, polyolefin, polyester, polyolefin, polycarbonate, polyacrylate, poly-allylate, polyether sulfon, polyimide, poly-phenylene sulfide, poly-phenylene  
10 ether, nylon, and polystyrene. Among them, polyester, polystyrene, polyolefin, cellulose derivatives, polyallylate, and polycarbonate are preferred.

15 As a coating method to obtain the birefringent RM lens of the present invention, the well-known and commonly used method can be used. The examples are an applicator method, bar coating method, spin coating method, gravure print method, flexographic method, inkjet method, die coating method, cap coating method, and the dipping method.

20 The preferred coating temperature is dependent, inter alia, on the melting point of the polymerizable liquid-crystalline medium.

Preferably, the coated film of the polymerizable liquid crystalline medium exhibit a room temperature a suitable stability against crystallization for at  
25 least 1 hour, more preferably for at least 3 hours, and most preferably for at least 16 hours.

The thickness of the coated layer of the melt of the polymerizable liquid crystalline medium is dependent, inter alia, on the thickness of used lens  
30 mould or the preferred lens thickness in dependence of the value for the birefringence of the RM lens.

Initial alignment (e.g. planar alignment) of the polymerizable liquid crystalline medium can be achieved by annealing the polymerizable liquid  
35 crystalline medium before polymerization, or also by application of an alignment layer, by applying a magnetic or electric field to the coated

- polymerizable liquid crystalline medium, or by the addition of surface-active compounds to the polymerizable liquid crystalline medium. Reviews of alignment techniques are given for example by I. Sage in "Thermotropic Liquid Crystals", edited by G. W. Gray, John Wiley & Sons, 1987, pages 75-77; and by T. Uchida and H. Seki in "Liquid Crystals - Applications and Uses Vol. 3", edited by B. Bahadur, World Scientific Publishing, Singapore 1992, pages 1-63. A review of alignment materials and techniques is given by J. Cognard, Mol. Cryst. Liq. Cryst. 78, Supplement 1 (1981), pages 1-77.
- It is also possible to apply an alignment layer onto the substrate and provide the polymerizable liquid crystalline medium onto this alignment layer. Suitable alignment layers are known in the art, like for example rubbed polyimide or alignment layers prepared by photo alignment as described in US 5,602,661, US 5,389,698 or US 6,717,644.
- In detail, suitable alignment treatments are for example a stretch treatment, rubbing treatment, polarized UV- visible light irradiation treatment, and the ion beam treatment. In the case that the alignment film is used, the well- known and commonly used alignment film can be used.
- Detailed examples of such the alignment film are polyimide, polysiloxane, polyamide, polyvinyl alcohol, polycarbonate, polystyrene, poly- phenylene ether, poly- allylate, polyethylene terephthalate, polyether sulfone, epoxy resin, epoxy acrylate resin, acryl resin, cumarine compound, chalcone compound, cinnamate compound, fulgide compound, anthraquinone compound, azo compound, and aryl ethane compound. For the compounds, which are alignment- processed by the methods beside the rubbing treatment, the use of the light alignment material is desirable.
- Forming a birefringent RM lens of the present invention can be carried out by polymerizing polymerizable liquid crystalline medium into a lens shape by using a photo mask. When the photo mask is used, the photo mask is designed in such the manner that the desired lens shape is obtained after the polymerization of the birefringent RM lens material or polymerizable liquid crystalline medium.

However, the coated film of the polymerizable liquid crystalline medium is preferably covered with a lens mould. When the mould is used, the coating film of the birefringent RM lens material or polymerizable liquid crystalline medium is covered with a plano-convex lens mould having preferably the same refractive index as the ordinary refractive index ( $n_o$ ) of the polymerizable liquid crystalline medium of the present invention, and the polymerization is carried out while being covered.

Polymerization is achieved for example by exposing the polymerizable liquid crystalline medium to 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, polymerization is carried out by. As a source for actinic radiation, for example a single UV lamp or a set of UV lamps can be used. When using a high lamp power the curing time can be reduced. Another possible source for actinic radiation is a laser, like for example a UV, IR or visible laser.

When the polymerization is carried out by the UV irradiation, it is generally preferable to irradiate it with the UV ray having at most 390 nm wavelengths, and more preferably with the light having the wavelength of 250 to 370 nm, in concrete. However, in the case that the decomposition of the polymerizable liquid crystal composition is caused by the UV ray having at most 390 nm, it may be preferable to carry out the polymerization treatment with the UV ray having at least 390 nm. This light is preferably diffused light, however in case, a dichroic photo initiator is present, it is preferred to use polarized light.

The curing time is dependent, inter alia, on the reactivity of the polymerizable liquid-crystalline medium, the thickness of the coated layer, the type of polymerization initiator and the power of the UV lamp. The curing time is preferably  $\leq 5$  minutes, very preferably  $\leq 3$  minutes, most preferably  $\leq 1$  minute.



A suitable UV radiation power is preferably in the range from 5 to 200 mWcm<sup>-2</sup>, more preferably in the range from 10 to 175 mWcm<sup>-2</sup> and most preferably in the range from 20 to 150 mWcm<sup>-2</sup>.

5 In connection with the applied UV radiation and as a function of time, a suitable UV dose is preferably in the range from 25 to 7200 mJcm<sup>-2</sup> more preferably in the range from 500 to 7200 mJcm<sup>-2</sup> and most preferably in the range from 1000 to 7200 mJcm<sup>-2</sup>.

10 The curing temperature is desirably a lower temperature than the temperature at which the inhomogeneous polymerization is induced by heat, in addition to the consideration to the transition temperature from the liquid crystal phase to the isotropic phase of the polymerizable liquid crystal composition. Here, when the substrate made of the organic  
15 material exceeds the glass transition point, the thermal deformation of the substrate becomes severe.

The preferred curing temperature range is between 10 to 70 °C, more preferably between 15 to 50°C, and even more preferably between 20 to  
20 30 °C.

A polymerizable liquid crystal medium preferably has a clearing point in the range from about 50°C to about 150°C, especially up to about 100°C or even 80°C.

25 The optical retardation ( $\delta(\lambda)$ ) of a RM lens as a function of the wavelength of the incident beam ( $\lambda$ ) is given by the following equation:

$$\delta(\lambda) = (2\pi\Delta n \cdot d)/\lambda$$

30 wherein ( $\Delta n$ ) is the birefringence of the RM lens, ( $d$ ) is the thickness of the RM lens and  $\lambda$  is the wavelength of the incident beam.

According to Snellius law, the birefringence as a function of the direction of  
35 the incident beam is defined as

$$\Delta n = \sin\Theta / \sin\Psi$$

wherein  $\sin\Theta$  is the incidence angle or the tilt angle of the optical axis in the film and  $\sin\Psi$  is the corresponding reflection angle.

5

Based on these laws, the birefringence and accordingly optical retardation depends on the thickness of a RM lens and the tilt angle of optical axis in the film (cf. Berek's compensator). Therefore, the skilled expert is aware that different optical retardations or different birefringence can be induced either by adjusting the orientation of the liquid-crystalline molecules in the RM lens or by adjusting the lens thickness.

10

Preferably, the birefringence ( $\Delta n$ ) of the RM lens in accordance with the present invention is preferably in the range from 0.10 to 0.50, more preferable in the range from 0.15 to 0.45 and even more preferable in the range from 0.18 to 0.40.

15

The birefringence ( $\Delta n$ ) was calculated using the following formula,

$$\delta n = \delta(\lambda)/d,$$

20

wherein

$\delta(\lambda)$  is retardation as explained above and ( $d$ ) is the thickness of the RM lens as mentioned above. Above and below, the  $\Delta n$  values are given at a wavelength of  $\lambda=550\text{nm}$ .

25

The thickness of the RM lens obtained by the method according to the present invention is preferably in the range from 3 to 200  $\mu\text{m}$ , more preferable in the range from 3 to 100  $\mu\text{m}$  and even more preferable in the range from 3 to 30  $\mu\text{m}$ .

30

The thickness of the RM lens is measured by making a scratch in the polymerized film and measuring the depth of the scratch with an Alpha step surface profileometer.

35

The difference in retardation between  $-40^\circ$  and  $+40^\circ$  viewing angle expressed as a percentage of the on axis retardation obtained by the method according to the present invention is preferably less than 5%, more preferably less than 1% and even more preferably 0%

5

Retardation is measured using a spectroscopic ellipsometer.

10

The birefringent RM lens according to the present invention can be used in a wide variety of electro optical devices, such as autostereoscopic 3D displays, polarized light guide plates, optical drives (DVD, blue ray, CD), etc.

15

The transmission of the birefringent RM lens at 550 nm is preferably higher than 85 %, more preferably higher than 90 %, and even more preferably higher than 93 %. The transmission of the birefringent RM lens can be measured in a Hitachi 3310 UV-vis spectrometer.

20

Yellowness index (b-value) of the birefringent RM lens is preferably lower than 11, more preferably lower than 9, and even more preferably lower than 7.

25

The yellowness index or b-value in accordance with the CIE LAB colour scale is measured using a Konica Minolta CR300 colour camera, in reflection mode. In this test an empty PI glass cell measures at a "b-value" of 4.14 as a reference.

30

Accordingly, in a preferred embodiment, the birefringent RM lens can be used in an autostereoscopic display device. Such device comprises a display panel on top of which is provided a lens arrangement comprising at least one birefringent RM lens.

35

A suitable display panel according to the present invention is a liquid crystal (LCD), a plasma (PDP), an organic light emitting diode (OLED) or cathode ray tube (CRT) display panel, preferably a liquid crystal display. However, it will be apparent to those skilled in the art that alternative types of display panels may also be employed.

The display panel has an array of display pixels for producing a display image and the display pixels are arranged in rows and columns. In a preferred embodiment, the preferred display pixel pitch is in the range  
5 50 $\mu$ m to 1000  $\mu$ m.

In a preferred embodiment of the present invention, a transparent coupling film is laminated between the front side of the display panel and said lens arrangement, which substantially couples the incident light of the display  
10 panel at an oblique angle to the lens arrangement. Preferably, this transparent coupling film has a prismatic grid structure.

However, in the preferred embodiment, a plane transparent spacer sheet is laminated between the front side of the display panel and said lens  
15 arrangement.

The lens arrangement enables an autostereoscopic image to be viewed. Therefore, each lens arrangement overlies a small group of display pixels in each row or column or at least one display pixel. The lens arrangement  
20 projects each display pixel or a group of display pixels in a different direction, to form the several different views. As the user's head moves from left to right, his/her eyes will receive different ones of the several views, in turn.

In a preferred embodiment of the present invention, the lens arrangement in is a lenticular screen plate. A lenticular screen plate is defined by a one-dimensional periodic arrangement of a plurality of lenses, preferably a row of lenses extending parallel to one another. In this connection, the  
25 lenticular screen plate can be a cylindrical lens grid disc, elliptical lens grid disc or prismatic lens grid disc, preferably a cylindrical lens grid disc.  
30

The present invention is described above and below with particular reference to the preferred embodiments. It should be understood that various changes and modifications might be made therein without  
35 departing from the spirit and scope of the invention.

Many of the compounds or mixtures thereof mentioned above and below are commercially available. All of these compounds are either known or can be prepared by methods which are 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 said reactions. Use may also be made here of variants which are known per se, but are not mentioned here. Unless the context clearly indicates otherwise, as used herein plural forms of the terms herein are to be construed as including the singular form and vice versa.

Throughout this application, unless explicitly stated otherwise, all concentrations are given in weight percent and relate to the respective complete medium, all temperatures are given in degrees centigrade (Celsius) and all differences of temperatures in degrees centigrade. All physical properties have been and are determined according to "Merck Liquid Crystals, Physical Properties of Liquid Crystals", Status Nov. 1997, Merck KGaA, Germany and are given for a temperature of 20 °C, unless explicitly stated otherwise.

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.

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 of 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. In particular, 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).

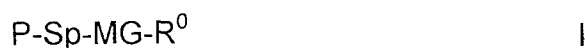
It will be appreciated that many of the features described above, particularly of the preferred embodiments, are inventive in their own right and not just as part of an embodiment of the present invention. Independent protection may be sought for these features in addition to or alternative to any invention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

The invention will now be described in more detail by reference to the following examples, which are illustrative only and do not limit the scope of the invention.

Preferred features of the invention are summarized in form of a numbered list:

1. Birefringent RM lens obtainable from a polymerizable liquid crystalline medium consisting of
  - a polymerizable liquid crystalline component (A) consisting of one or more polymerizable mesogenic compounds, and
  - a non-polymerizable component (B), consisting of one or more non-polymerizable compounds.

