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one or two substrates, one or more orientation layers on each
substrate and one or more anisotropic films of cross-linked liquid
crystalline monomers or oligomers with locally different
orientation of the liquid crystal molecules on the substrate or
10 between the substrates. The invention also relates to the
production and use of such components.

 Anisotropic transparent or coloured polymer network layers
with highly-resolved preset three-dimensional orientation of the
15 optical axis are of great importance in display technology,
integrated optics and prevention of forgery.

 EP-A-545 234 discloses liquid crystal cells with fine
structures comprising regions with defined different orientation
20 and consequently different refractive indices. Refractive index
patterns of this kind in a liquid crystal are produced by micro-
mechanically generating a line structure on the surface of the
orientation layer bounding the liquid crystal using a stylus
moving in correspondence with the scanning pen of a scanning
25 force microscope (scanning probe or atomic force microscope
[AFM]). Depending on the pressure exerted by the stylus the lines
can consist of relatively pronounced grooves or only of strings of
uniformly aligned molecules. In the following description the
term "scratching" is used for the process of producing a line
30 structure by means of a stylus. In a cell of plates structured in
this manner the pattern on the orientation layer constitutes an
orientation pattern which is transferred to the liquid crystal.
Optically non-linear liquid crystalline or optionally frozen-in
optical waveguide structures are important applications.

35

 EP-A-611 981 discloses materials and methods of stabilising
orientation structures in monomeric liquid crystals by cross-
linking. The orientation structures in the liquid crystal are



induced by orientation layers of a photo-orientatable polymer network ("PPN layers"). To this end, in a first step the desired pattern is generated photochemically with polarised light in the PPN orientation layer and in a second step is transferred to a liquid crystal layer deposited thereon by spin coating (the PPN method). The liquid crystal structure is then stabilised by cross-linking. A cross-linked liquid crystal layer of this kind will hereinafter be called LCP (liquid crystal polymer) for short.

European Patent Application No. 689 084 describes optical components having a layer structure of a number of PPN orientation layers and anisotropic layers of cross-linked liquid crystalline monomers, all subject to the limitations of the PPN method, i.e. limited resolution, only slightly variable direction of director and limited control of tilt angle.

The not-yet published Swiss Patent Application No. 2036/95 describes the production and use of optical components for use as masks, e.g. for transferring a polarisation pattern to a polarisation-sensitive layer.

European Patent Application No. 689 065 describes the optical PPN components with a layer structure and the production thereof, the components being particularly suitable for use against forgery.

It has now been found that the use of cross-linkable liquid crystals together with micromechanically scratched orientation layers can result in structures having much better or even completely new properties.

According to the invention, the component referred to hereinbefore is characterized in that the surfaces of the orientation layers adjacent the liquid crystal layers have orientation patterns with a defined parallel or fan-like line structure in locally limited regions, the average spacing between the lines not being greater than the thickness of the liquid crystal

layer and the angle between neighbouring lines being not greater than 30°.

Smaller structures, for example, can be produced in this way, in contrast to the PPN process. In addition to the preferred direction, the tilt angle of the molecules can be controlled and altered, and the preferred direction can vary continuously locally. The present component needs only one substrate, in contrast to the liquid crystal cells described in EP-A-545 234. Three-dimensional structures (multiple layers) can also be constructed.

Embodiments of the invention will now be described with reference to the accompanying drawings in which:

Fig. 1 is a diagrammatic sectional representation of an embodiment of the component according to the invention;

Fig. 2 is a diagrammatic sectional representation of another embodiment;

Fig. 3 is a diagrammatic top view of another embodiment;

Fig. 4 shows an arrangement for producing components according to the invention, and

Fig. 5 shows variant ways of guiding the stylus.

