P-11: LC Display Cell Photo-alignment by a Super-thin Azo-dye Layer

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Abstract

We proposed a novel method of forming a super-thin azo-dye molecular alignment layer for LC display cell without spin-coating and rubbing processes. The high electrooptical performance of photo-aligned LC cells was demonstrated in ECB and TN modes. Providing the advantages of conventional photoalignment methods, the use of super thin layer simplifies the alignment procedure, makes possible high contrast ratio and better adhesion on ITO rough surface.

1. Introduction

Since the first research by Ichimura et al. in 1988[1], a considerable amount of research has been directed toward the photoinduced alignment of liquid crystals (LCs) using polarized irradiation of a polymer film. This noncontact alignment technique is based on the generation of a surface anisotropy of a photoreactive polymer film by photochemical means. The impurities, electrostatic charges of polyimide aligning films and the mechanical damage produced by rubbing can be completely avoided by the photo-alignment technique[2]. The technique is attractive as a promising alternative to the rubbing process to be used in the next generation of displays, such as large area, multidomain, vertically aligned, and/or in-plane switching mode displays.

In the present research, a new photochemical stable azobenzene sulfuric dye, SD-1, has been synthesized (Fig.1) [2,3] and polarization-sensitive photo-anisotropic layers on basis of this dye were successfully tested for the LC display alignment. One of remarkable properties of this azo-dye is the pure orientation of the molecular absorption oscillators perpendicular to the UV light polarization, which is practically not accompanied with photochemical transformations.

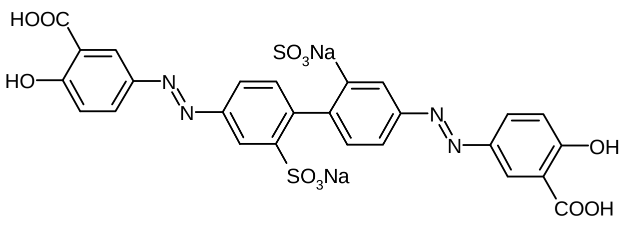

Figure 1: Chemical structure of SD-1

Nowadays, the process of spin-coating is needed in photo-alignment techniques to make sure that the ITO surface is covered by a uniform alignment layer. But spin-coating is not suitable for some special conditions, such as LCDs based on large size substrates, flexible substrates, or curved surfaces etc. On the other hand, the uniformity and mechanical stability of any thin layer onto ITO surface depends on its thickness, which will also affect the optical quality for LC display. Further, there exist certain adhesion problems of azo dye layers on some surfaces. Finally, the roughness of ITO surface (10~18nm) is usually larger than the thickness of alignment layer, so for SD-1 layer thickness, which is about 3~10nm, the island or porous defects in LC cells may appear.

In this paper, we proposed and studied a novel method to form a super-thin layer of SD-1 as the alignment agent in LC display. This new method includes the formation of a very neat “textile knitwear” by a super-thin SD-1 layer and can avoid island structures of alignment layers on the ITO surface. The original thickness and quality of the pre-photo-alignment dye layers is not important in forming the final alignment surfaces. This super-thin layer can be obtained by any accessible methods: draw from solution, roll deposited or orifice drawing, spin-coating, vacuum or doctoring deposited, screen printing, tampon printing etc. It shows that such super-thin SD-1 layer can provide good electro-optical properties and alignment quality for LC display cell comparable with a traditional alignment layer.

2. Experiments

To produce such super thin alignment layer, the procedure is as following. First, draw the original thick azo-dye layer, e.g. 3% SD-1 in N,N-Dimethylformamide (DMF) solvent, onto the substrate with ITO to make sure that surface is completely covered by azo-dye layer. Then, anneal of this original dye layer up to high temperature to increase the molecular quantity of azo-dye molecules which generated chemical bonding with ITO surface. Use pure solvents, e.g. DMF, to remove SD-1 molecules in the bulk. So only the super-thin SD-1 layer which is chemically adsorbed on the ITO surface remains. The new super-thin SD-1 layer is exposed with a polarized UV-light to form alignment layer. Finally, anneal of the photo-aligned SD-1 layer for increasing the order parameter of the azo-dye molecules.