2. Birefringent RM lens according to note 1, characterized in that the polymerizable liquid crystalline component (A) comprises at least one polymerizable mesogenic compound selected of formula I,

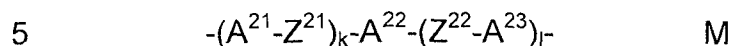


wherein

P is a polymerizable group,

Sp is a spacer group or a single bond,

MG is a rod-shaped mesogenic group selected of formula M,



10  $A^{21}$  to  $A^{23}$  are in each occurrence independently of one another an aryl-, heteroaryl-, heterocyclic- or alicyclic group optionally being substituted by one or more identical or different groups L,

15  $Z^{21}$  and  $Z^{22}$  are in each occurrence independently from each other, -O-, -S-, -CO-, -COO-, -OCO-, -S-CO-, -CO-S-, -O-COO-, -CO-NR<sup>01</sup>-, -NR<sup>01</sup>-CO-, -NR<sup>01</sup>-CO-NR<sup>02</sup>-, -NR<sup>01</sup>-CO-O-, -O-CO-NR<sup>01</sup>-, -OCH<sub>2</sub>-, -CH<sub>2</sub>O-, -SCH<sub>2</sub>-, -CH<sub>2</sub>S-, -CF<sub>2</sub>O-, -OCF<sub>2</sub>-, -CF<sub>2</sub>S-, -SCF<sub>2</sub>-, -CH<sub>2</sub>CH<sub>2</sub>-, -(CH<sub>2</sub>)<sub>4</sub>-, -CF<sub>2</sub>CH<sub>2</sub>-, -CH<sub>2</sub>CF<sub>2</sub>-, -CF<sub>2</sub>CF<sub>2</sub>-, -CH=N-, -N=CH-, -N=N-, -CH=CR<sup>01</sup>-, -CY<sup>01</sup>=CY<sup>02</sup>-, -C≡C-, -CH=CH-COO-, -OCO-CH=CH-, or a single bond,

20 L is, in case of multiple occurrences independently of one another, H, halogen, CN or optionally halogenated alkyl, alkoxy, alkylcarbonyl, alkoxycarbonyl, alkylcarbonyloxy or alkoxycarbonyloxy with 1 to 5 C atoms,

25 R<sup>0</sup> is H, alkyl, alkoxy, thioalkyl, alkylcarbonyl, alkoxycarbonyl, alkylcarbonyloxy or alkoxycarbonyloxy with 1 to 20 C atoms or is Y<sup>0</sup> or P-Sp-,

30 Y<sup>0</sup> is F, Cl, CN, NO<sub>2</sub>, OCH<sub>3</sub>, OCN, SCN, optionally fluorinated alkylcarbonyl, alkoxycarbonyl, alkylcarbonyloxy or alkoxycarbonyloxy with 1 to 4 C atoms, or mono- oligo- or polyfluorinated alkyl or alkoxy with 1 to 4 C atoms,

35

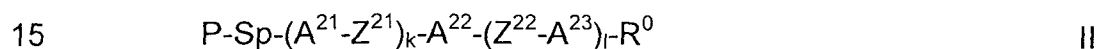
- 47 -

$Y^{01}$  and  $Y^{02}$  each, independently of one another, denote H, F, Cl or CN.

5  $R^{01}$  and  $R^{02}$  are independently of each other H, or straight chain or branched alkyl with 1 to 20 C-atoms, preferably 1 to 6 C-atoms, and

$k$  and  $l$  are each and independently 0, 1, 2, 3 or 4.

10 3. Birefringent RM lens according to note 1 or 2 characterized in that the polymerizable liquid crystalline component (A) comprises at least one polymerizable mesogenic compound selected formula II, and at least one polymerizable mesogenic compound selected of formula III,



wherein

20

$P$  is a polymerizable group,

$Sp$  is a spacer group or a single bond,

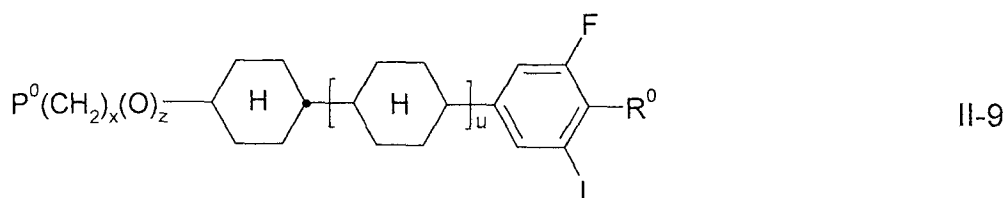
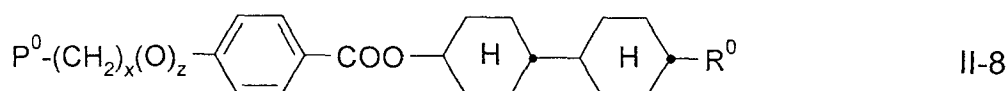
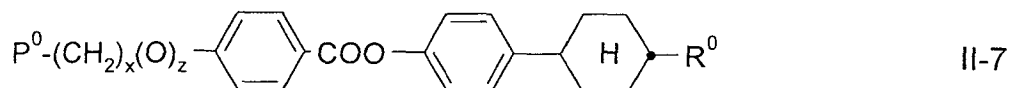
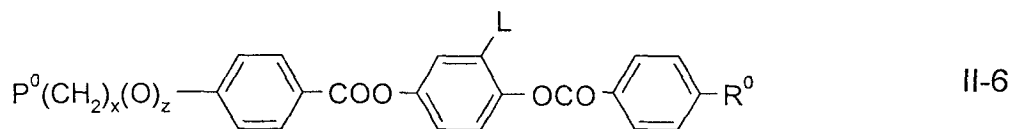
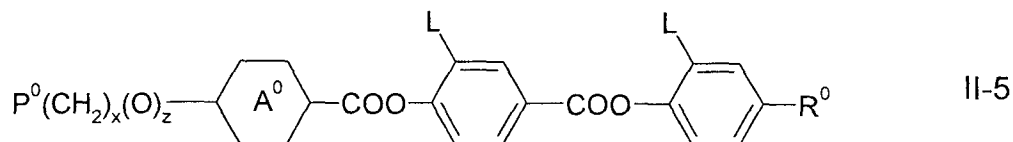
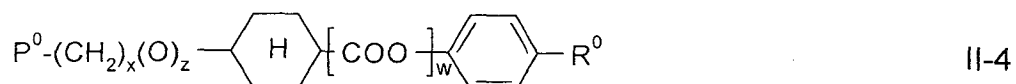
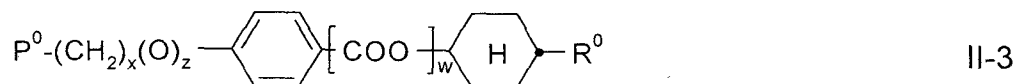
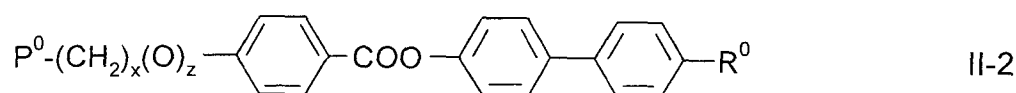
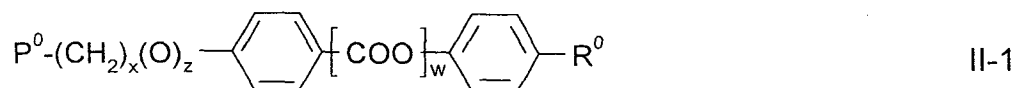
25  $A^{21}$  to  $A^{33}$  are in each occurrence independently of one another an aryl-, heteroaryl-, heterocyclic- or alicyclic group optionally being substituted by one or more identical or different groups  $L$ ,

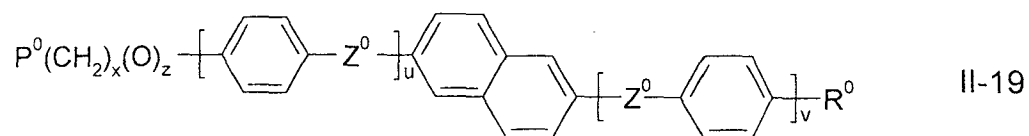
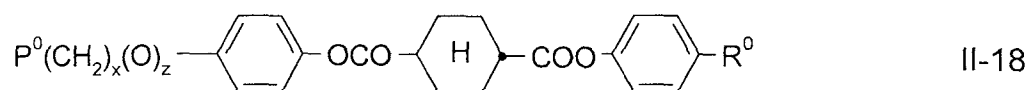
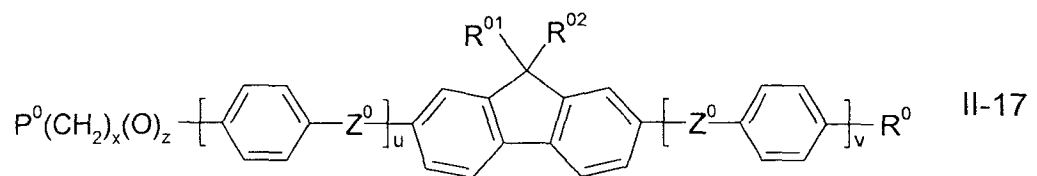
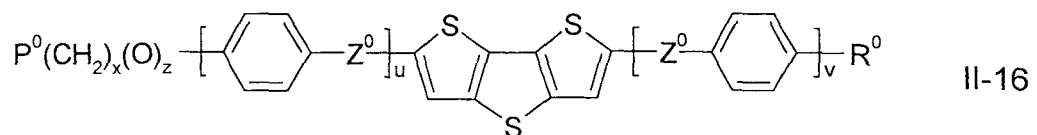
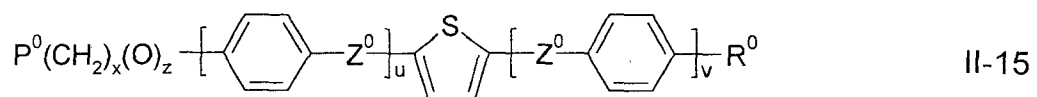
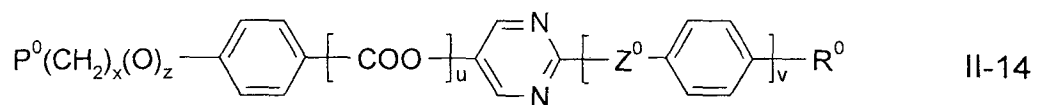
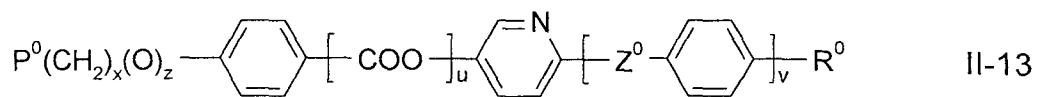
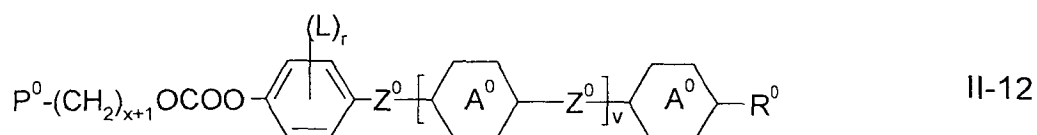
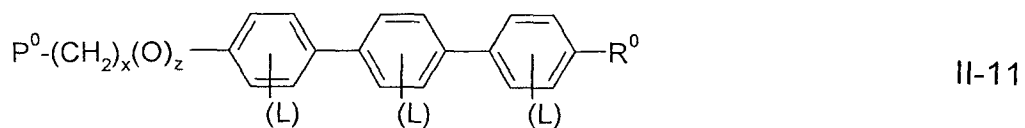
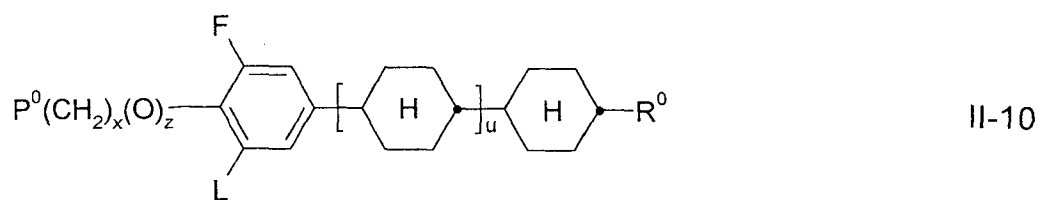
30  $Z^{21}$  and  $Z^{22}$  are in each occurrence independently from each other, -O-, -S-, -CO-, -COO-, -OCO-, -S-CO-, -CO-S-, -O-COO-, -CO-NR<sup>01</sup>-, -NR<sup>01</sup>-CO-, -NR<sup>01</sup>-CO-NR<sup>02</sup>-, -NR<sup>01</sup>-CO-O-, -O-CO-NR<sup>01</sup>-, -OCH<sub>2</sub>-, -CH<sub>2</sub>O-, -SCH<sub>2</sub>-, -CH<sub>2</sub>S-, -CF<sub>2</sub>O-, -OCF<sub>2</sub>-, -CF<sub>2</sub>S-, -SCF<sub>2</sub>-, -CH<sub>2</sub>CH<sub>2</sub>-, -(CH<sub>2</sub>)<sub>4</sub>-, -CF<sub>2</sub>CH<sub>2</sub>-, -CH<sub>2</sub>CF<sub>2</sub>-, -CF<sub>2</sub>CF<sub>2</sub>-,  
35 , or a single bond,