As shown in Fig. 1, an orientation layer 2 is disposed on a substrate 1 (e.g. glass). The layer preferably consists of polyimide and is applied preferably by spin coating in a manner known to a person skilled in the art. In a first step the orientation layer is rubbed in a conventional manner parallel to the y-direction shown in the drawing. The purpose, as is known, is to obtain substantially uniform orientation of an adjacent liquid crystal layer parallel to the direction of rubbing. Next, a desired orientation pattern is scratched by a micromechanical stylus. The method of controlling a stylus is known from the technique of scanning probe microscopy. The stylus moves parallel to the

x-axis and produces a fine structure on the surface, diagrammatically indicated by grooves 4 in the drawing. Next, a suitable liquid crystal monomer mixture of desired thickness is applied by spin-coating. In the non-scratched regions 5 the liquid crystal layer becomes oriented parallel to the original direction of rubbing y and in the scratched region 4 parallel to the direction x of scratching. The orientation pattern can be written in with a single stylus or by a number of styluses in parallel.

Next, the liquid crystal layer is stabilized by chemical or photochemical cross-linking. If individual parts of the layer do not need to be fixed, in the case of photochemical cross-linking, illumination can be through a suitable mask in the last-mentioned step. In this example, therefore, the finished LCP layer comprises regions 7 in which the liquid crystal molecules are oriented parallel to the direction y of rubbing, and regions 6 in which the molecules are oriented parallel to the direction x of rubbing.

The stylus can also be controlled so as to control and modulate the tilt angle of the liquid crystal molecules. As is known, liquid crystal molecules are not necessarily parallel to the surface, but are tilted from the plane through an angle depending on the polymer in the orientation layer. The direction of rubbing or scratching decides whether they tilt through a positive or negative angle to the x direction. How this can be used according to the invention is shown in Fig. 5; the scratching movement can occur always in the same direction, when a) the stylus is raised when returning or b) during the return each previously written track is overwritten. In the latter case the feed in the y direction must be synchronised accordingly. These two scratching methods result in the maximum polymer-specific tilt angle. The scratching pattern shown in c) results in a zero tilt angle, whereas pattern d) or e) results in values lower than the possible maximum. The tilt angle can therefore be controlled and modulated through choice of the method of scratching.

Since the cross-linked polymer is mechanically stable, the above method can be repeatedly used with or without buffer

polymer layers. This is shown in Fig. 2. Layers 21, 22, 23 correspond to layers 1, 2, 3 in Fig. 1. After the layer 23 has been cross-linked it is again rubbed and micromechanically scratched. Alternatively, further layers can be applied before rubbing and scratching, e.g. in order to improve the optical properties or the orientation properties. Spin-coating of the layer 24 and subsequent cross-linking results in a further orientation pattern 25, 26. The method can be repeated as often as required, so that structured, three-dimensional refractive index patterns are obtained in the z direction also.

The invention is of use wherever static, i.e. non-switching, refractive-index patterns with high resolution are needed. The range of application also includes all areas where components produced by the PPN process can be used. However, the invention can also be used to obtain finer structures, continuous changes in the direction of the director and additional control of the tilt angle, thus opening completely new possibilities in addition to the already-known PPN applications.

Such possibilities include e.g. optical waveguide structures in integrated optics, such as couplers, coupling-in structures (e.g. gratings), delay lines or polarisation-influencing structures. In combination with active or NLO-active components, these optical waveguide structures can also be used in simple manner as a connecting network. Three-dimensional networks can in particular be used for coupling between layers or interaction-free crossings of optical waveguides. One example of the possibilities of the invention is the 180° optical waveguide bend in Fig. 3. Light 31 is conveyed in a waveguide 33 and makes a 180° bend as far as point 32. To produce a waveguide structure of this kind, the direction of scratching must be continuously variable locally both in the region 34 inside the bend and in the region 35 outside the bend, i.e. in the waveguide 33 itself. This is not possible with any of the previously-known processes.

Static refractive-index patterns can also be used to produce high-resolution masks, e.g. for PPN illumination. The invention

can be used to produce masks with higher resolution and complexity than in the photolithographic methods described in Swiss Patent Application No. 2036/95.

