

Description

The invention relates to a micromechanical process for structuring a polymer orientation layer which is on a plate and which has been oriented in a preferred direction by friction.

For the purpose of this description, fine structures are defined as two-dimensional or three-dimensional extensions in the order of 0.1 to about 100 μm .

It is known to produce such fine structures in liquid crystal layers by applying an electric field to suitably segmented electrodes. In the region exposed to the electric field the orientation of the liquid crystal is changed relative to the surrounding field-free regions. This usually results in a change in the optical properties of the affected region, and is therefore the basis of the electro-optical display effects of liquid crystal cells.

It is also known to produce fine structures in liquid crystal layers which are formed in the field-free state. To this end, the wall orientation of the liquid crystal molecules is brought about by oriented photopolymers. Orientation patterns can be produced in the liquid crystal by different molecular alignment (see Swiss Patent Applications Nos. 2244/91, 2245/91 and 2246/91 of 26 July 1991; 2244/91 corresponding to EP-A-525 477, 2245/91 corresponding to EP-A-525 473 and 2246/91 corresponding to EP-A-525 478).

DE-A-3 234 074 discloses a liquid crystal cell in which one of the two plates has regions which orientate adjacent liquid crystal molecules in various preferred directions. There are therefore regions in which the liquid crystal molecules are aligned differently from in the remaining liquid crystal layer. The regions of the orientation layer can be structured by stamping.

The publication "The Homogenous Alignment of Liquid Crystal Layers" by U. Wolff, W. Greubel and H. Krüger describes a process for the preparation of liquid crystal cells in which a predetermined surface region of the glass plate is structured mechanically in a consistent direction by means of a moving stylus.

EP-A-0 249 311 discloses liquid crystal cells in which strip-like photoconductors are formed. The light is therefore

propagated parallel to the plates bounding the liquid crystal layer. Photoconduction on both sides of the strip is produced by the difference between the refractive indices of the differently oriented volume regions of the liquid crystal and on the underside by the lower refractive index of the glass.

According to the invention, the micromechanical structuring is distinguished in that after the aforementioned polymer layer has been orientated in a preferred direction by friction, at least one surface region of the oriented polymer layer, of which region at least one lateral dimension is of the order of magnitude of from 0.1 to about 100 μm , is provided mechanically by means of a piezoelectrically moved stylus with a structure of recesses which extend parallel to one another.

Orientation patterns thus produced can be used, for example, to produce liquid crystal cells having patterns consisting of regions with different preferred orientations, patterns consisting of regions with and without preferred orientation or patterns consisting of regions of different twisting - i.e., patterns consisting of TN and STN regions.

It is relatively simple to produce photoconductors from the fine structures prepared in accordance with the invention. The prerequisite for photoconduction is of course total reflection on the boundary surfaces of the photoconductor, i.e., these boundary surfaces are distinguished by a change of the refractive index from a relatively high value inside the photoconductor to a lower value outside.

Liquid crystals have properties which are interesting for the production of photoconductor structures. They have a high optical anisotropy, their orientation can be controlled by boundary conditions and they have very powerful electro-optical effects in quasi-static operation. Some recently developed ferroelectric liquid crystals also have high optical non-linearity. Also, liquid crystals can be used in a simple manner to produce thin layers.

Slow (static) switching networks can therefore be produced by means of conventional (nematic) liquid crystals. However, when ferroelectric liquid crystals are used, extremely short switching times ($\ll 1$ ns via the Pockels' effect) are also attainable. Also, the light energy is concentrated in a very small volume in light conducting structures, so that efficient frequency doubling and frequency mixing are possible.

An embodiment of the invention will be described hereinafter with reference to the accompanying drawings.

Fig. 1 shows a diagrammatic view of a liquid crystal cell having differently oriented regions.

Fig. 2 shows a diagrammatic view of a device for "inscribing" microstructures.

The liquid crystal cell shown in Fig. 1 consists of two parallel spaced-apart glass plates 1, 4. The bottom glass plate 1 has an ITO electrode coating 2 covered by a polymer orientation layer 3. Similarly, the top glass plate 4 has an ITO electrode coating 5 and a polymer orientation layer 6. A nematic liquid crystal layer 7 is disposed in the space between the two plates.

The polymer layer 3, over most of its surface, has a surface structure 8 which orientates the adjacent molecules in the liquid crystal 7 in the direction shown by chain lines 8. The polymer layer 6 in the top plate 4 has a surface structure 10 parallel thereto. The parallel alignment of the wall orientations of the two plates results in a known manner in uniform alignment of the entire liquid crystal 7. This liquid crystal structure is called homogeneous or planar.

This homogeneous liquid crystal layer, oriented in one direction, is provided according to the invention with a strip a few μm wide having a different orientation and produced according to the invention as follows: the polymer layer 3 is structured into a direction different from the remaining area, e.g. at right-angles to the orientation 8, in a given limited region 9 on the surface of the bottom plate 1. The liquid crystal molecules adjacent the region 9 are aligned in the aforementioned different direction by the wall orientation forces.