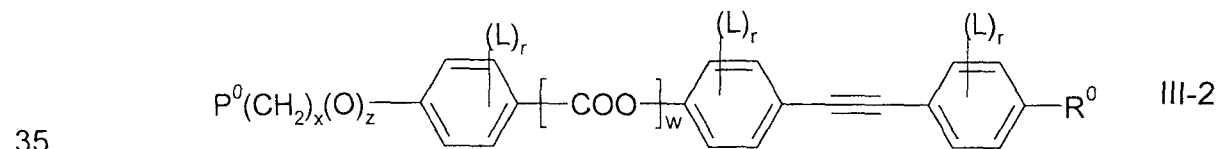
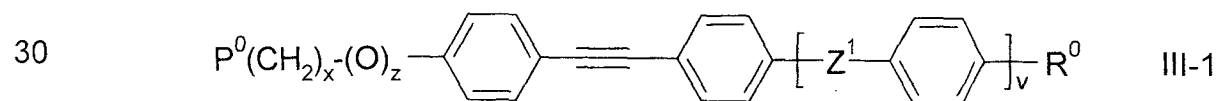
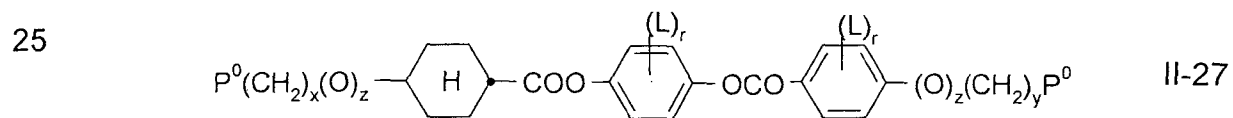
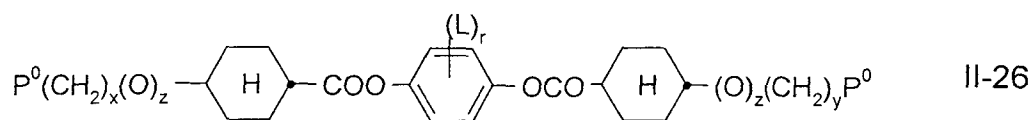
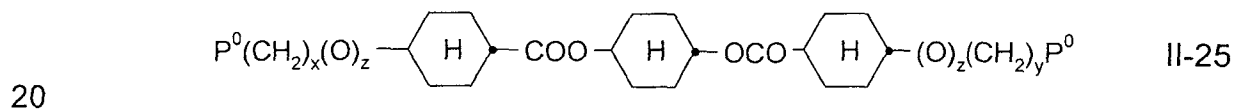
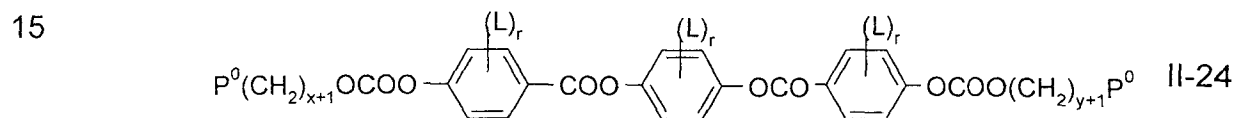
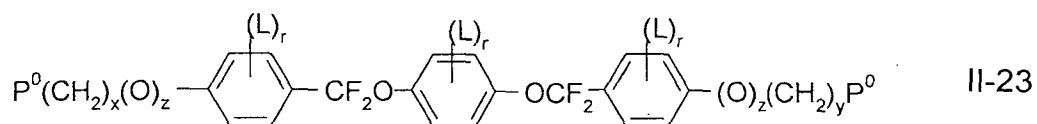
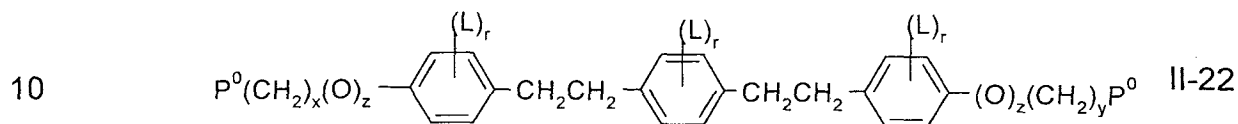
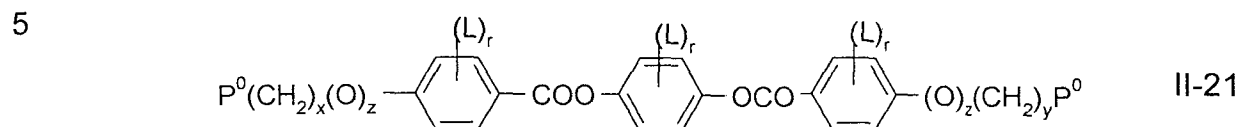
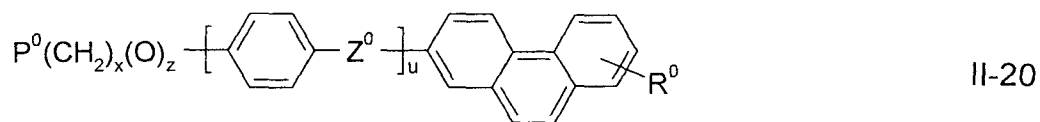


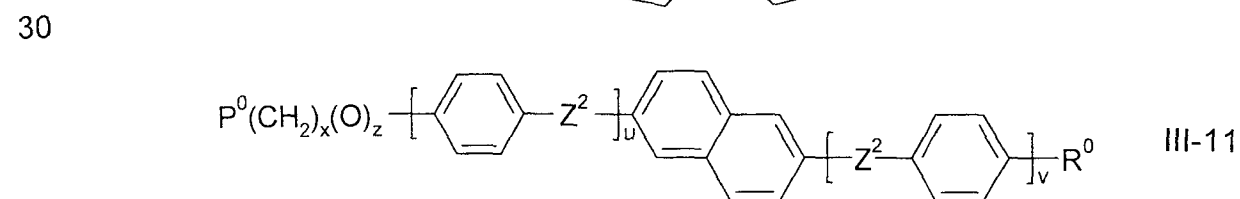
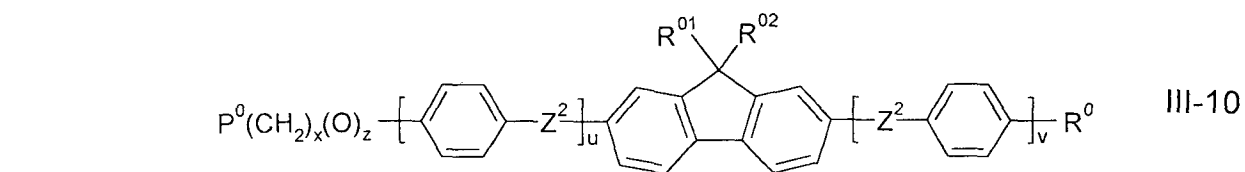
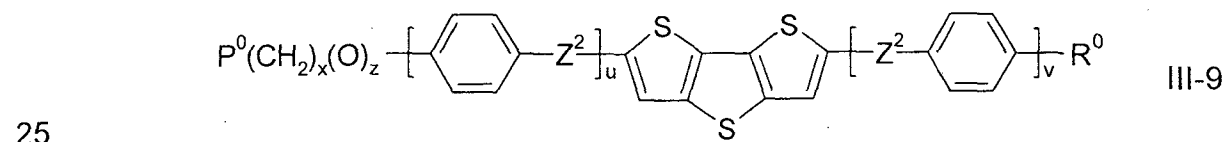
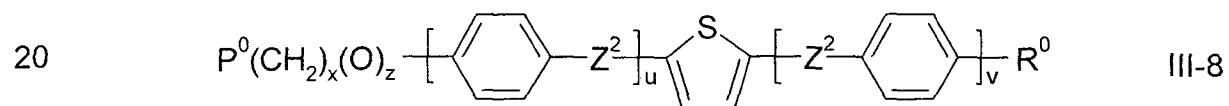
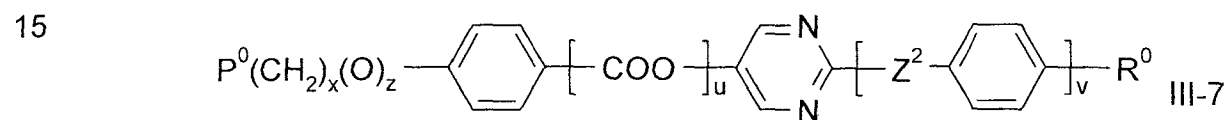
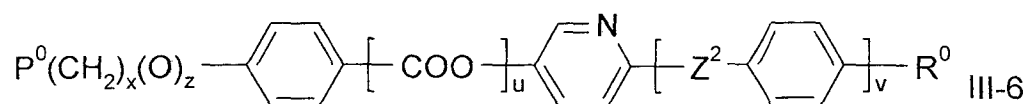
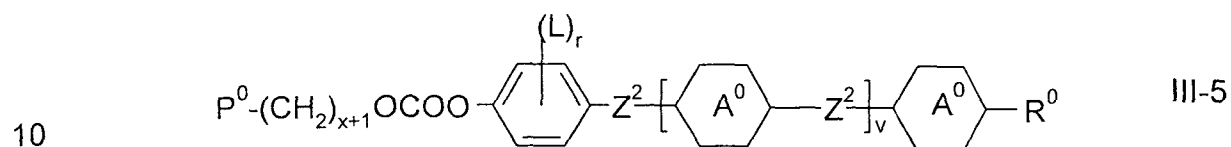
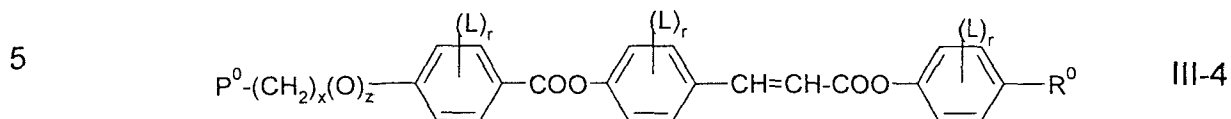
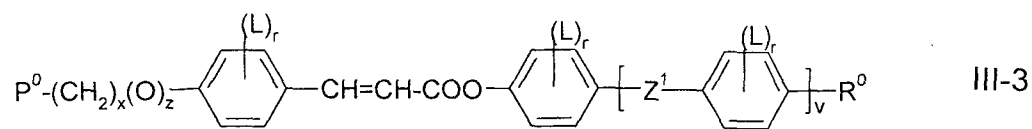
- $Z^{31}$  and  $Z^{32}$  are in each occurrence independently from each other  
 $-\text{CH}=\text{N}-$ ,  $-\text{N}=\text{CH}-$ ,  $-\text{N}=\text{N}-$ ,  $-\text{CH}=\text{CR}^{01}-$ ,  $-\text{CY}^{01}=\text{CY}^{02}-$ ,  
 $-\text{C}\equiv\text{C}-$ ,  $-\text{CH}=\text{CH}-\text{COO}-$ ,  $-\text{OCO}-\text{CH}=\text{CH}-$ , and if present  
 5 both, one of  $Z^{31}$  and  $Z^{32}$  can also denote  $-\text{O}-$ ,  $-\text{S}-$ ,  $-\text{CO}-$ ,  
 $-\text{COO}-$ ,  $-\text{OCO}-$ ,  $-\text{S}-\text{CO}-$ ,  $-\text{CO}-\text{S}-$ ,  $-\text{O}-\text{COO}-$ ,  $-\text{CO}-\text{NR}^{01}-$ ,  
 $-\text{NR}^{01}-\text{CO}-$ ,  $-\text{NR}^{01}-\text{CO}-\text{NR}^{02}$ ,  $-\text{NR}^{01}-\text{CO}-\text{O}-$ ,  
 $-\text{O}-\text{CO}-\text{NR}^{01}-$ ,  $-\text{OCH}_2-$ ,  $-\text{CH}_2\text{O}-$ ,  $-\text{SCH}_2-$ ,  $-\text{CH}_2\text{S}-$ ,  
 $-\text{CF}_2\text{O}-$ ,  $-\text{OCF}_2-$ ,  $-\text{CF}_2\text{S}-$ ,  $-\text{SCF}_2-$ ,  $-\text{CH}_2\text{CH}_2-$ ,  $-(\text{CH}_2)_4-$ ,  
 10  $-\text{CF}_2\text{CH}_2-$ ,  $-\text{CH}_2\text{CF}_2-$ ,  $-\text{CF}_2\text{CF}_2-$ , or a single bond,
- $L$  is, in case of multiple occurrences independently of one  
 another, H, halogen, CN or optionally halogenated alkyl,  
 alkoxy, alkylcarbonyl, alkoxy carbonyl, alkylcarbonyloxy  
 15 or alkoxy carbonyloxy with 1 to 5 C atoms,
- $R^0$  is H, optionally fluorinated alkyl, alkoxy, thioalkyl,  
 alkylcarbonyl, alkoxy carbonyl, alkylcarbonyloxy or  
 alkoxy carbonyloxy with 1 to 20 C atoms or is  $Y^0$  or P-  
 20  $\text{Sp}-$ ,
- $Y^0$  is F, Cl, CN,  $\text{NO}_2$ ,  $\text{OCH}_3$ ,  $\text{OCN}$ ,  $\text{SCN}$ , optionally  
 fluorinated alkylcarbonyl, alkoxy carbonyl,  
 alkylcarbonyloxy or alkoxy carbonyloxy with 1 to 4 C  
 25 atoms, or mono- oligo- or polyfluorinated alkyl or alkoxy  
 with 1 to 4 C atoms, preferably F, Cl, CN,  $\text{NO}_2$ ,  $\text{OCH}_3$ ,  
 or mono- oligo- or polyfluorinated alkyl or alkoxy with 1  
 to 4 C atoms,
- $Y^{01}$  and  $Y^{02}$  each, independently of one another, denote H, F, Cl or  
 30 CN.
- $R^{01}$  and  $R^{02}$  are independently of each other H, or straight chain or  
 branched alkyl with 1 to 20 C-atoms, preferably 1 to 6  
 C- atoms, and
- 35  $k$  and  $l$  are each and independently 0, 1, 2, 3 or 4.