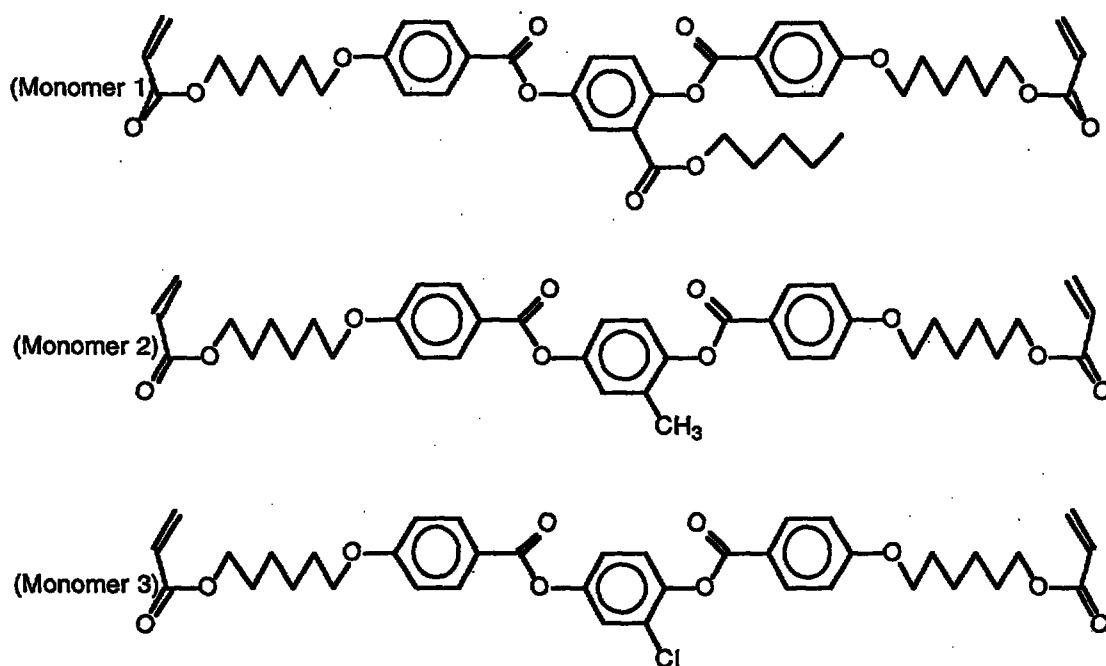
5 Static refractive-index patterns are also of great importance in preventing forgery of identity cards and documents of all kinds. Owing to the high resolution of the scratched patterns according to the invention, diffraction effects can be used as an additional security element, i.e. the refractive-index pattern operates as a
10 polarisation-dependent hologram. If three-dimensional structures (volume holograms) are generated as described hereinbefore, a great improvement can also be made in the scatter efficiency.

 The invention is also very important in combination with
15 the PPN process. The large-area regions can be optically structured by the PPN process, after which the micro-structures can be applied by the method according to the invention. In that case, for example, the orientation layer 2 shown in Fig. 1 or the layer 22 shown in Fig. 2 will not consist of rubbed polymer layers
20 or the possible intermediate layer between 23 and 24 will not consist of scratched polymer layers, but of photostructured polymer networks in which the additional patterns are scratched after cross-linking. The same applies to all the examples listed hereinbefore.

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Example: Production of a component according to the invention

 The following diacrylate components were used as cross-
30 linkable monomers:



These components were used to develop a super-coolable nematic mixture MLCP with a particularly low melting-point (about 35°C), permitting preparation at room temperature. The proportion of monomers 1, 2, 3 in the mixture was 80:15:5. 2% of the Ciba-Geigy photo-initiator IRGACURE 369 was also added to the mixture.

A polyimide layer about 100 nm thick was applied in known manner by spin-coating to test plates of ITO (indium-tin oxide)-coated glass. The layer was rubbed in a conventional rubbing apparatus. Next, grating structures having a variable grating constant and at an angle of 45° to the original direction of rubbing were scratched with a piezoelectrically driven stylus. This is shown diagrammatically in Fig. 4; the coated sample 41 is secured to a table mechanically moved in the direction 45 ($v = 3.6$ mm/s). The stylus 43 was secured to a small bar 44 and could be moved piezoelectrically in both directions 46 and 47. A constant frequency of 240 Hz was applied in the direction 46, corresponding to an average spacing of 7.5 nm between scratched lines, the line length being 10 μ m. The grating period was produced by periodic interruption of the modulation. Alternatively the stylus could be periodically raised and lowered in direction 47.