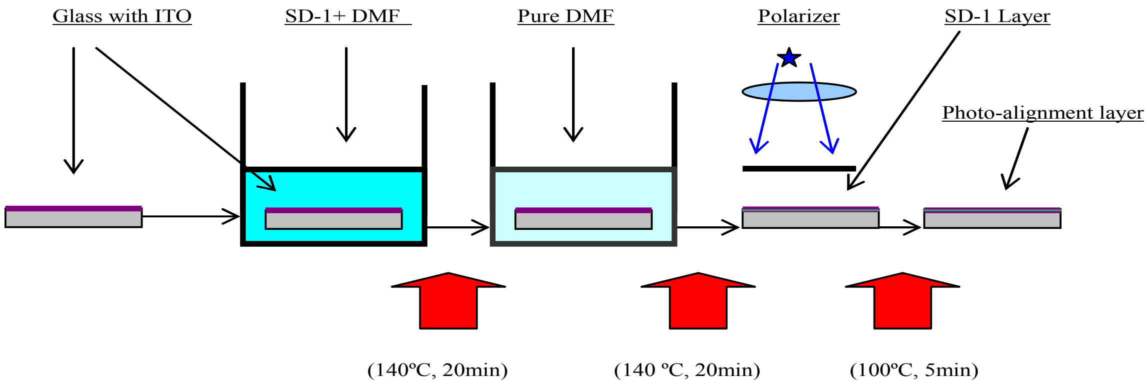

Figure 2: Illustration of forming mono-molecular photo-alignment layer

Figure 2 illustrates the formation of a super thin azo-dye alignment layer on ITO glass substrate. The method is very simple and suitable for large quantity fabrication of glass or plastic substrates.

3. Results and discussions

3.1 Polar anchoring energy

The polar anchoring energy of this super thin alignment layer was measured. We use RV high voltage technique [4-6] and differential method for the measurement of polar anchoring properties of the super thin layer of azo-dyes. This method is to find the LC phase retardation dependence on electric field. The normalized phase retardation R/R_0 was based on the equation:

$$R/R_0 = (1/C + 1/C_{al}) * C_\perp I_0 (V_c / V) - 2 * (K_{11} / Wd) \quad (1)$$

where W is polar anchoring energy; d is LC layer thickness; K_{11} is LC dielectric constants; C, $C_\perp$ and C_{al} are capacitances of LC layer under the applied voltage and of the aligning layer respectively; V_c is a critical (threshold) voltage.

To measure the polar anchoring energy of the substrate, sample cells were made with an anti-parallel alignment of a small pretilt angle. Before filling, the cell gap d and the retardation of this empty cell R_0 need to be measured. Then MLC 5700-100 was filled into the cell. By carefully adjusting the exposure time of linear polarized UV light (500 Wt Hg lamp with interferometric filter, λexp = 365 nm, Pexp =3.8 mWt/cm²), a controllable polar anchoring strength can be obtained.

Figure 3 shows the varied polar anchoring energy of this layer. The results are comparable with the conventional SD1 layer (~4.7×10^{-4}J/m2) when the exposure time is longer than 10 minutes, which can make LC properly aligned.

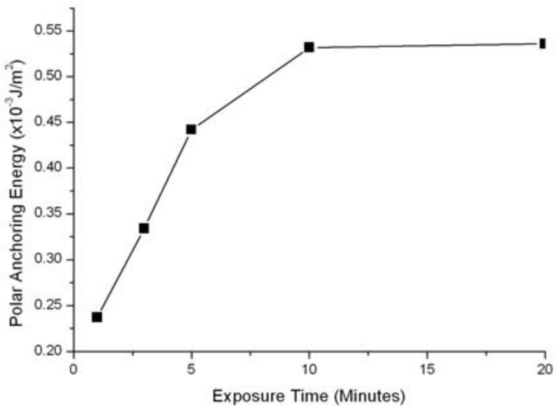

Figure 3: Polar anchoring energy of super thin layer with different exposure time

3.2 Azimuthal anchoring energy

In order to obtain good alignment qualities, sufficiently strong azimuthal anchoring energy of this photo-aligned layer should be obtained.