The co-operating interacting forces of the liquid crystal molecules, the aforementioned different alignment extends into the liquid crystal. The wall orientation at the opposite side, i.e. on the top plate, is not altered, i.e. is parallel to direction 8. The result is a twisted molecular arrangement (TN or rotary cell configuration) in the space 11 defined by the area 9 and shown by chain lines. This strip-like space 11 acts as an optical conductor, the optical conduction of both sides of the strip being brought about by the defined difference in refractive index between the differently oriented spatial regions of the liquid

crystal and, on the underside, by the lower refractive index of the glass. At the top, the twisted molecular arrangement results in a refractive-index gradient which causes light to be conducted. Conduction of light through the glass plate is also operative at the top, however, depending on the thickness of the liquid crystal layer.

Alternatively, the polymer layer on the top plate 4 can likewise be given a different fine structure corresponding to the area 9. If the two facing fine-structured areas have parallel orientation directions to one another, the corresponding spatial region 11 will be uniformly aligned, i.e. uniaxially.

Another alternative is to give one or both plates a homeotropic instead of a planar general wall orientation. The homeotropic molecular arrangement also has a lower refractive index than the space 11.

The area 9 is structured, for example, in the following way by means of the device shown in Fig. 2. The plate 1, whose polymer layer 3 has previously been oriented in the preferred direction 8 by grinding, is made movable in the two directions indicated by double arrows. A stylus 14 attached to a piezo-tube 12 by a spring 13 is disposed above the plate. This arrangement corresponds to the known scanning means in a power scanning microscope.

By electrical excitation of the piezo-tube 12, the stylus 14 is moved selectively in any arbitrary desired direction. The stylus 14 can be simply moved by reciprocation over the polymer layer 3 at a right angle to the direction of motion of the plate 1, at a right angle slowly moved in the direction of the existing orientation 8. The pressure on stylus 14 can be monitored as in the aforementioned power scanning microscope.

The motion of the stylus 14 in contact with the polymer layer 3 provides the layer with a structure which can be imagined as fine engraved lines, the lines extending in the direction of motion of the stylus. The space between lines, which is typically in the nm region, depends on the speed at which the plate is moved.

The stylus 14 can also be moved over the polymer layer at an angle ϕ different from 90° to the motion of the plate 1, so that the structural lines extend at the angle ϕ to the orientation 8. This "sloping" structuring is useful, for example, for Sc material

where the molecules are at an angle to the wall orientation. Structuring at the appropriate angle results in an exactly transverse molecular alignment in the space 11.

On the other hand, the refractive index of the liquid crystal can be varied by deliberately sloping the molecules in the space 11. This is useful, for example, for phase-matching in the application to frequency doubling.

The tilt of the liquid crystal molecules can also be influenced by structuring. If all the lines are drawn by the stylus 14 in the same direction by the stylus touching the surface in only one direction and is lifted during the return movement, the resulting line structure tilts the molecules.

The light can be coupled in the optically conducting space by known means using an interference grating (not shown). The same applies to coupling out the light. These gratings can also be produced by the stylus by suitable choice of the parameters for structuring. The gratings can also be embossed in a known manner.

Instead of nematic liquid crystals, other liquid crystals, for example, ferroelectric liquid crystals, can also advantageously be used. Nematic liquid crystals form components which are static or electro-optically relatively slow. Ferroelectric liquid crystals are preferred for rapid electro-optical switching processes, particularly those which have high optical non-linearity and which are frozen in a vitreous state at room temperature.

The electrode layers 2, 5 on the two plates 1, 4 can be segmented in a suitable manner depending on the intended use of the cells.

The principle described can also be used to produce complicated structures such as Mach-Zehnder interferometers. In combination with the substantial electro-optical effects in liquid crystals, this opens the way to integrated optics with complex switching networks.

In addition to the production of optical conductors, the fine structuring according to the invention can also be used to produce liquid crystal display cells as described in the aforementioned Swiss Patent Application 2246/91 of 26 July 1991. More particularly, produce a cell similar to that described therein

having a chessboard arrangement of adjacent spaces with different molecular configurations can be advantageously produced using the method according to the invention. To this end, the polymer layer 3 on the plate 1 is provided with a chessboard arrangement of surface regions structured micromechanically in different orientation directions. The facing plate can either be structured in the same manner or treated so that it homeotropically orients the liquid crystal. The liquid crystal has differently orientated spatial regions corresponding to the aforementioned wall orientation(s).

A liquid crystal shaped in this manner scatters incident light, provided the dimensions of the individual areas are in the light wavelength range, and is therefore opaque. If an electric field is applied, the liquid crystal molecules are aligned and transmit light. The result therefore is a simple electro-optical switch.

Optically, this cell behaves similarly to the first commercially available cells during the initial period of liquid crystal technology, based on the dynamic scattering (DS) effect. The present cell is similar in that it requires no polarizers. In contrast to the DS cell, however, the present cell is based on a true field effect with all the advantages as regards current consumption, service life, etc.

If the actuating electrodes are suitably segmented, the aforementioned cells are also suitable for projection purposes.

Claim

A process for the micromechanical structuring of a polymer orientation layer on a plate wherein a polymer layer is first oriented in a preferred direction by friction, characterized in that thereafter at least one surface region of the oriented polymer layer, of which region at least one lateral dimension is of the order of magnitude of from 0.1 to about 100 μm , is provided mechanically by means of a piezoelectrically moved stylus with a structure of recesses which extend parallel to one another.



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