The LCP layer was then applied by spin-coating (parameters: 2 minutes at 2000 rpm). The layer thickness could be varied within wide limits via choice of the concentration of MLCP in the anisole solvent. A concentration of 5% yielded a layer
5 thickness of e.g. about 65 nm. Next, the layer was photo-cross-linked in vacuo (Hg arc lamp, 30 minutes). The cross-linked structures were investigated in a polarisation microscope and in the atomic force microscope (AFM). In the polarisation
10 microscope the gratings were clearly visible down to the limit of resolution of the microscope (i.e. down to grating periods of 720 nm), i.e. the strips 42 in Fig. 4 had a differently oriented double refraction from the rest of the sample. Observation under the
AFM showed gratings with a period of 240 nm. These
15 measurements show that extremely fine refractive-index patterns can be generated in anisotropic cross-linked polymers.

Claims

1. An optical component comprising a substrate, one or more orientation layers and one or more anisotropic layers of cross-linked liquid crystalline monomers or oligomers with locally
5 different orientation of the liquid crystal molecules, wherein the surfaces of the orientation layers adjacent the liquid crystal layers have orientation patterns with a defined parallel or fan-like line structure in locally limited regions, the average spacing between
10 the lines being not greater than the thickness of the liquid crystal layer and the angle between neighbouring lines being not greater than 3° .
2. An optical component comprising a cell consisting of two
15 spaced-apart substrates, one or more orientation layers on each substrate and one or more anisotropic layers of cross-linked liquid crystalline monomers or oligomers disposed between the layers and with locally different orientation of the liquid crystal
20 molecules, wherein the surfaces of the orientation layers adjacent the liquid crystal layers have orientation patterns with a defined parallel or fan-like line structure in locally limited regions, the average spacing between the lines being not greater than the
thickness of the liquid crystal layer and the angle between
neighbouring lines being not greater than 3° .
- 25 3. An optical component according to one of claims 1-2, wherein the orientation layers consist of photo-structured polymer networks.
- 30 4. An optical component according to one of claims 1-2, wherein the line structure consists of micromechanically produced groove-like structural elements.
5. An optical component according to one of claims 1-2,
35 wherein at least one layer of cross-linked liquid crystal molecules comprises a mixture of monomers or oligomers which before cross-linking were liquid crystalline during at least the period of



processing and over a temperature interval of at least 1°C in the range from 0°C to 60°C.

6. A method of producing an optical component according to
5 any one of claims 1-5, which process comprises micromechanically producing of a fine structure on the surface of an orientation layer, then applying a layer of liquid crystalline oligomers or monomers and subsequently cross-linking the liquid crystal layer.
- 10 7. A method according to claim 6, wherein the direction of the optical axis varies depending on the orientation of the scratched lines.
8. A method according to claim 7, wherein one of the two
15 substrates is removed after cross-linking in a cell.
9. A method according to claim 5, wherein at least one layer of cross-linked liquid crystal molecules consists of a mixture of monomers or oligomers which before cross-linking are liquid
20 crystalline during at least the period of processing and over a temperature interval of at least 1°C in the range from 0°C to 60°C.
10. The use of an optical component according to any one of claims 1 to 5 as a mask for producing a defined light polarisation
25 pattern, i.e. a light beam with locally variable polarisation.
11. The use of an optical component according to any one of claims 1 to 5 for the photo-induced production of orientation patterns in polarisation-sensitive photo-layers.
- 30 12. The use of an optical component according to any one of claims 1 to 5 as an optical waveguide or optical waveguide network.
- 35 13. The use of an optical component according to any one of claims 1 to 5 as a security element in identity cards or documents.



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14. The use of an optical component according to any one of claims 1 to 5 as a light-refracting element.