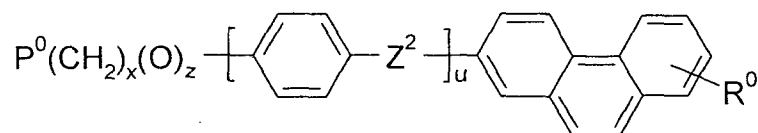
4. Birefringent RM lens according to one or more of notes 1 to 3  
 characterized in that the polymerizable liquid crystalline component  
 comprises A at least one polymerizable mesogenic compound  
 selected of formulae II-1 to II-27, and at least one polymerizable  
 mesogenic compound selected of formulae III-1 to III-12,







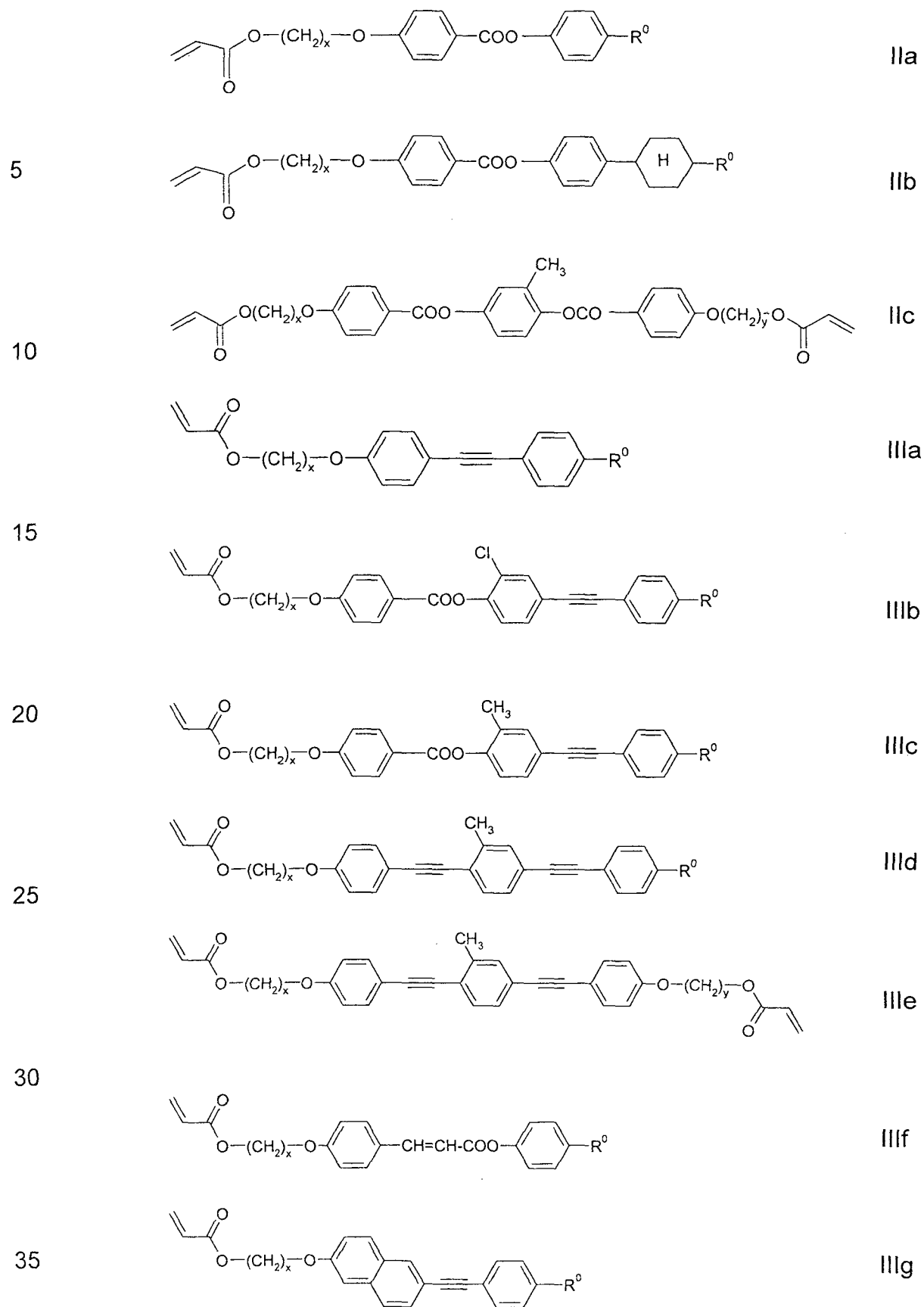


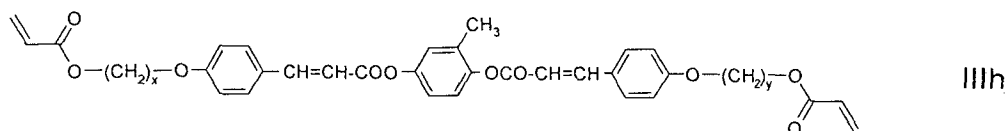


III-12

- 5            wherein  
                $P^0$             is, in case of multiple occurrences independently of one  
    another, a polymerizable group,
- 10             $A^0$             is, in case of multiple occurrences independently of one  
    another, 1,4-phenylene that is optionally substituted  
    with 1, 2, 3 or 4 groups L, or trans-1,4-cyclohexylene,
- $Z^0$             is, in case of multiple occurrences independently of one  
    another, -COO-, -OCO-, -CH<sub>2</sub>CH<sub>2</sub>-, or a single bond,
- 15             $r$             is 0, 1, 2, 3 or 4,
- $u$  and  $v$         are independently of each other 0, 1 or 2,
- $w$             is 0 or 1,
- 20             $x$  and  $y$         are independently of each other 0 or identical or  
    different integers from 1 to 12,
- $z$             is 0 or 1, with  $z$  being 0 if the adjacent  $x$  or  $y$  is 0,
- 25            the benzene and naphthalene rings can additionally be substituted  
    with one or more identical or different groups L, and
- the parameter  $R^0$ ,  $Y^0$ ,  $R^{01}$ ,  $R^{02}$  and L have the same meanings as
- 30            given above in formula I, and

5. Birefringent RM lens according to one or more of notes 1 to  
    4, characterized in that the polymerizable liquid crystalline component  
    A comprises at least one polymerizable mesogenic compound  
    selected of formulae IIa to IIc, and at least one polymerizable  
    mesogenic compound selected of formulae IIIa to IIIh,
- 35





- 5 wherein the parameter  $R^0$  has the same meaning as given above in formula I, x and y are independently of each other integers from 1 to 12.
- 10 6. Birefringent RM lens according to one or more of notes 1 to 5, characterized in that the non-polymerizable component (B) consists of at least one non-polymerizable compound selected from catalysts, sensitizers, stabilizers, polymerization initiators, inhibitors, chain-transfer agents, lubricating agents, wetting agents, dispersing agents, hydrophobing agents, adhesive agents, flow improvers,
- 15 defoaming agents, deaerators, diluents, reactive diluents, auxiliaries, colourants or pigments.
- 20 7. Birefringent RM lens according to one or more of notes 1 to 6, characterized in that the amount of the polymerizable liquid-crystalline component A in the liquid crystalline medium is more than 95 % by weight of the total liquid crystalline medium.
- 25 8. Birefringent RM lens according to one or more of notes 1 to 7, characterized in that the amount of the non-polymerizable component B in the liquid crystalline medium is less than 5 % by weight of the total liquid crystalline medium.
- 30 9. Birefringent RM lens according to one or more of notes 1 to 8, characterized in that the birefringence ( $\Delta n$ ) of the RM lens is in the range from 0.10 to 0.50.
- 35 10. Method of production of a birefringent RM lens according to one or more of notes 1 to 9, comprising the steps of
- providing a layer of a melt of the polymerizable liquid crystalline medium onto a substrate at room temperature or elevated temperature



- 56 -

- providing an inverse lens mould on top of the coated polymerizable liquid crystalline medium,
- annealing the polymerizable liquid crystalline medium in the mould at elevated temperature,
- 5       - cooling the mould,
- curing of the polymerizable liquid crystalline medium, and
- optionally removing the mould.

10       11. Use of a birefringent RM lens according to one or more of notes 1 to 9, in an electro optical device.

15       12. Electro optical device comprising at least one birefringent RM lens according to one or more of notes 1 to 9.

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## Examples

### General procedure

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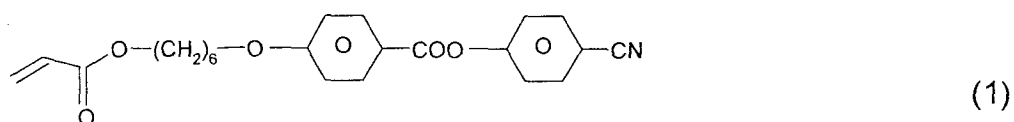
Test cells, are prepared from polymerizable liquid-crystalline media summarized in **table 2**, comprising the given amounts of the compounds summarized in **table 1**, by melting the medium, flow filling the medium into a rubbed polyimide glass cell having a thickness of 20  $\mu\text{m}$ , annealing the medium at the given temperature for 3 min, cooling the medium to room temperature and curing the medium using UV light (250nm-450 nm bandpass filter) at 50 mW/cm<sup>2</sup> for 60 seconds (irradiation dose of 3000 mJ).

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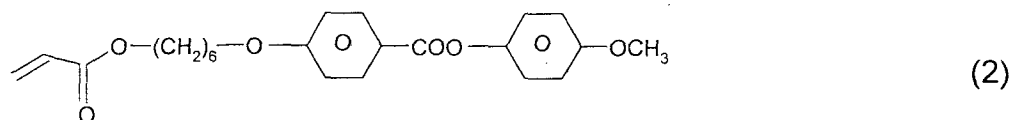
The melting points, annealing temperatures and the physical characteristics, such as the resulting  $\Delta n$  and b-value for each example are summarized in **table 3**.

