47.3: Thin Photo-Patterned Internal Polarizers for LCDs

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Abstract

We describe the novel technology of thin photo-patterned polarizers for LCDs. The polarizer consists of small regions with different orientations of the absorption axis and/or colors. It can be placed on the interior of the LCD cell substrate. The polarizer material consists of thin (about 0.3-0.7 micrometers) lyotropic dye layers, transferred to the substrates by UV-curing glue or by the "photo-alignment" method. We use photo-chemically stable dyes as the photo-alignment layers for the lyotropic LC and as the thin photo-patterned polarizers.

1. Introduction

Polarizing films have wide applications in LCD industry [1]. Common LCDs have polarizers based on polyvinyl-alcohol-iodine (PVA) films of 30-50 microns thick. Usually, the polarizers are placed outside the LC cells, and require protection films (e.g. cellulose triacetate or cellulose acetate butyrate), which makes their fabrication complicated and expensive. The outer location of polarizers results in additional reflections and parallax effect, which deteriorate the LCD contrast and optical performance. Consequently, thin internal polarizers for LCDs are highly desirable.

Another problem is to pattern the polarizers by dividing them to small regions with different orientations of the absorption axis and/or absorption colors in each region. The technology of pixelated polarizers on the basis of PVA doped with dichroic dyes is described in Ref. [2]. Similar polarizers were reported in Ref. [3] by spin-coating using lyotropic liquid crystals (LLC) [3-4].

In this paper, we propose new methods, which utilize LLC and photo-anisotropic materials (PAM), for the fabrication of gray or color pixelated polarizers. A high order parameter can be induced in PAM materials by polarized or non-polarized light. We discover that these materials can be used as the photo-alignment layer for LLCs. Moreover, they themselves can be used to form the pixelated polarizers.

2. Experimental

We use the LLC (Crystal InkTM from OPTIVA Inc). This composition includes sulphonated textile dye molecules stacked up to form the tubular supramolecular complexes with a high dichroic ratio [3,5]. We use UV-glue (Norland 65), for the LLC polarizer transfer. We apply an azodye AD-1 with a chemical formula shown in Fig.1.

In order to prepare the pre-alignment layer of various thickness, 0.5 – 5.0 wt/wt % solution of AD-1 in chlorobenzene was spin-coated on a glass substrate at room temperature. The pre-alignment

layer was irradiated with UV light using a 1000 W Oriel Xenon arc lamp. An UV sheet polarizer from Oriel was used to linearly polarize the UV light. The intensity of UV light with and without the polarizer was about 6 mW/cm² and 18 mW/cm² respectively. In the following discussion, the UV irradiation time was 20 min.

Figure.1 The chemical structure of the azodye AD-1.

3. Results and Discussion

Figure 2 shows the first method of the polarizer fabrication. Using a technology described in [3, 5], we prepared a lyotropic polarizer (LP), composed of LLC (Crystal InkTM), which was coated on a flexible film polyethyleneterephthalate (PET). The adhesion at the interface of LP- PET film is weak. The LP on the flexible film was laminated onto the glass substrate which was coated with an UV photo-polymerizable glue layer. The subsequent exposure of the UV-glue layer with a photolithographic mask hardened the glue in accordance with the mask pattern. Afterward the PET film was separated from the glass substrate so that a patterned LP can be transferred onto the glass substrate.

After the removal of the non-polymerized UV-glue from the substrate by using a solvent, this photolithographic stage can be repeated with other masks. Finally we obtain a photo-patterned (pixelated) polarizer having the desired local orientations of the principal absorbing axis. The pixel size can be about 10 micrometers. The polarization transmission spectra of the thin internal lyotropic polarizer on the glass substrate are shown in Fig.3.

Since the pixelated LP polarizers can have specific orientation in the local areas of the display, many new possible applications are envisaged (e.g. in stereoscopic TV LCDs). The thin lyotropic polarizers are UV- and temperature stable. They possess a high light fastness [5] and can be used as the internal polarizers between the glass substrate and the transparent electrodes.

The second method for polarizer formation was the photo-alignment method, which was a useful technique for aligning the thermotropic LCs [1]. We find that it is also possible to orient the lyotropic LC as the photo-patterned polarizers.

If the alignment layer is photo-chemically stable, the order parameter becomes saturated after the UV irradiation [1]. Thus the degree of lyotropic LC ordering is not so critically affected by the exposure energy, which is important for display applications.

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As an example of such photochemical stable substance we use an azodye AD-1 with a structural formula given in Fig.1. This azodye as used as a photo-alignment layer for lyotropic LC in the fabrication of a photo-patterned (pixelated) polarizer (See Fig.4).

Figure 2. The fabrication method of the patterned polarizers using the UV glue.

Figure 3. Polarized transmission spectra of a thin lyotropic polarizer [3,5]. Tp and Ts represent respectively the transmission spectrum perpendicular and parallel to the dye absorption axis.

In the first stage of the fabrication process, we spin-coated about 0.1 micron thick isotropic layer of the azodye AD-1 onto the glass substrate and illuminated it with a mask. Afterward we put few drops of an isotropic solution of LLC (Crystal Ink™) on the photo-alignment layer AD-1. When the solvent was evaporated, the patterned polarizer film was formed with a thickness of about 0.5 microns. Our technology allows us to prepare thin color pixelated polarizers with pixel size of about 10 microns or less.

In our third method we prepare the photo-patterned color polarizer directly in a sufficiently thick (one micron) layer of azodye AD-1 by the above-mentioned technique. The transmission spectra of this alignment layer are shown in Fig.5. The photoinduced anisotropy in this layer is not changed for years and is stable up to 130°C.

Figure 4. Photo-patterned LLC polarizer prepared by photo-alignment.

Figure 5. Transmission spectra of the azodye AD-1 before and after exposure by a polarized light. Tp and Ts represent respectively the transmission spectrum perpendicular and parallel to the dye absorption axis, whereas To is the transmission spectrum before UV irradiation.

It is noted that numerous photolithographic stages can be avoided and the alignment pattern can be generated in a single exposure stage by using an alignment master (AM) [6-7]. The AMs proposed in Refs. [6-7] require a projection exposure due to their large thickness. We believe that AM could be more flexible and enable to use both projection and contact exposure utilizing the photo-patterned lyotropic polarizers, proposed by us.

4. Summary

We developed new photo-alignment methods to fabricate thin internal patterned (pixelated) polarizers with different local orientations of the absorption axis and/or absorption colors. To prepare the novel polarizers we used lyotropic LCs and novel photo-alignment materials based on photo-chemically stable azodye films. These materials exhibit a high photoinduced order after absorption of a linearly polarized or non-polarized light. Moreover, these materials can be used for the formation of the photo-patterned polarizers. To obtain the patterned polarizer by a single exposure, we propose to use the alignment master – the special mask with a patterned UV polarizer fabricated by our method.

We propose also to use the UV-glue to fabricate a patterned polarizer by transferring the lyotropic LC polarizer from the flexible film onto the glass substrate. We foresee the application of the patterned polarizers in the new LCDs.

5. Acknowledgment

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6. References

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