P-158: Recent Developments in Photo Alignment Technology: Alignment Properties of Novel Azo Dye CD-1

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Abstract

Liquid crystal photoalignment using commercially available azo dye CD-1 is reviewed. Proposed dye shows excellent alignment properties which is highly promisable for future applications. This photoalignment is based on rotational diffusion in a potential created by the light field as well as intermolecular forces. It will be shown that this photo-aligning dye shows strong anchoring energy of the LC cell and also having high thermal and ultraviolet (UV) stability. The application of liquid crystal displays using this dye is also discussed.

1. Introduction

The surface alignment of liquid crystals is an important research subject since it plays vital role in manufacturing of liquid crystal displays. Although polyimide (PI) can be used for aligning the surface, but aligning the large area surface is a big problem. One of the drawback of using PI is it creates defects because of mechanical contact to the surface. To overcome this many alignment mechanisms appeared. Among all these liquid crystal photoalignment is considered as future technology. Since from its discovery [1, 2], the phenomenon of photoalignment attracted wide variety of attractions. Although huge amount of materials for alignment has been synthesized, azo dye materials remain among best candidates for technological applications.

The field of LC photoalignment is very rapidly developing and a vast amount of the new materials, techniques and LCD prototypes based on photoalignment (PA) technology have appeared recently [3-6]. However, despite these potential advantages, the application of PA to LCD production is still limited to the laboratory. Large scale development of PA is hampered by the lack of good material and by long term stability, not to mention the lack of suitable mass production scale equipment.

Earlier we discussed extraordinary good photoalignment properties of the sulfuric azo dye SD-1 and its applications [7, 8]. Similar dye but slight different in the structure called as CD-1 showed excellent alignment properties and it is highly competent for SD-1 dye. Here in this paper we are showing alignment properties of CD-1 which also shows good thermal and photo stability and also very well electro optic performance. This results open up the new path for making LCD's using highly stable dye.

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The effect of LC photoalignment is a direct consequence of the appearance of the photo-induced optical anisotropy and dichroic absorption in thin amorphous films, formed by molecular units with anisotropic absorption properties.

2. Experimental

Figure 1 shows the chemical structure of azo dye CD-1 and also SD-1 (SD-1 is shown for comparison). Only the difference in the structure is, in CD-1, the sulfuric group has been replaced by COOH group and COONa is replaced by COOH. Figure 2 shows the UV/vis absorption spectrum of CD-1 and SD-1, both are exhibiting almost the same wavelength.

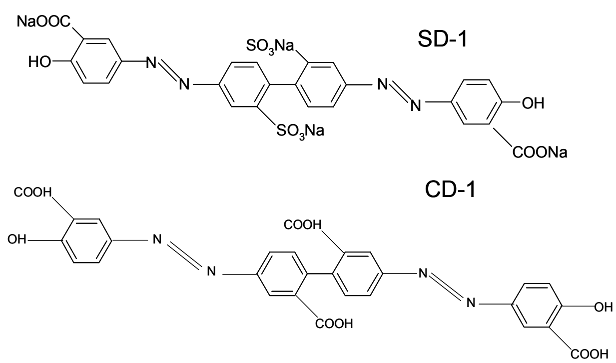

Figure 1: Chemical structure of azo dye SD-1 and CD-1

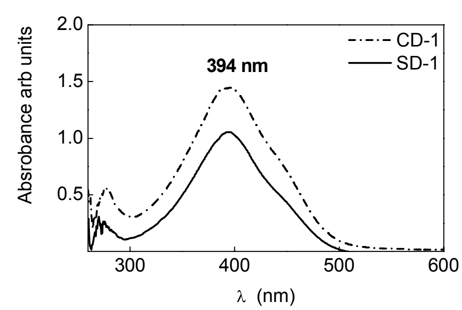

Figure 2. The UV-Vis absorption spectra of CD-1 and SD-1 in the solid film showing the absorption maxima at 394 nm.

CD-1 is dissolved in DMF solution with fixed concentration of 1% by weight. The solution was spin coated at 800 rpm for 10 seconds and 3000 rpm for 40 seconds onto substrates of ITO preliminary treated for 20 minutes with the ozone plasma in UVO-cleaning machine. Subsequently films were dried at 100 ^{o}C for 10 minutes and 140 ^{o}C for 20 minutes. After this step films were irradiated with linearly polarized UV light from the high pressure mercury lamp. The light intensity on the film position was found to be 3 mW/cm^2. The parallel and TN cells were prepared and filled with liquid crystals designed for different LCD modes. The cell gap used for these measurements is 5 µm.