Abstract

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consisting of two spaced-apart substrates, one or more orientation
layers on the substrates and one or more anisotropic layers of
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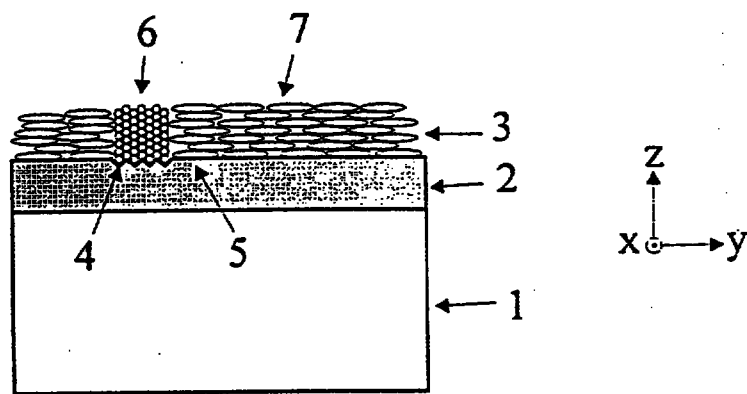


Fig. 1

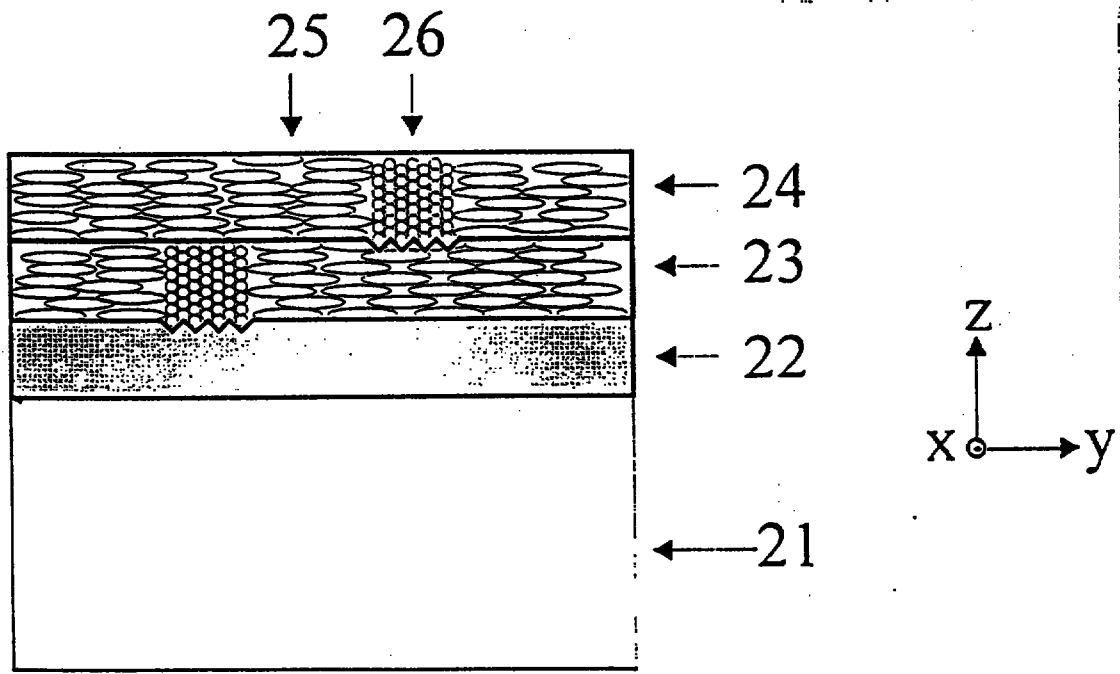
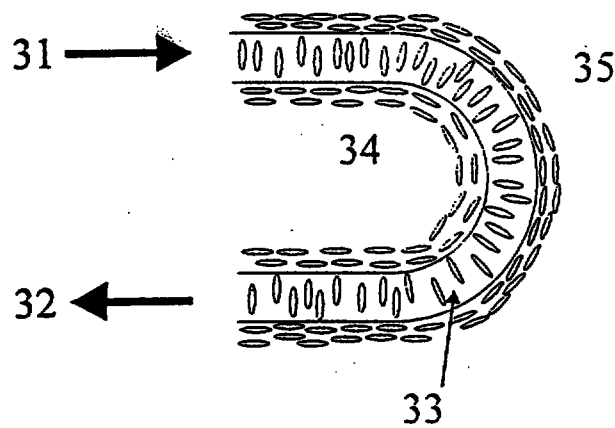