Azimuthal anchoring energy was measured by making TN LC cells. Two substrates with super thin photoaligned layer were assembled with 90^0 twist configuration. The resulting twist angle could be equal to 90^0 only in the case of a sufficiently high azimuthal anchoring energy on the photo-aligned substrates, otherwise it decreased due to the elastic torgue. The MLC 5700-000 was injected into the cells with a cell gap of 5 um. The azimuthal anchoring energy of the azo-dyes W_ϕ was calculated from the torque balance energy equation:

$$W_\varphi = \frac{2K_{22}\phi}{d \sin 2(\phi_0 - \phi)} \quad (2)$$

where K_{22} is elastic constant of LC material; d is cell gap of LC cell; ϕ_0 and ϕ are the assumed initial twist angle and the really measured twist angle.

Figure 4 shows the measured azimuthal anchoring strength, which increases with the exposure time. The results show the azimuthal anchoring energy is much smaller than the conventional SD1 layer (~10^{-4}J/m^2) even after very long UV exposure time.

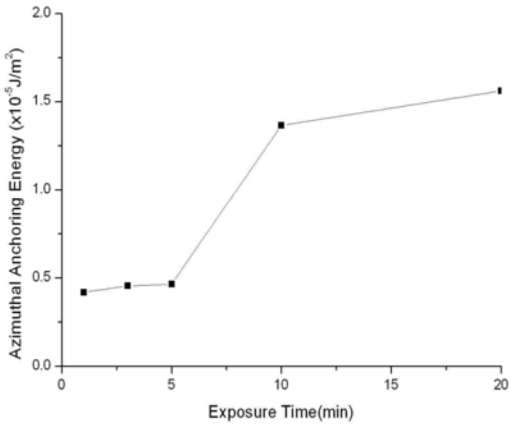

Figure 4: Azimuthal anchoring energy of super thin layer with different exposure time

3.3 Excellent optical properties

Using the super thin-molecular alignment layer, we successfully demonstrated 5μm TN and 18μm ECB cells filled with liquid crystal MLC 5700-000. Both of them give contrast ratio about 140:1 reliably at the wavelength 632nm. Figure 5 shows the transmission voltage curve of this super thin-molecular SD-1 layer and ordinary thick SD-1 layer of a 5μm TN cell. It shows that when super thin-molecular layer is used, even better contrast ratio can be obtained since the bright state is higher. Maybe it is because the thickness of super thin layer is much smaller than ordinary SD1 layer.

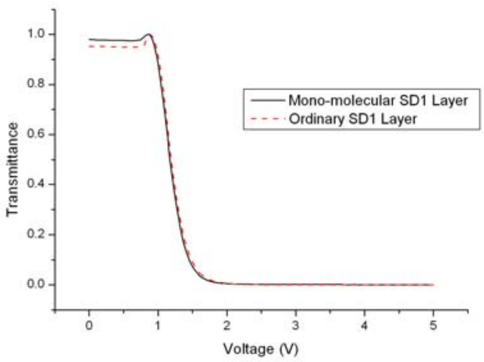

Figure 5: TVC of super thin and ordinary SD-1 layer

3. Conclusions

In summary, we have demonstrated LC display cells based on a super-thin photo-aligned layer. This new method includes the formation of a very neat "textile knitwear" by a super-thin SD-1 layer and allows to avoid the spin-coating procedure. Moreover, the photosensitivity of azo-dye after photo-alignment can be further reduced and "island" azo-dye structure onto the rough ITO surface can be prevented due to better adhesion of SD-1 molecules.

Using this super-thin SD-1 layer as an alignment agent, the sufficiently high polar and azimuthal anchoring energy and an excellent electrooptical performance in TN and ECB LC cells can be obta ined. The method allows to have a perfect LC photo-alignment in large or curved cells and is very attractive for mass production. We hope, that the results of our work can be used to develop fast reliable low power optical switches and other passive elements for fiber optical communication systems, which are based on LC devices and photonic crystals because it is impossible to use rubbing technology for align LC in fiber optics.

Acknowledgements

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