Figure 3 shows the polarized absorption spectra (absorbance or optical density) before (curve 1) and after (curves 2 and 3) the UV irradiation. Before the irradiation the absorption of the azo dye layer does not depend on the polarization of the light, used in measurements. After the irradiation by linearly polarized UV light, the absorption of the light with the polarization direction parallel to the polarization direction of the activated light ($D_{\|}$) decreases (curve 2) while that one with orthogonal to the polarization direction increases (curve 3).

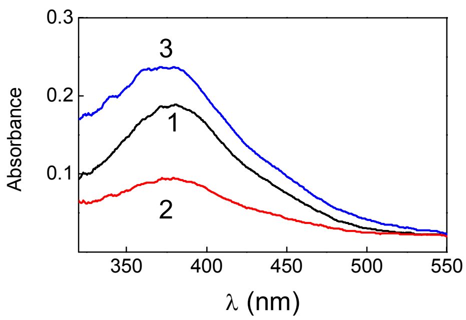

Figure 3. Absorption spectra of CD-1 layer before the polarized UV exposure (curve 1). Curves 2 and 3 show the polarized absorption spectra after the exposure by a polarized UV light in the direction parallel ($D_{\|}$) and perpendicular ($D_{\perp}$) to the activating light polarization accordingly.

The evolution of the polarized absorption spectra after UV illumination does not reveal any noticeable contribution of photochemical reactions [9], as the average absorption

$$D_{ave} = (D_{\|} + 2D_{\perp}) / 3$$

remains the same for any fixed value of the exposure time. From figure 3, the order parameter S of the azo dye chromophores can be expressed as [10]

$$S = (D_{\|} - D_{\perp}) / (D_{\|} + 2 D_{\perp})$$

where $D_{\|}$ and $D_{\perp}$ are absorption (optical density) of parallel and orthogonal polarized light to the polarization of the activated UV light. The order parameter S of CD-1 is equal to

-0.24 at λ = 394 nm.

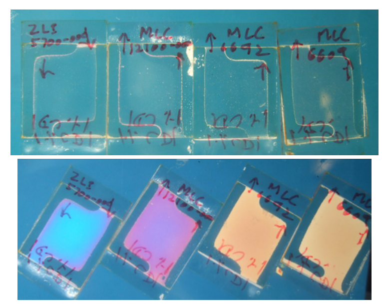

Figure 4. Macroscopic Photographs of the symmetric cells based on CD-1 alignment layers and filled with different nematic liquid crystals: STN LC ZLI 5700-100 (1), AM TN LC MLC 12100-000 (2), IPS LC MLC 6692 (3), VA LC MLC 6609 (4).The easy axis of LC forms angle 0^{o} and 45 ^{o} with polarizer in upper and lower row, respectively. Cell gap used is 5 µm.

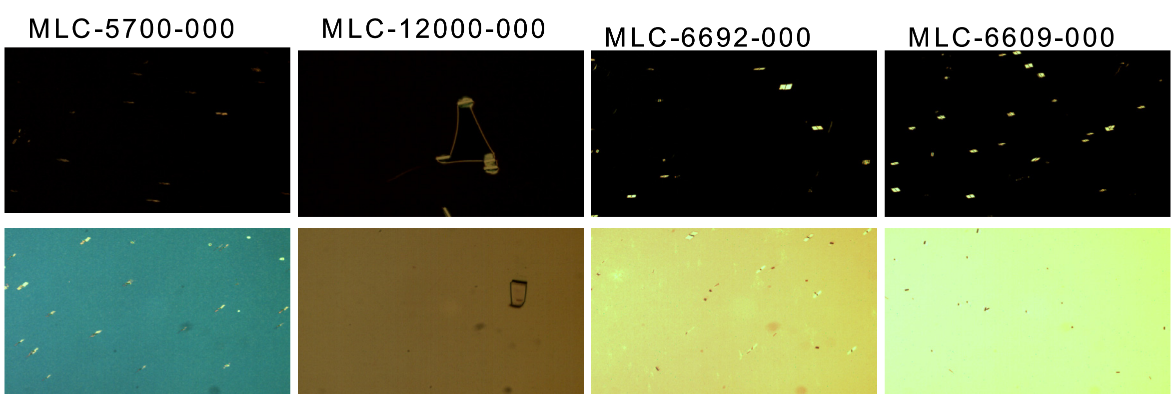

Figure 5. Microscopic Photographs of the symmetric cells based on CD-1 alignment layers and filled with different nematic liquid crystals: STN LC ZLI 5700-100 (1), AM TN LC MLC 12100-000 (2), IPS LC MLC 6692 (3), VA LC MLC 6609 (4). The easy axis of LC forms angle 0^{o} and 45 ^{o} with polarizer in upper and lower row, respectively. Cell gap used is 5 µm. Magnification used is 200X.