Table 1: Compounds

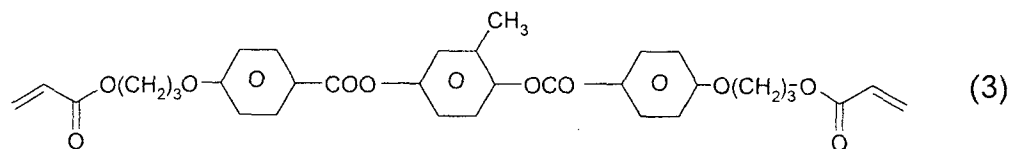
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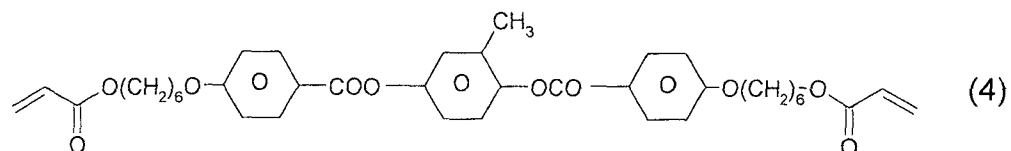
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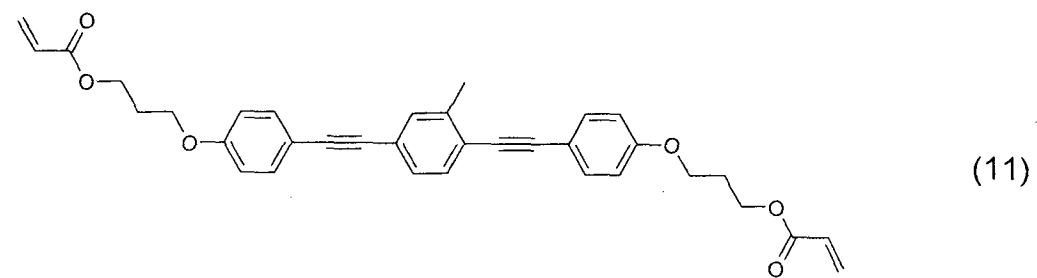
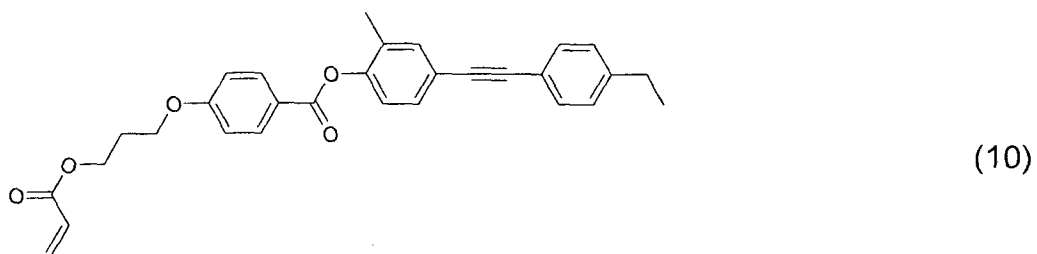
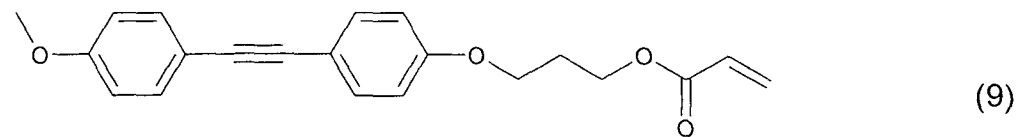
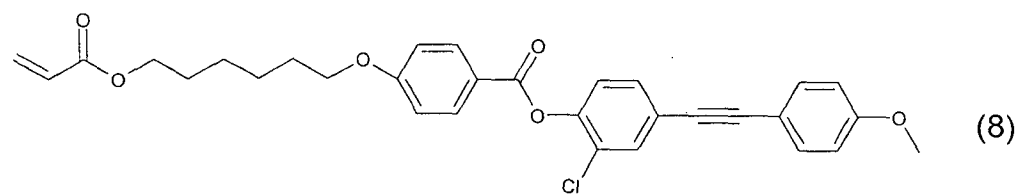
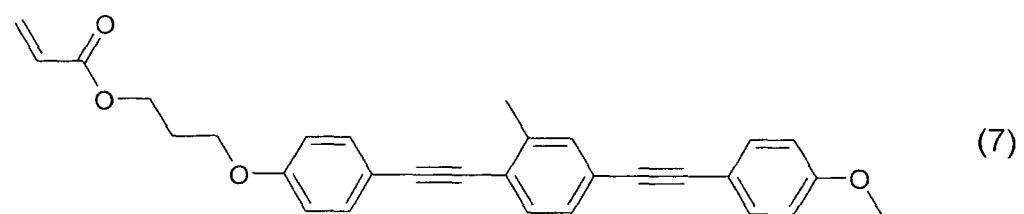
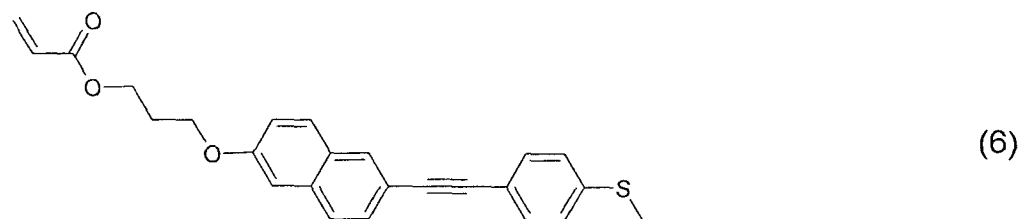
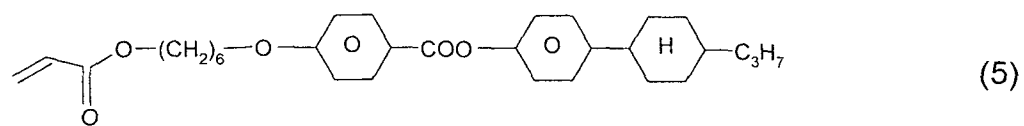


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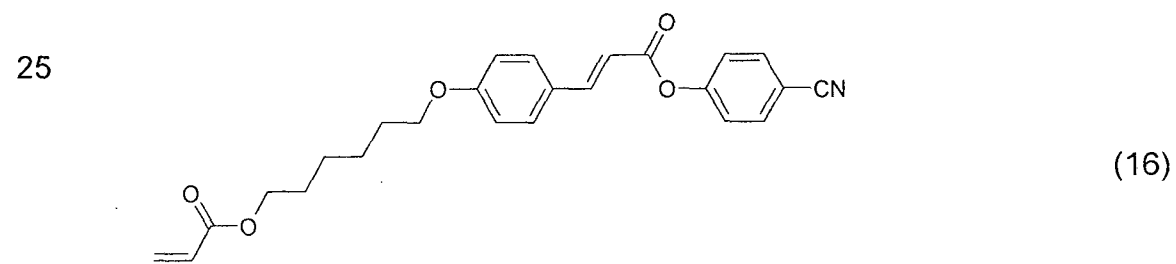
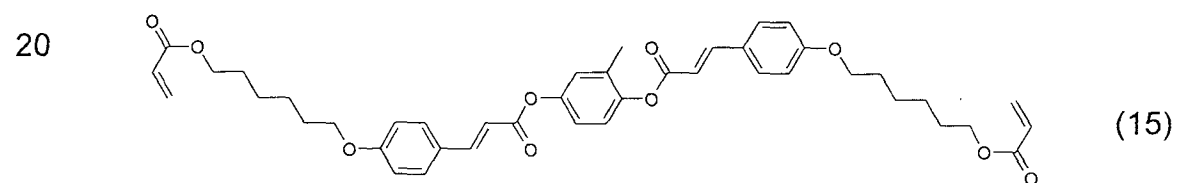
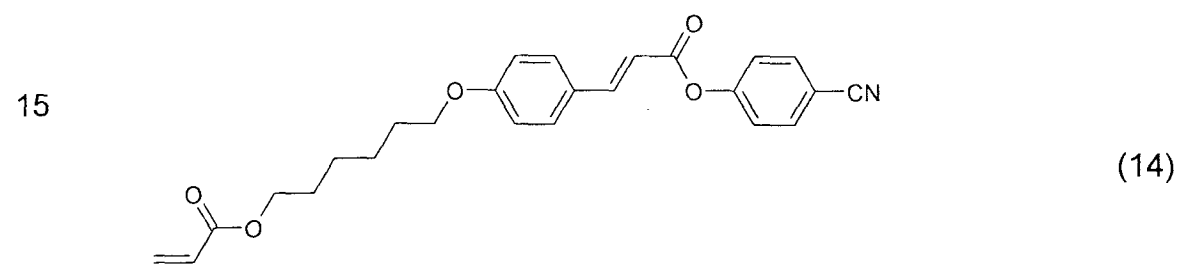
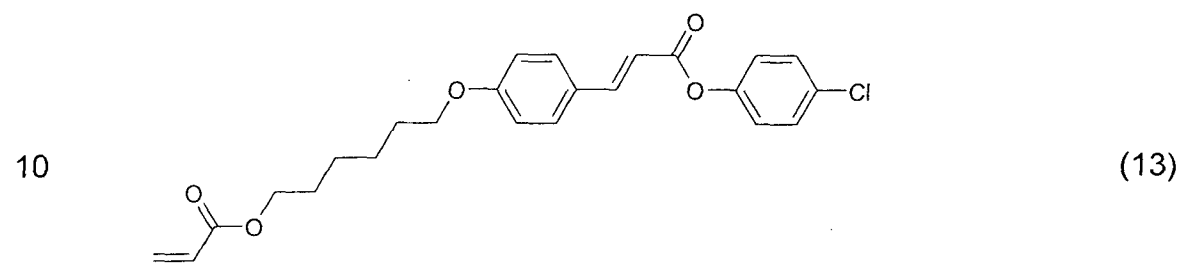
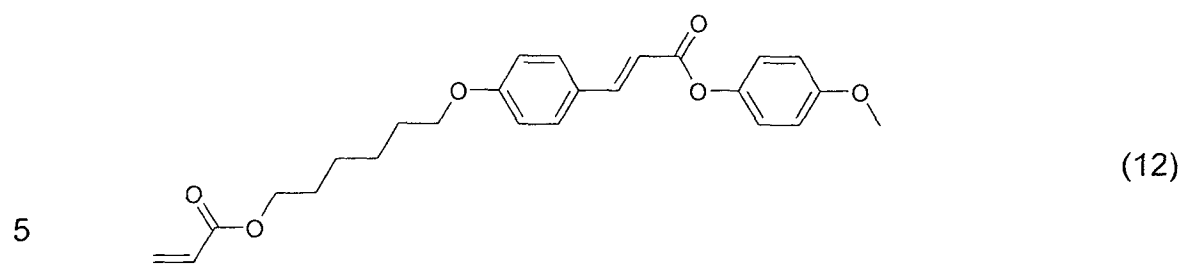


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Table 2 : Compositions of examples 1 to 14

	Compound*	Example1	Example 2	Example 3	Example 4	Example 5
5	(1)	19,73	19,73	19,73	19,73	19,73
	(2)	15,78	15,78	15,78	15,78	15,78
	(3)	23,68	23,68	23,68	23,68	23,68
10	(4)	11,84	11,84	11,84	11,84	11,84
	(5)	7,89	7,89	7,89	7,89	7,89
	(6)	20,00	-	-	-	-
15	(7)	-	20,00	-	-	-
	(8)	-	-	20,00	-	-
	(9)	-	-	-	20,00	-
20	(10)	-	-	-	-	20,00
	(11)	-	-	-	-	-
	(12)	-	-	-	-	-
	(13)	-	-	-	-	-
25	(14)	-	-	-	-	-
	(15)	-	-	-	-	-
	(16)	-	-	-	-	-
30	Irganox® 1076	0,08	0,08	0,08	0,08	0,08
	Irgacure® 651	1,00	1,00	1,00	1,00	1,00
35	Total amount	100,00	100,00	100,00	100,00	100,00

\*all given amounts in %w/w

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Compound*	Example 6	Example 7	Example 8	Example 9	Example 10
(1)	19,73	19,73	19,73	19,73	19,73
(2)	15,78	15,78	15,78	15,78	15,78
(3)	23,68	23,68	23,68	23,68	23,68
(4)	11,84	11,84	11,84	11,84	11,84
(5)	7,89	7,89	7,89	7,89	7,89
(6)	-	-	-	-	-
(7)	-	-	-	-	-
(8)	-	-	-	-	-
(9)	-	-	-	-	-
(10)	-	-	-	-	-
(11)	20,00	-	-	-	-
(12)	-	20,00	-	-	-
(13)	-	-	20,00	-	-
(14)	-	-	-	20,00	-
(15)	-	-	-	-	20,00
(16)	-	-	-	-	-
Irganox® 1076	0,08	0,08	0,08	0,08	0,08
Irgacure® 651	1,00	1,00	1,00	1,00	1,00
Total amount	100,00	100,00	100,00	100,00	100,00

\*all given amounts in %w/w

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Compound*	Example 11	Example 12	Example 13	Example 14
(1)	19,73	32,00	7,00	24,73
(2)	15,78	14,92	7,00	19,78
(3)	23,68	8,00	29,92	29,68
(4)	11,84	4,00	10,00	14,84
(5)	7,89	-	5,00	9,89
(6)	-	-	-	-
(7)	-	-	-	-
(8)	-	40,00	40,00	-
(9)	-	-	-	-
(10)	-	-	-	-
(11)	-	-	-	-
(12)	-	-	-	-
(13)	-	-	-	-
(14)	-	-	-	-
(15)	-	-	-	-
(16)	20,00	-	-	-
Irganox® 1076	0,08	0,08	0,08	0,08
Irgacure® 651	1,00	1,00	1,00	1,00
Total amount	100,00	100,00	100,00	100,00

\*all given amounts in %w/w

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Compound*	Example 15	Example 16	Example 17	Example 18
(1)	21,73	18,73	15,78	12,73
(2)	17,38	14,98	12,57	10,18
(3)	26,08	22,48	18,86	15,28
(4)	13,04	11,24	9,43	7,64
(5)	8,69	7,49	6,28	5,09
(6)	-	-	-	-
(7)	12,00	24,00	36,00	48,00
(8)	-	-	-	-
(9)	-	-	-	-
(10)	-	-	-	-
(11)	-	-	-	-
(12)	-	-	-	-
(13)	-	-	-	-
(14)	-	-	-	-
(15)	-	-	-	-
(16)	-	-	-	-
Irganox® 1076	0,08	0,08	0,08	0,08
Irgacure® 651	1,00	1,00	1,00	1,00
Total amount	100,00	100,00	100,00	100,00

\*all given amounts in %w/w



Table 3 : Physical characteristics and annealing temperatures of examples 1 to 14

5	<b>Example</b>	<b><math>\Delta n</math></b>	<b>Mp. [°C]</b>	<b>Annealing temp. [°C]</b>	<b>b-value</b>	<b>Transmission at 550 nm [%]</b>
	1)	0,235	89,0	86,0	10,0	95,4
	2)	0,220	106,7	104,0	6,4	96,1
10	3)	0,219	97,7	95,0	5,4	95,4
	4)	0,210	76,7	74,0	5,7	97,1
	5)	0,214	92,8	90,0	5,0	96,6
15	6)	0,226	100,3	97,0	6,8	93,4
	7)	0,165	86,8	84,0	6,6	95,5
	8)	0,185	83,8	81,0	5,0	96,9
20	9)	0,193	89,6	87,0	5,0	96,1
	10)	0,189	106,0	103,0	4,7	96,5
	11)	0,185	88,6	86,0	5,3	94,9
25	12)	0,240	90,1	80,0	6,6	-
	13)	0,240	122,1	112,0	6,5	-
	14)	0,157	91,2	89,0	5,1	97,6
30	15)	0,212	97,7	80,0	8,8	96,9
	16)	0,254	109,0	80,0	9,5	95,4
	17)	0,294	124,9	80,0	9,8	96,0
35	18)	0,338	137,5	80,0	10,2	93,4

As can be seen from table 3, all examples show high values for the birefringence, low values for the yellowness index and high values for the transmission. Moreover, all examples showed an homogeneous planar alignment, which was confirmed by dark state testing between crossed polarizers.