Fig. 2

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Fig. 3

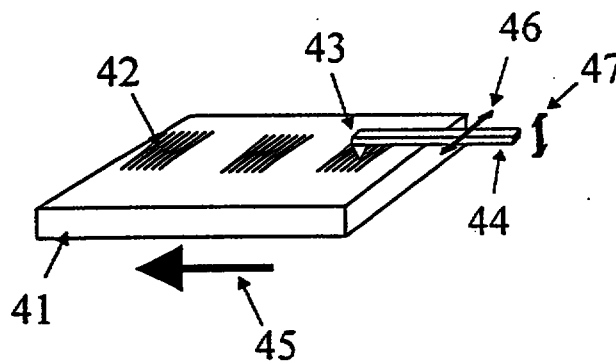


Fig. 4

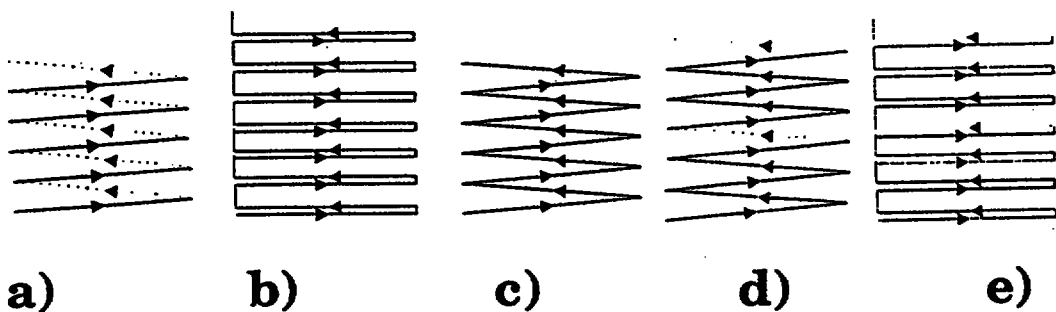


Fig. 5

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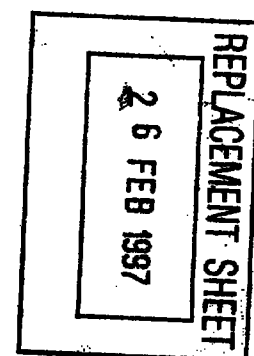


LIQUID CRYSTAL CELLS FOR INTEGRATED OPTICAL COMPONENTS

The invention relates to an optical component comprising one or two substrates, one or more orientation layers on each substrate and one or more anisotropic films of cross-linked liquid crystalline monomers or oligomers with locally different orientation of the liquid crystal molecules on the substrate or between the substrates. The invention also relates to the production and use of such components.

Anisotropic transparent or coloured polymer network layers with highly-resolved preset three-dimensional orientation of the optical axis are of great importance in display technology, integrated optics and prevention of forgery.

EP-A-545 234 discloses liquid crystal cells with fine structures comprising regions with defined different orientation and consequently different refractive indices. Refractive index patterns of this kind in a liquid crystal are produced by micro-mechanically generating a line structure on the surface of the orientation layer bounding the liquid crystal using a stylus moving in correspondence with the scanning pen of a scanning force microscope (scanning probe or atomic force microscope [AFM]). Depending on the pressure exerted by the stylus the lines can consist of relatively pronounced grooves or only of strings of uniformly aligned molecules. In the following description the term "scratching" is used for the process of producing a line structure by means of a stylus. In a cell of plates structured in this manner the pattern on the orientation layer constitutes an orientation pattern which is transferred to the liquid crystal. Optically non-linear liquid crystalline or optionally frozen-in optical waveguide structures are important applications.



