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Liquid Crystal Display Cell

The invention relates to liquid crystal display cells
10 comprising an oriented liquid crystal between two plates
(substrates) provided with transparent electrode layers and
orientation layers.

In liquid crystal display cells based on an electric field
15 effect, the glass or plastic plates bounding the liquid crystal are
provided on the surfaces facing the liquid crystal with coatings
which orient the immediately adjacent liquid crystal molecules
along a preferred direction. This applies to liquid crystal displays
based on the so-called rotation cell (twisted nematic, TN) effect
20 and displays based on a higher twisting, e.g. so-called super
twisted nematic (STN) cells, as well as, finally, also to ferroelectric
liquid cells.

Hitherto the wall orientation of the liquid crystal molecules
25 in display cells has been achieved either by oblique vapour
deposition of SiO_x on the substrate surface or, nowadays, almost
exclusively by mechanical treatment (abrasion) of a polymer layer
previously applied to the substrate surface(s). This abrasion
method does not enable selective areas of the substrate surface to
30 be provided with a preferred orientation. In particular, it is not
possible by previous methods to manufacture orientation patterns
such as e.g. a wall orientation varying from pixel to pixel.
Moreover, the modern almost exclusively-used method of
abrading a polymer layer frequently reduces the efficiency in
35 producing actively addressed twisted cells, since the electrostatic
charge on the substrate produced by abrasion results in electric
breakdowns in the thin film transistors on the substrate surface.

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The aim of the invention is to provide a novel and improved method of surface orientation of liquid crystals, which avoids the disadvantages of the known methods and above all enables
5 orientation patterns to be manufactured.

This is achieved according to the invention by applying, in the case of a liquid crystal cell of the kind mentioned earlier, oriented photopolymer layers to the inner sides of the plates
10 which are provided with the electrodes, said layers aligning the adjacent liquid crystal molecules in a preferred direction.

For the purpose of the present description, the term "photopolymer" is used for a polymer or a composition of
15 polymers which are photochemically modified by polarized light. This modification is called polymerisation or photopolymerization hereinafter. Reference is also made to Swiss Patent Application No.2244/91 entitled "Orientierte Photopolymere und Verfahren zu deren Herstellung".
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Preferably, the preferred direction on the two plates are different.

Particularly preferably, a nematic liquid crystal is plane-
25 oriented by the orientation layers in a preferred direction, the angle θ between the nematic director and the substrate surface being $0 \leq \theta < 85^\circ$.

In accordance with a preferred embodiment of the
30 invention, a pattern of regions with different preferred orientations or a pattern of regions with preferred orientation and non-oriented regions is present.

In accordance with a further preferred embodiment, the two
35 plates have different orientation patterns differing by different preferred orientations, which leads to different angles of twisting.



It has now surprisingly been found that oriented photopolymer layers, i.e. photopolymers polymerized by irradiation with linear polarized light, orient liquid crystals, which come into contact with them, in a preferred direction. This does not apply
5 only in respect of the preferred direction parallel to the plates. An angle of tilt in the direction right angles to the plates can also be induced by the orientated photopolymers.

Thereby, the manufacture of surface orientation layers in
10 liquid crystal display cells without vapour deposition of SiO_x and without abraded polymers is made possible for the first time.

The use of photopolymer orientation layers also permits for the first time the production of orientation patterns by the
15 irradiation of photographic masks with linear polarized light having a desired oscillation direction and the formation of an image on the coated substrate. Alternatively, interferometric imaging techniques can be used (polarized holograms).

20 Embodiments of the invention will be illustrated in detail hereinafter with reference to the accompanying drawings and Examples.

Fig. 1 shows a liquid crystal display cell according to the
25 invention;

Fig. 2 shows a device for the manufacture of an orientation layer;

30 Fig. 3 shows a set of masks for use in the device in Fig. 1,

Figs. 4-5 show various orientation patterns resulting from illumination with the set of masks according to Fig. 3.

35 The liquid crystal cell shown schematically in section in Fig. 1 consists, as usual, of two transparent plates 1, 2 and a liquid crystal layer 7 between them. The two plates of glass or plastic are provided with control electrodes 3, 4 and with overlying



orientation layers 5, 6. In contrast to previously-known liquid crystal cells, the orientation layers consist of oriented photopolymer.