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### Patent Claims

1. Birefringent RM lens obtainable from a polymerizable liquid crystalline medium consisting of
- 5       - a polymerizable liquid crystalline component (A) consisting of one or more polymerizable mesogenic compounds, and
- a non-polymerizable component (B), consisting of one or more non-polymerizable compounds.

- 10    2. Birefringent RM lens according to claim 1, characterized in that the polymerizable liquid crystalline component (A) comprises at least one polymerizable mesogenic compound selected of formula I,



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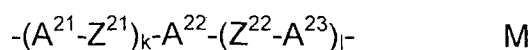
wherein

P       is a polymerizable group,

Sp       is a spacer group or a single bond,

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MG       is a rod-shaped mesogenic group selected of formula M,



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$A^{21}$  to  $A^{23}$    are in each occurrence independently of one another an aryl-, heteroaryl-, heterocyclic- or alicyclic group optionally being substituted by one or more identical or different groups L,

30

$Z^{21}$  and  $Z^{22}$    are in each occurrence independently from each other, -O-, -S-, -CO-, -COO-, -OCO-, -S-CO-, -CO-S-, -O-COO-, -CO-NR<sup>01</sup>-, -NR<sup>01</sup>-CO-, -NR<sup>01</sup>-CO-NR<sup>02</sup>-, -NR<sup>01</sup>-CO-O-, -O-CO-NR<sup>01</sup>-, -OCH<sub>2</sub>-, -CH<sub>2</sub>O-, -SCH<sub>2</sub>-, -CH<sub>2</sub>S-, -CF<sub>2</sub>O-, -OCF<sub>2</sub>-, -CF<sub>2</sub>S-, -SCF<sub>2</sub>-, -CH<sub>2</sub>CH<sub>2</sub>-, -CH<sub>2</sub>CF<sub>2</sub>-, -CF<sub>2</sub>CH<sub>2</sub>-, -CF<sub>2</sub>CF<sub>2</sub>-, -CH=N-,

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-N=CH-, -N=N-, -CH=CR<sup>01</sup>-, -CY<sup>01</sup>=CY<sup>02</sup>-, -C≡C-,  
 -CH=CH-COO-, -OCO-CH=CH-, or a single bond,

5 L is, in case of multiple occurrences independently of one another, H, halogen, CN or optionally halogenated alkyl, alkoxy, alkylcarbonyl, alkoxy carbonyl, alkylcarbonyloxy or alkoxy carbonyloxy with 1 to 5 C atoms,

10 R<sup>0</sup> is H, alkyl, alkoxy, thioalkyl, alkylcarbonyl, alkoxy carbonyl, alkylcarbonyloxy or alkoxy carbonyloxy with 1 to 20 C atoms or is Y<sup>0</sup> or P-Sp-,

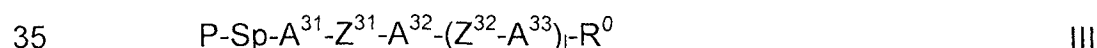
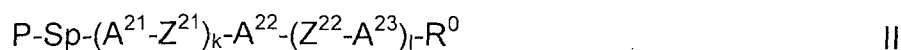
15 Y<sup>0</sup> is F, Cl, CN, NO<sub>2</sub>, OCH<sub>3</sub>, OCN, SCN, optionally fluorinated alkylcarbonyl, alkoxy carbonyl, alkylcarbonyloxy or alkoxy carbonyloxy with 1 to 4 C atoms, or mono- oligo- or polyfluorinated alkyl or alkoxy with 1 to 4 C atoms,

20 Y<sup>01</sup> and Y<sup>02</sup> each, independently of one another, denote H, F, Cl or CN.

25 R<sup>01</sup> and R<sup>02</sup> are independently of each other H, or straight chain or branched alkyl with 1 to 20 C-atoms, preferably 1 to 6 C- atoms, and

k and l are each and independently 0, 1, 2, 3 or 4.

3. Birefringent RM lens according to claim 1 or 2 characterized in that the polymerizable liquid crystalline component (A) comprises at least one polymerizable mesogenic compound selected formula II, and at least one polymerizable mesogenic compound selected of formula III,



wherein

P is a polymerizable group,

5 Sp is a spacer group or a single bond,

10  $A^{21}$  to  $A^{33}$  are in each occurrence independently of one another an aryl-, heteroaryl-, heterocyclic- or alicyclic group optionally being substituted by one or more identical or different groups L,

15  $Z^{21}$  and  $Z^{22}$  are in each occurrence independently from each other, -O-, -S-, -CO-, -COO-, -OCO-, -S-CO-, -CO-S-, -O-COO-, -CO-NR<sup>01</sup>-, -NR<sup>01</sup>-CO-, -NR<sup>01</sup>-CO-NR<sup>02</sup>-, -NR<sup>01</sup>-CO-O-, -O-CO-NR<sup>01</sup>-, -OCH<sub>2</sub>-, -CH<sub>2</sub>O-, -SCH<sub>2</sub>-, -CH<sub>2</sub>S-, -CF<sub>2</sub>O-, -OCF<sub>2</sub>-, -CF<sub>2</sub>S-, -SCF<sub>2</sub>-, -CH<sub>2</sub>CH<sub>2</sub>-, -(CH<sub>2</sub>)<sub>4</sub>-, -CF<sub>2</sub>CH<sub>2</sub>-, -CH<sub>2</sub>CF<sub>2</sub>-, -CF<sub>2</sub>CF<sub>2</sub>-, or a single bond,

20  $Z^{31}$  and  $Z^{32}$  are in each occurrence independently from each other -CH=N-, -N=CH-, -N=N-, -CH=CR<sup>01</sup>-, -CY<sup>01</sup>=CY<sup>02</sup>-, -C≡C-, -CH=CH-COO-, -OCO-CH=CH-, and if present both, one of  $Z^{31}$  and  $Z^{32}$  can also denote -O-, -S-, -CO-, -COO-, -OCO-, -S-CO-, -CO-S-, -O-COO-, -CO-NR<sup>01</sup>-, 25 -NR<sup>01</sup>-CO-, -NR<sup>01</sup>-CO-NR<sup>02</sup>-, -NR<sup>01</sup>-CO-O-, -O-CO-NR<sup>01</sup>-, -OCH<sub>2</sub>-, -CH<sub>2</sub>O-, -SCH<sub>2</sub>-, -CH<sub>2</sub>S-, -CF<sub>2</sub>O-, -OCF<sub>2</sub>-, -CF<sub>2</sub>S-, -SCF<sub>2</sub>-, -CH<sub>2</sub>CH<sub>2</sub>-, -(CH<sub>2</sub>)<sub>4</sub>-, -CF<sub>2</sub>CH<sub>2</sub>-, -CH<sub>2</sub>CF<sub>2</sub>-, -CF<sub>2</sub>CF<sub>2</sub>-, or a single bond,

30 L is, in case of multiple occurrences independently of one another, H, halogen, CN or optionally halogenated alkyl, alkoxy, alkylcarbonyl, alkoxycarbonyl, alkylcarbonyloxy or alkoxycarbonyloxy with 1 to 5 C atoms,

35 R<sup>0</sup> is H, optionally fluorinated alkyl, alkoxy, thioalkyl, alkylcarbonyl, alkoxycarbonyl, alkylcarbonyloxy or

alkoxycarbonyloxy with 1 to 20 C atoms or is  $Y^0$  or P-Sp-,

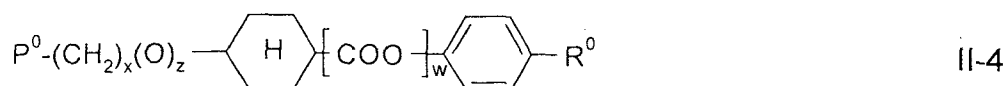
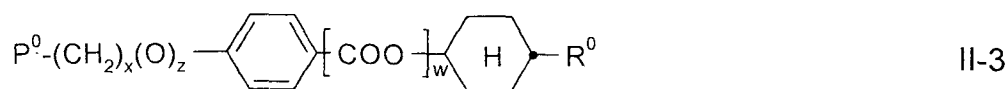
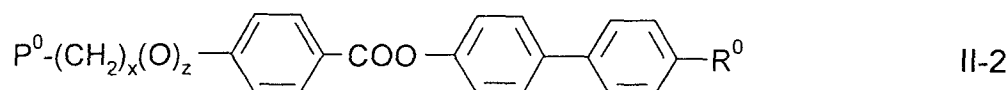
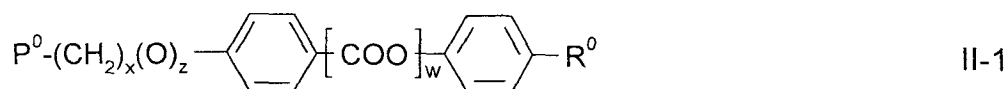
$Y^0$  is F, Cl, CN,  $NO_2$ ,  $OCH_3$ , OCN, SCN, optionally fluorinated alkylcarbonyl, alkoxycarbonyl, alkylcarbonyloxy or alkoxycarbonyloxy with 1 to 4 C atoms, or mono- oligo- or polyfluorinated alkyl or alkoxy with 1 to 4 C atoms, preferably F, Cl, CN,  $NO_2$ ,  $OCH_3$ , or mono- oligo- or polyfluorinated alkyl or alkoxy with 1 to 4 C atoms,

$Y^{01}$  and  $Y^{02}$  each, independently of one another, denote H, F, Cl or CN.

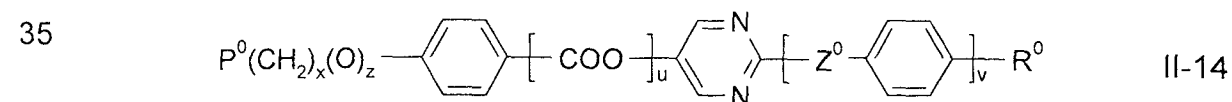
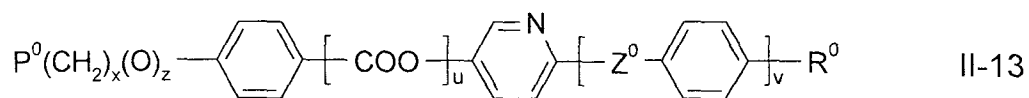
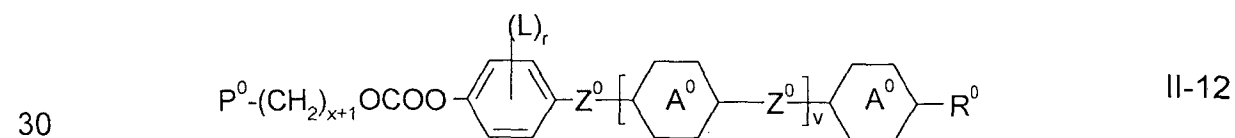
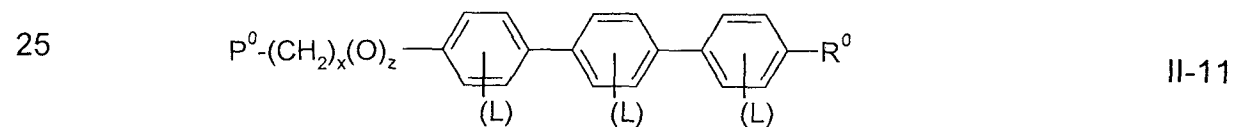
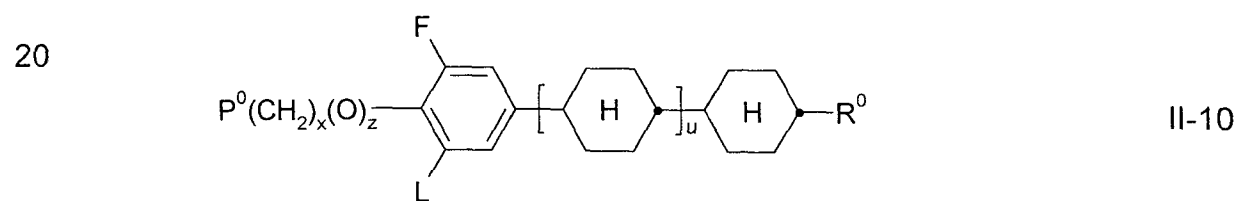
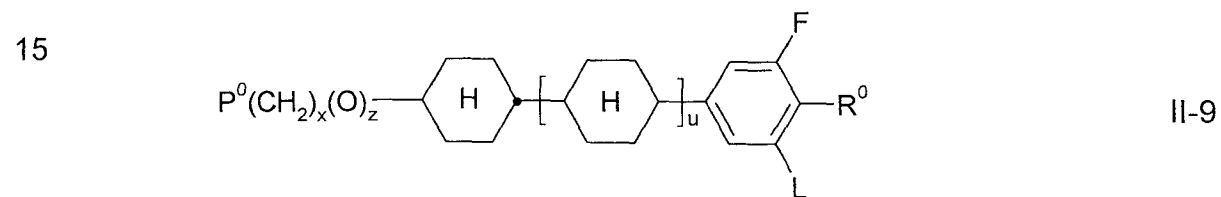
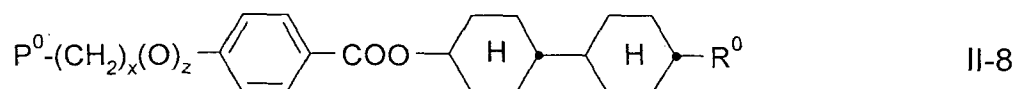
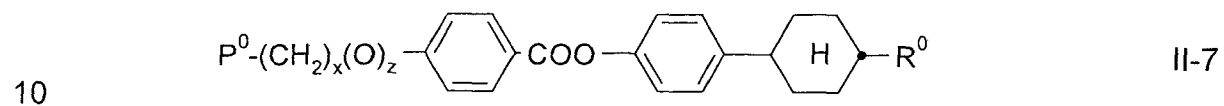
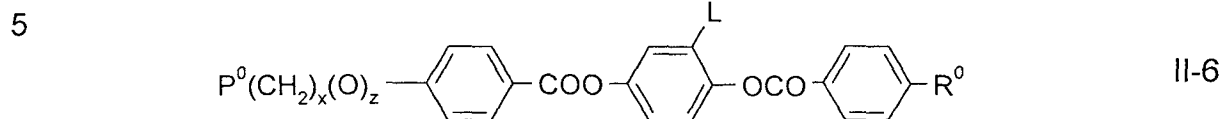
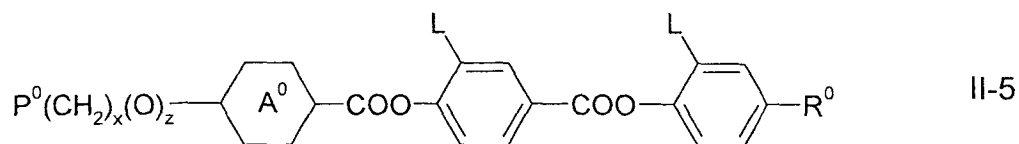
$R^{01}$  and  $R^{02}$  are independently of each other H, or straight chain or branched alkyl with 1 to 20 C-atoms, preferably 1 to 6 C- atoms, and