Figure 4 shows the macroscopic photographs of the parallel cell filled with different kinds of liquid crystals like, STN, IPS, AM TN, VA LC etc. Figure 5 shows the microscopic photo graphs of the above cells. In all these cases excellent alignment is achieved.

Figure 6 shows the better alignment quality for TN cells also. The azimuthal anchoring coefficient Wa determined by measuring deviation angle in TN cell filled with LC MLC-12100-000 is about 9.89×10^{-5} J/m^2 which is nearly equal to the anchoring energy obtained for SD-1. In these cells we irradiated unpolarized UV light for 30 minutes. We have not detected any change in alignment quality and also twist angle for the irradiated and non-irradiated parts. The cells were also heated for 150 ^{o}C and kept for 1 hour that also suggests good thermal stability of LC alignment.

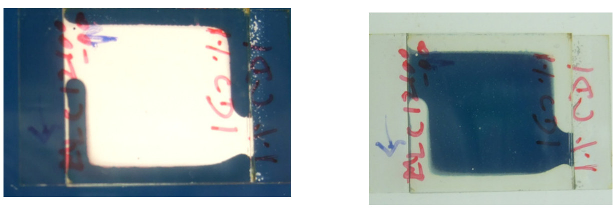

Figure 6. Bright state of 5 µm TN cell using CD-1 photoalignment layers coated on ITO glass plate, (b) Dark state of 5 µm cell. Both showing excellent photo alignment properties. Liquid Crystal used was MLC 12100-000.

Figure 7 shows the microscopic photographs exhibiting excellent alignment for ferroelectric liquid crystals FELIX-017. That means even for commercially available FLC materials also exhibits very uniform alignment using CD-1 photo aligned layers.

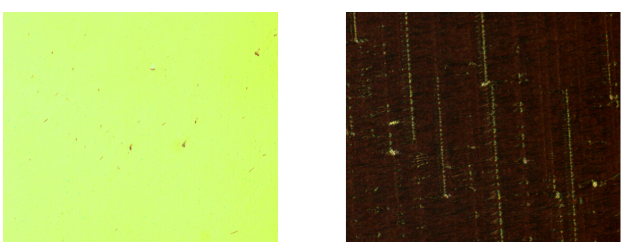

Figure 7. The microscopic photographs of the symmetric cells filled with ferroelectric liquid crystal FELIX-017 aligned by CD-1 photo alignment layers placed between the two crossed polarizers. The bright state (left) and dark state (right) shows the excellent photoalignment properties with high contrast ratio. Magnification used is 200X. Alignment improves drastically after applying the electric field.

Figure 8 shows the possible mechanisms behind this phenomena. This mechanism based on photo-orientation process in which molecules align perpendicular to the polarized UV light after irradiation. Detail investigation on this new dye is under strong consideration and more light will be thrown in future research.

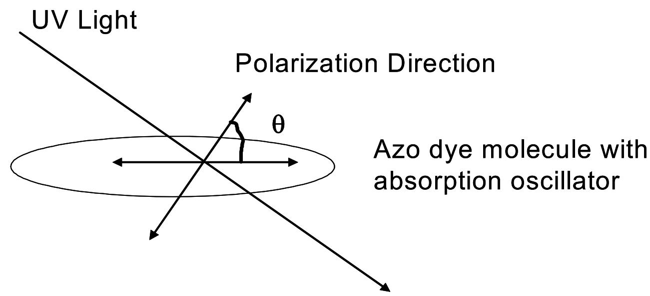

Figure 8. Photo-induced order in photochemical stable azo dye film CD-1.

3. Conclusion

CD-1, a commercially available azo dye exhibits excellent photo alignment quality which can be successfully used for display industry and also many other applications. Since anchoring energy is very promisable and also thermal and photo stability results made this dye attracting for many devices.

4. Acknowledgements

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