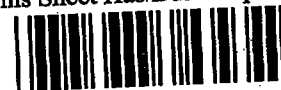
5 In the device shown simply in Fig. 2 for the manufacture of the oriented photopolymer layers, a glass plate 1 is provided with a transparent conductive electrode layer 2 and with a layer 3 of a photopolymerizable organic material. The layer is irradiated with linear polarized light by means of a lens 4 behind a mask 5. The
10 light comes from a polarizer 6 which is illuminated with non-polarized UV light 7.

The mask 5 is shown in Fig. 3 as a set of masks comprising two complementary masks 8, 9; in other words, a positive mask 8
15 (Fig. 3a) and a negative mask 9 (Fig. 3b). The two masks have a chessboard pattern, i.e. they cover alternating squares 10 of equal size over the entire cell surface and leave other square surfaces 11 exposed.

20 Irradiation through the positive mask 8 with linear polarized light having the direction of polarization indicated by the arrow 12 brings about the oriented polymerization of the non-masked areas of polymerizable layer 2. After this first step, the mask 8 is replaced by the negative mask 9 and the polymerizable
25 layer 3 is irradiated with light having a direction of polarization rotated through 90° as shown by arrow 12. The now exposed areas of the layer are polymerized with a corresponding twisted orientation.

30 When complete polymerization has been achieved in the first step, no mask is necessary for the second step, because the orientation induced in the first step is maintained.

35 An orientation pattern in the photopolymer layer as shown in Fig. 4. results by this two-stage irradiation with different masks and different linear polarized light. The preferred orientation of the polymer layers is offset from one adjacent square region to another. In a liquid crystal cell constructed from plates coated in



this manner, the liquid crystal molecules are oriented in accordance with the changing orientations of the photopolymer layer.

5 Instead of orientation offset by 90° from area to area, other combinations of angles are also possible. Above all, opposite regions in the cell can be oriented in directions such that the angles of twist or the pitches of the intermediate parts of the liquid crystal vary from region to region. In this manner, TN
10 regions and STN regions can be obtained side by side in a single display by suitable chiral doping of the nematic liquid crystal. This can be of significance if a display has to show a large area of information together with complex items, e.g. requiring multiplex control. Also, various strongly twisted STN cells can be achieved
15 in one and the same display.

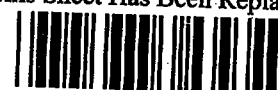
One example of such a display is shown in Fig. 5, in which a liquid crystal is disposed between pixels having a first helix angle ϕ_1 of the liquid crystal and pixels having a second helix angle ϕ_2
20 thereof. Both plates are shown having the preferred orientations.

The bottom plate 14 has a preferred orientation α_{11} in a first group 15 of areas disposed in a grid, and a preferred orientation α_{12} in a second group 16, where α is the angle of the preferred
25 orientation relative to an edge of the substrate.

Correspondingly, the top plate 17 has a preferred orientation α_{21} in a first group 18 of areas and a preferred orientation α_{22} in a second group 19 of areas. If the plates are
30 suitably adjusted, the helix angle in the liquid crystal between them is $\phi_1 = \alpha_{11} - \alpha_{12}$ or $\phi_2 = \alpha_{21} - \alpha_{22}$. Stable helix configurations with uniform direction of rotation and $70^\circ \leq |\phi_1 - \phi_2| \leq 220^\circ$ can be achieved by doping with cholesteric additives, which bring about suitable natural twisting in known manner.

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Some Examples which have been carried out are described hereinafter in order to illustrate the invention.



Example 1

5 A glass plate was coated with a 2% solution of polyvinyl
cinnamate (mol. wt. ~ 15000) in methyl cellosolve acetate in a
spin-coating process at 3000 rpm for about 30 s. The thickness
of the resulting layer was about 0.1 μ . The layer was then dried
in air for about 20 minutes and then heated to about 80-90°C for
about 20 seconds. After this pre-treatment the layer was
10 exposed for about 100 s. to irradiation with linear polarized light
from an HgHP lamp at a wavelength λ of about 365 nm, first
through a positive mask 8 and then through a complementary or
negative mask 9 at a direction of polarization rotated through 90°.
The irradiation energy in each case was about 15 mW/cm².