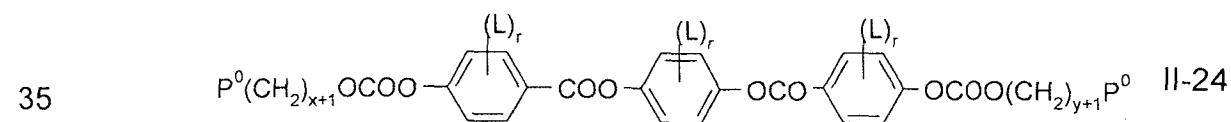
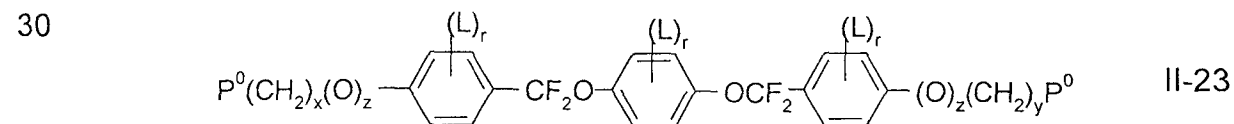
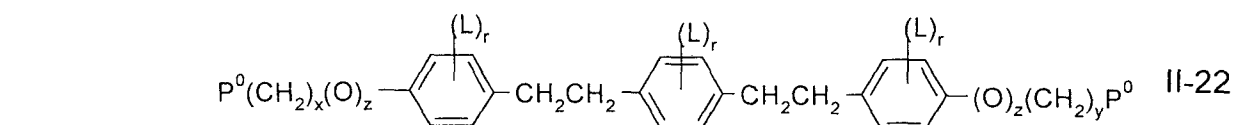
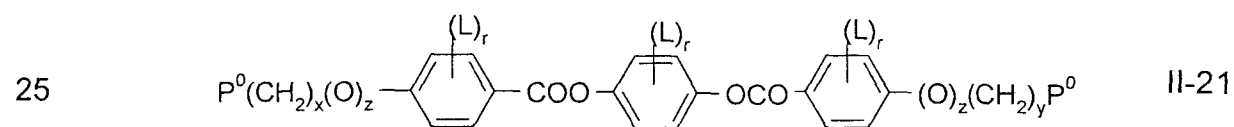
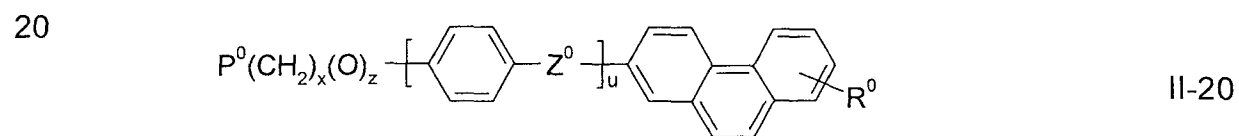
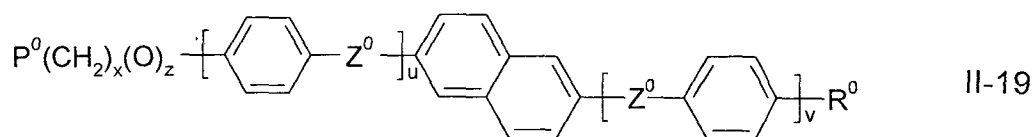
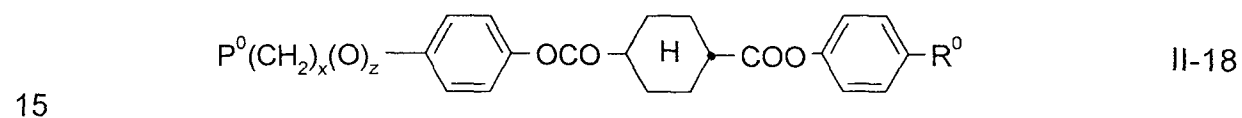
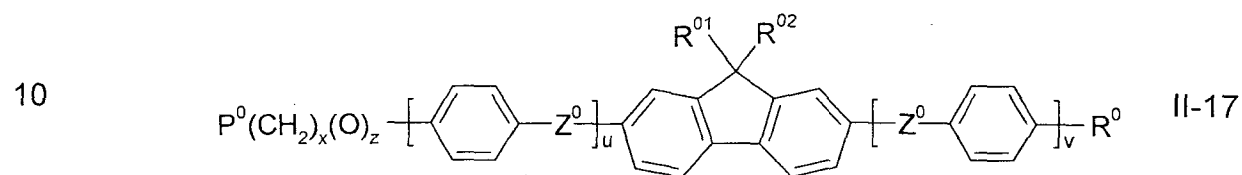
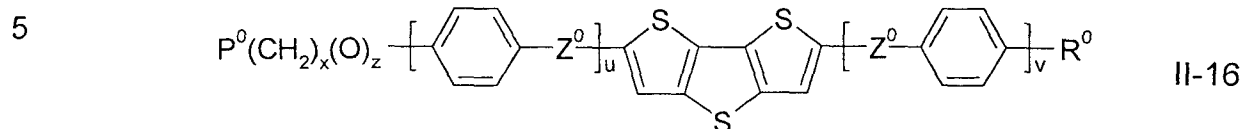
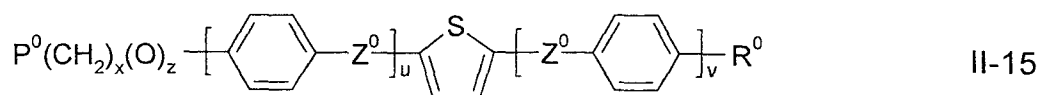
k and l are each and independently 0, 1, 2, 3 or 4.

4. Birefringent RM lens according to one or more of claims 1 to 3 characterized in that the polymerizable liquid crystalline component comprises A at least one polymerizable mesogenic compound selected of formulae II-1 to II-27, and at least one polymerizable mesogenic compound selected of formulae III-1 to III-12,

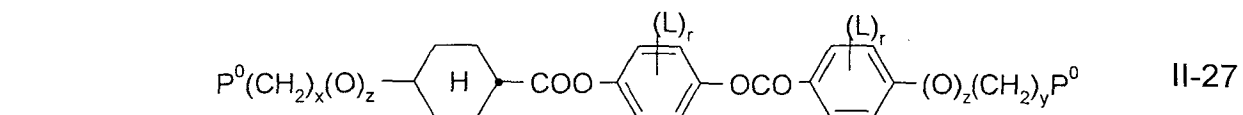
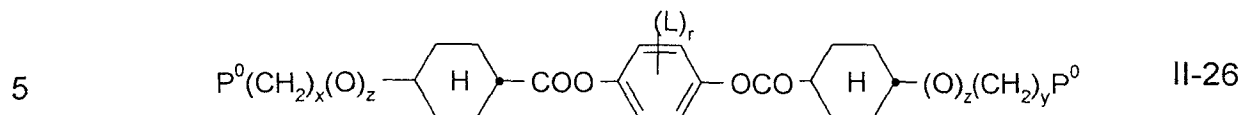
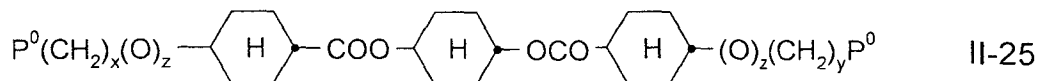


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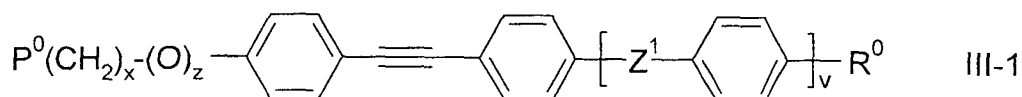