EP-A-611 981 discloses materials and methods of stabilising orientation structures in monomeric liquid crystals by cross-linking. The orientation structures in the liquid crystal are

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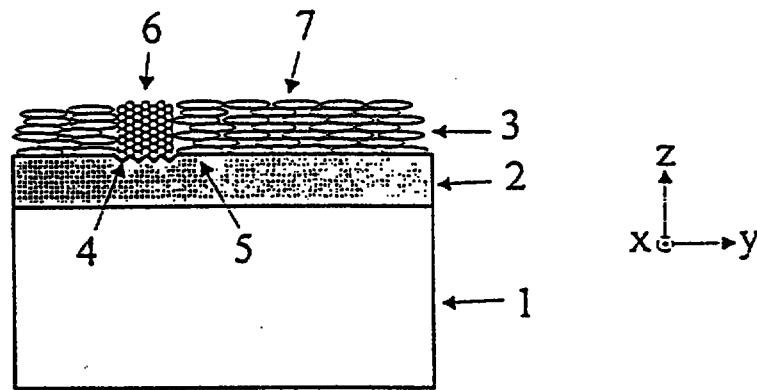
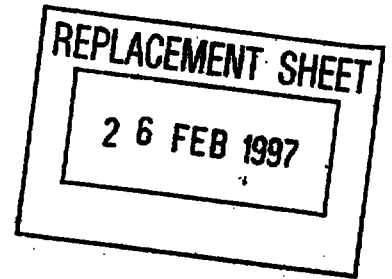