15 The plates which had been thus pre-treated were used in a
manner known per se to construct a cell which was filled with a
nematic liquid crystal. Exact adjustment may be necessary
depending on whether one or both plates have an orientation
pattern. It was found that the liquid crystal layer had planar
20 orientation in two preferred directions, i.e. the nematic director of
the liquid crystal layer was aligned in accordance with the
changing orientation in the photopolymer layers.

Example 2

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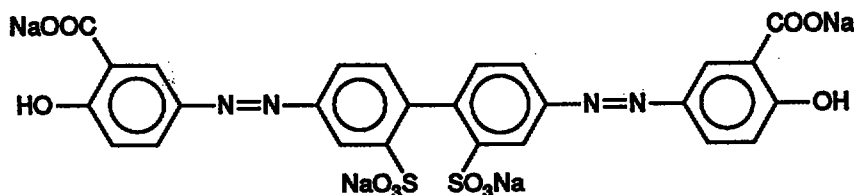
In a procedure similar to Example 1, a layer of a solution of
a polyvinyl ester of paramethoxycinnamic acid (molecular weight
about 15000-50000) in chlorobenzene and dichloroethylene 1:1
was exposed to irradiation at about 0.5 J/cm² for about 10 s.
30 The resulting layer likewise induced parallel orientation in an
adjacent liquid crystal.

Example 3

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A glass plate was coated with a 1% solution of





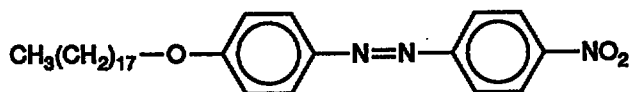
in an immersion process in water. The resulting layer had a thickness of about $0.07\ \mu$ and was irradiated with linear polarized light at a wavelength $\lambda = 400\text{--}500\ \text{nm}$ and a radiation intensity of about $47\ \text{mW/cm}^2$ for about 8 minutes.

A liquid crystal cell made of thus-coated plates was filled with a nematic liquid crystal and, to improve the orientation of the liquid crystal, was heated to 100°C for about 5 minutes until the liquid crystal reached its isotropic state, and was then cooled. The liquid crystal then had planar orientation.

Example 4

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A 3% solution of



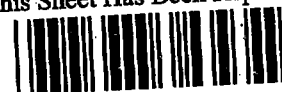
in chloroform was vapour-deposited on a glass plate. The resulting layer, about $1000\text{--}2000\ \text{\AA}$ thick, was irradiated with light at wavelength $\lambda \approx 400\text{--}550$ at an intensity of about $45\ \text{mW/cm}^2$ for about 3 minutes.

The thus-coated plates were used as in Example 3 to construct a liquid crystal cell, in which the liquid crystal had planar orientation as before.

Example 5

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Example 1 was repeated except that non-polarized light instead of plane-polarized light was used in the second illumination step. After the liquid crystal cell had been assembled, it was found that the regions photopolymerized with



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plane-polarized light gave a planar orientation in a preferred direction to the liquid crystal layer, whereas the liquid crystal did not have a preferred direction in the regions irradiated with non-polarized light.

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Patent Claims

1. A liquid crystal display cell comprising an oriented liquid crystal (7) between two plates (1,2) provided with transparent electrode layers (3,4) and orientation layers (5,6), characterized by applying oriented photopolymer layers to the inner sides of the plates where the electrodes are disposed, said layers aligning the adjacent liquid crystal molecules in a preferred direction.
2. A liquid crystal display cell according to claim 1, characterized in that the preferred directions in the two plates (1,2) are different.
3. A liquid crystal display cell according to claim 1, characterized in that a nematic liquid crystal is linear oriented by the orientation layers in a preferred direction, the angle θ between the nematic director and the substrate surface being between $0 \leq \theta < 85^\circ$.
4. A liquid crystal display cell according to claim 1, characterized by a pattern of regions with different preferred orientations.
5. A liquid crystal display cell according to claim 1, characterized by a pattern or regions with preferred orientation and non-oriented regions.
6. A liquid crystal display cell according to claim 3, characterized in that the two plates have different orientations patterns differing with respect to different preferred orientations and resulting in different twist angles.