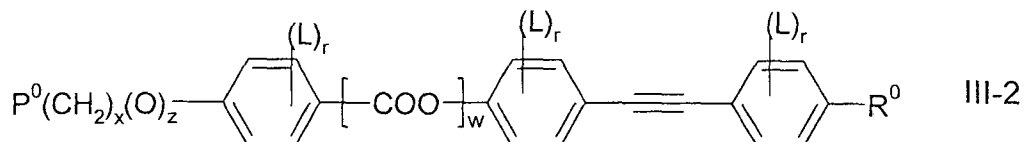




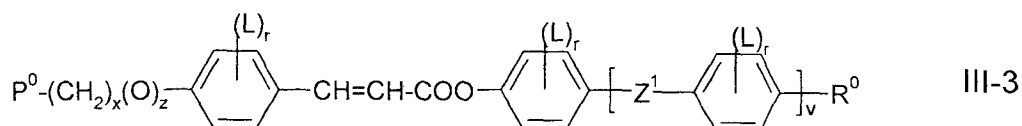
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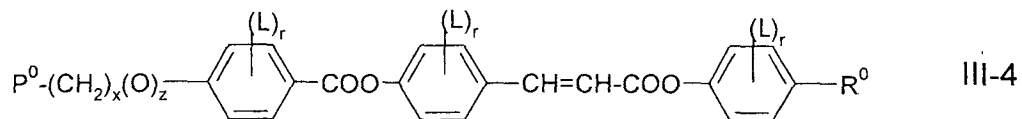
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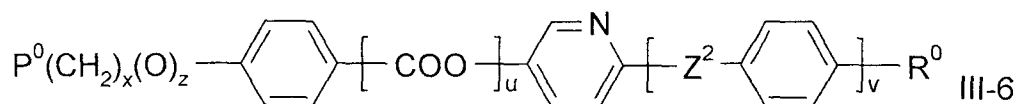
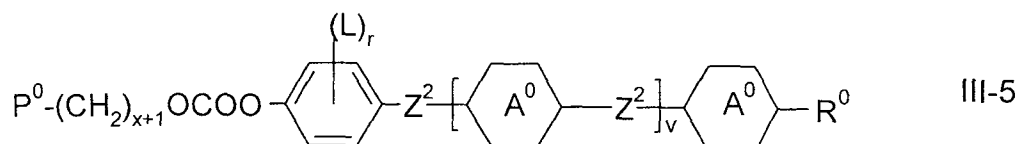
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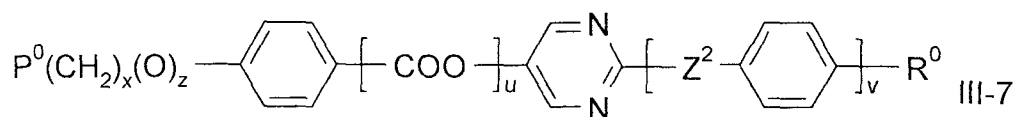
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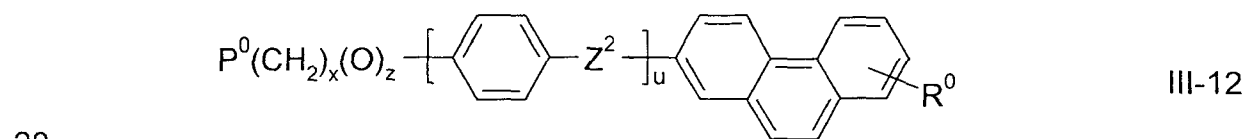
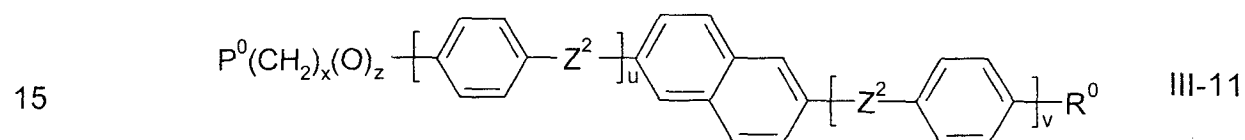
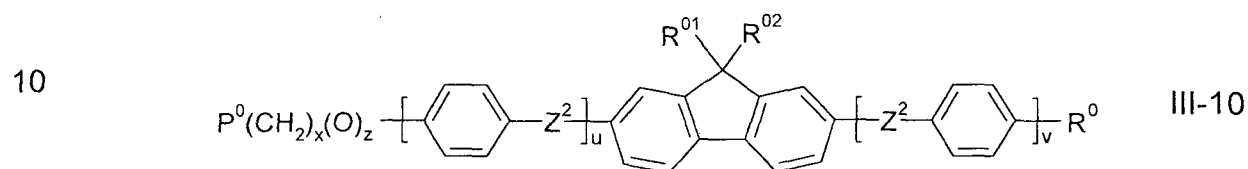
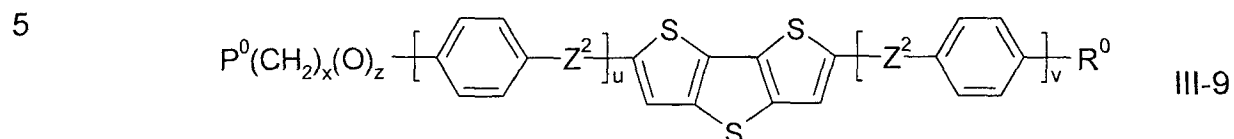
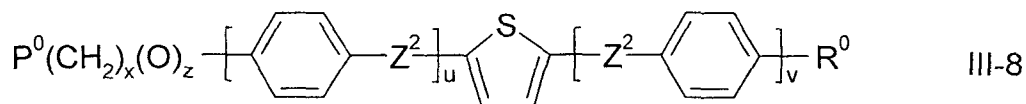


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wherein

$P^0$  is, in case of multiple occurrences independently of one another, a polymerizable group,

$A^0$  is, in case of multiple occurrences independently of one another, 1,4-phenylene that is optionally substituted with 1, 2, 3 or 4 groups L, or trans-1,4-cyclohexylene,

$Z^0$  is, in case of multiple occurrences independently of one another, -COO-, -OCO-, -CH<sub>2</sub>CH<sub>2</sub>-, or a single bond,  
 $r$  is 0, 1, 2, 3 or 4,

$u$  and  $v$  are independently of each other 0, 1 or 2,

$w$  is 0 or 1,

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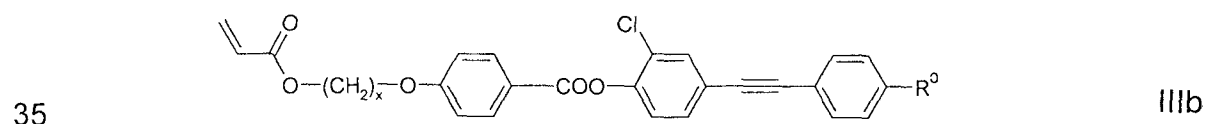
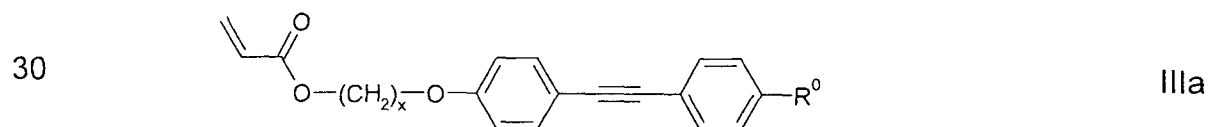
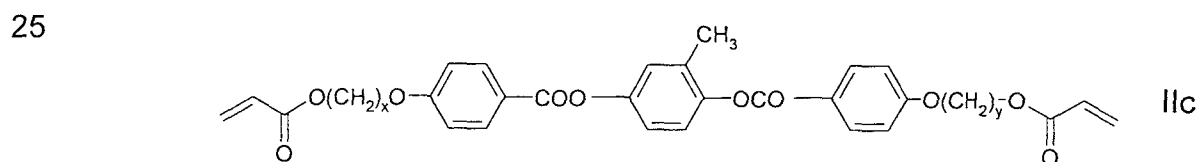
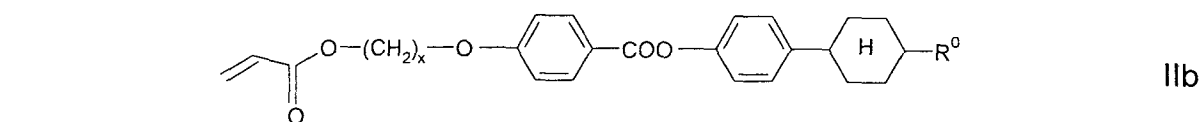
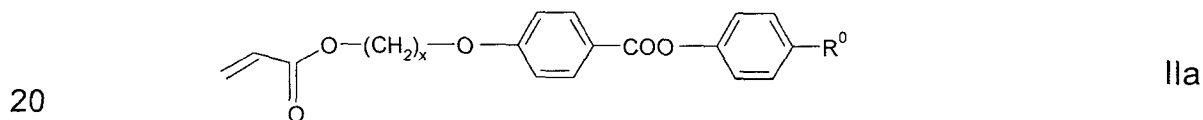
x and y are independently of each other 0 or identical or different integers from 1 to 12,

5 z is 0 or 1, with z being 0 if the adjacent x or y is 0,

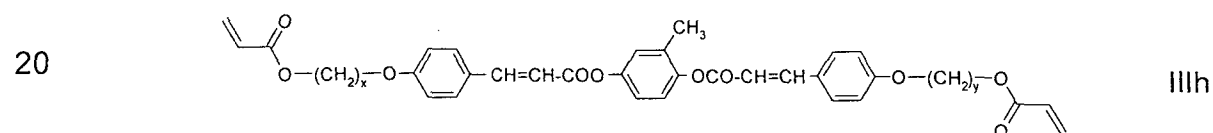
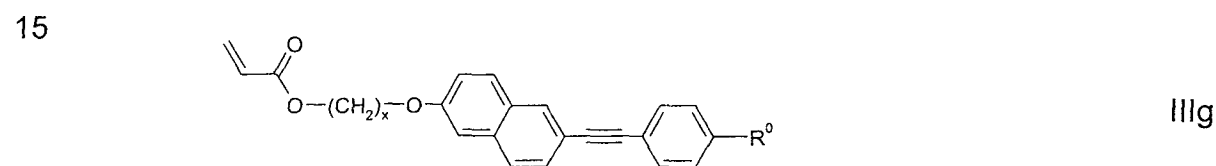
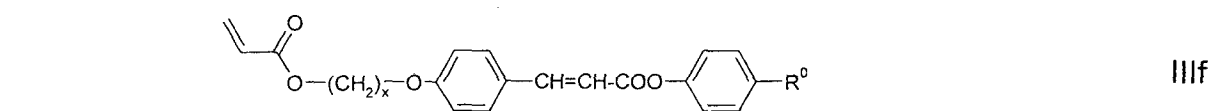
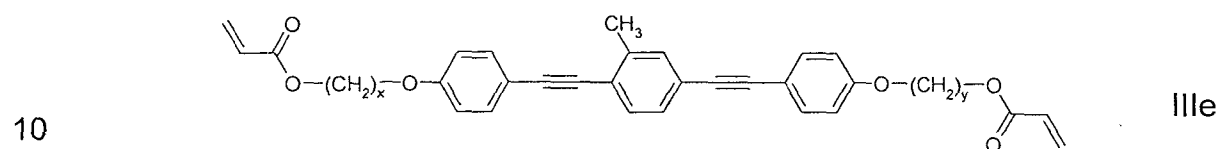
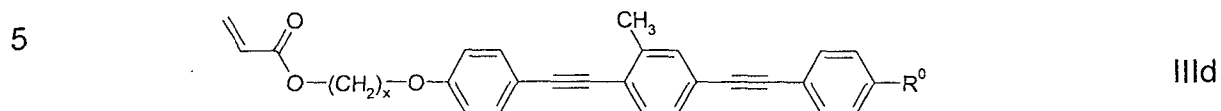
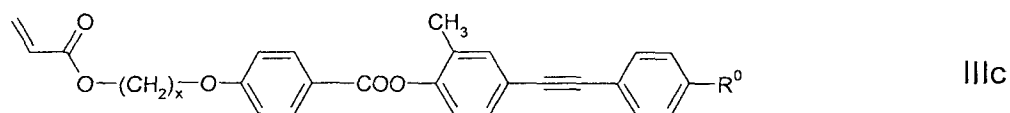
the benzene and naphthalene rings can additionally be substituted with one or more identical or different groups L, and

10 the parameter  $R^0$ ,  $Y^0$ ,  $R^{01}$ ,  $R^{02}$  and L have the same meanings as given above in formula I, and

5. Birefringent RM lens according to one or more of claims 1 to 4, characterized in that the polymerizable liquid crystalline component A comprises at least one polymerizable mesogenic compound selected of formulae IIa to IIc, and at least one polymerizable mesogenic compound selected of formulae IIIa to IIIh,



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 wherein the parameter  $R^0$  has the same meaning as given above in formula I, x and y are independently of each other integers from 1 to 12.

- 30
 6. Birefringent RM lens according to one or more of claims 1 to 5, characterized in that the non-polymerizable component (B) consists of at least one non-polymerizable compound selected from catalysts, sensitizers, stabilizers, polymerization initiators, inhibitors, chain-transfer agents, lubricating agents, wetting agents, dispersing agents, hydrophobing agents, adhesive agents, flow improvers, defoaming agents, deaerators, diluents, reactive diluents, auxiliaries, colourants or pigments.

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7. Birefringent RM lens according to one or more of claims 1 to 6, characterized in that the amount of the polymerizable liquid-crystalline component A in the liquid crystalline medium is more than 95 % by weight of the total liquid crystalline medium.
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8. Birefringent RM lens according to one or more of claims 1 to 7, characterized in that the amount of the non-polymerizable component B in the liquid crystalline medium is less than 5 % by weight of the total liquid crystalline medium.
- 15
9. Birefringent RM lens according to one or more of claims 1 to 7, characterized in that the uncured polymerizable liquid crystalline medium exhibits a room temperature stability against crystallization for at least 1 hour.
- 20
10. Birefringent RM lens according to one or more of claims 1 to 8, characterized in that the birefringence ( $\Delta n$ ) of the RM lens is in the range from 0.10 to 0.50.
- 25
11. Method of production of a birefringent RM lens according to one or more of claims 1 to 9, comprising the steps of
- providing a layer of a melt of the polymerizable liquid crystalline medium onto a substrate at elevated temperature
  - providing an inverse lens mould on top of the coated polymerizable liquid crystalline medium,
  - annealing the polymerizable liquid crystalline medium in the mould at elevated temperature ,
  - cooling the mould,
  - curing of the polymerizable liquid crystalline medium, and
  - 30 - optionally removing the mould.
- 35
12. Use of a birefringent RM lens according to one or more of claims 1 to 9, in an electro optical device.
13. Electro optical device comprising at least one birefringent RM lens according to one or more of claims 1 to 9.

## INTERNATIONAL SEARCH REPORT

International application No  
PCT/EP2013/003463

A. CLASSIFICATION OF SUBJECT MATTER  
INV. G02B5/30 C09K19/04  
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)  
G02B C09K

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

EPO-Internal, WPI Data

## C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	JP 2012 137616 A (DAINIPPON INK & CHEMICALS) 19 July 2012 (2012-07-19) cited in the application	1-4,6-13
Y	tables 1-3 paragraphs [0026] - [0071], [0080] - [0098], [0133] - [0147] -----	5
Y	GB 2 425 774 A (MERCK PATENT GMBH [DE]) 8 November 2006 (2006-11-08) example 1; table 1; compounds 1-4 -----	5
A	WO 2008/062188 A1 (AU OPTRONICS CORP; WOODGATE GRAHAM [GB]; HARROLD JONATHAN [GB]) 29 May 2008 (2008-05-29) claims 1-24 page 8, line 8 - line 36 -----	1,11



Further documents are listed in the continuation of Box C.



See patent family annex.

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"&" document member of the same patent family

Date of the actual completion of the international search

9 April 2014

Date of mailing of the international search report

16/04/2014

Name and mailing address of the ISA/

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NL - 2280 HV Rijswijk  
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Authorized officer

Bockstahl, Frédéric

# INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No

PCT/EP2013/003463

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