Fig. 1

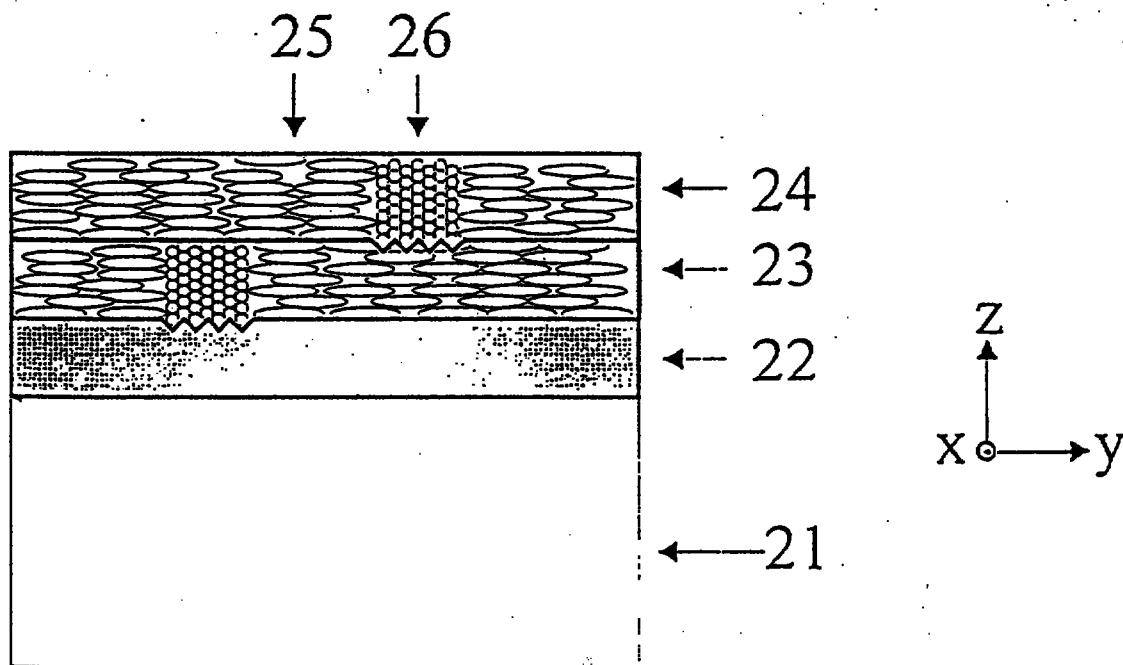


Fig. 2

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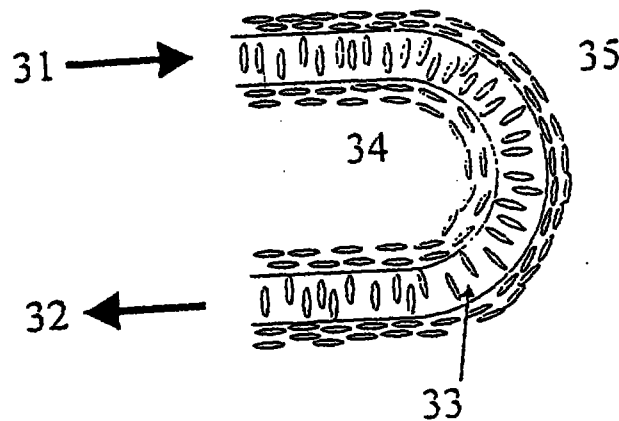


Fig. 3

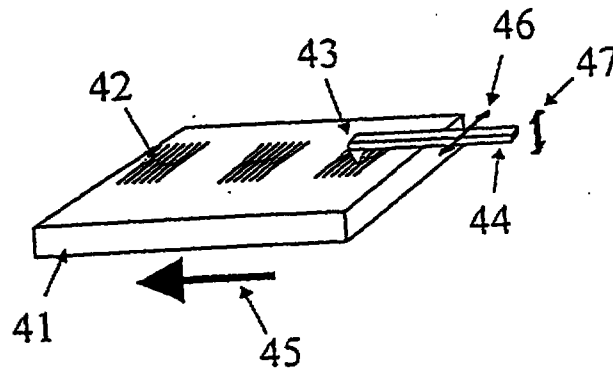


Fig. 4

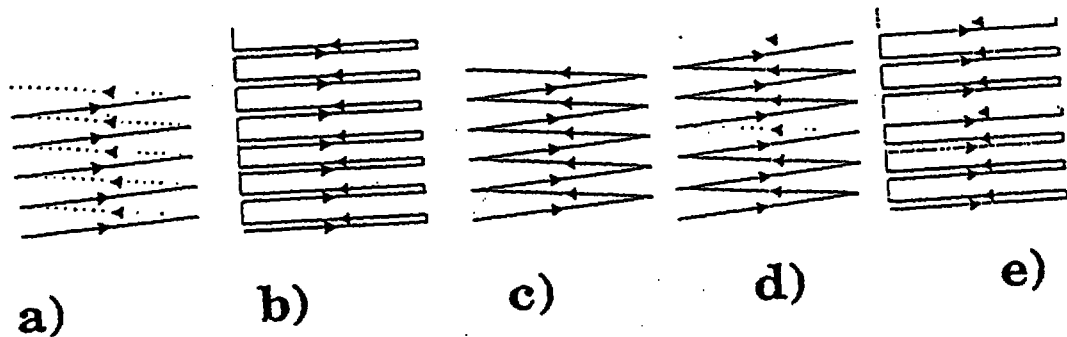
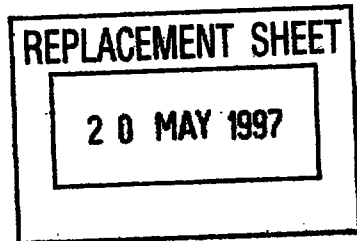


Fig. 5

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layer and the angle between neighbouring lines is not greater
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FIG. 1

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TEXT OF THE ABSTRACT

LIQUID CRYSTAL CELLS FOR INTERGRATED OPTICAL COMPONENTS

An optical component comprises a substrate or cell consisting of two spaced apart substrates, one or more orientation layers (2) on the substrates (1) and one or more anisotropic layers (3) of cross-linked liquid crystalline monomers or oligomers with locally different orientation of the liquid crystal molecules. The surfaces of the orientation layers (2) adjacent the liquid crystalline layers have orientation patterns (4) with a defined parallel or fan-line line structure in locally limited regions. The average spacing between the lines is not greater than the thickness of the liquid crystal layer and the angle between neighbouring lines is not greater than 3° .

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