Novel Photo-Aligned Twisted Nematic Liquid Crystal Cell

D.D. Huang, V.M. Kozenkov, V.G. Chigrinov, H.S. Kwok
Hong Kong University of Science and Technology Clear Water Bay, Kowloon, Hong Kong
Hirokazu Takada, Haruyoshi Takatsu
Corporate R&D Division, Dainippon Ink and Chemicals Inc., Japan

ABSTRACT

Novel photo-aligned twisted nematic liquid crystal (LC) cell based on one-step illumination with oblique unpolarized UV light of empty cell with azo-dye layers on ITO coated substrates is prepared. If the incident angle is high enough (>75^0), the P-polarization of the light is more pronounced for the bottom azo-dye layer in comparison with the upper one. Thus the photo-alignment of azo-dye layer on the bottom substrate is perpendicular to that of the upper one and LC directors on the top and bottom substrates also become perpendicular. Novel photo-aligned twisted nematic LC cell was fabricated using this technology.

INTRODUCTION

The photo-aligning technique has been widely recognized as a promising technology for the new generations of liquid crystal displays (LCDs), which can replace usual rubbing technology [1-3]. Azo-dye materials provide a perfect uniform alignment of nematic LC with a pretilt angle up to 5^0, strong anchoring energy both in azimuthal and polar directions, high voltage holding ratio and long term stability to UV and IR light. Recently we showed, that azo-dye materials can provide a perfect slightly tilted alignment for a verical aligned nematic LCDs (VAN-LCDs) [4].

In this report we propose a simple method of the preparation of photo-aligned twisted nematic (TN) LCD by one step illumination with oblique unpolarized UV light of empty cell with azo-dye layers on ITO coated substrates.

EXPERIMENTAL

The sulphuric azo-dye (SD-1) was dissolved in N,N-dimethylformamide (DMF) at a concentration of 1 wt %. The solution was spin coated onto glass substrates with ITO electrodes and dried at 100^{o}C. The coated film on the substrate was uniform and about 10 nm thick. UV light was irradiated onto the surface of the film using super-high pressure Hg lamp through an interference filter at 365 nm. The light intensity irradiated on the surface of the film was 5-15 mW/cm^2 for polarized light and 40 mW/cm^2 for non-polarized light. The ITO substrates covered the sulphuric azo-dye (SD-1) layer were cured together by obliquely incident non-polarized UV light. After the UV illumination of the empty cell with a thickness of 5 μm, it was filled with liquid crystal MLC-6080 (E.Merck) with the optical anisotropy $\Delta n = 0.2024$. Fig. 1 shows the scheme of the photo-alignment process by UV exposure in oblique incidence with a dosage of 5 J/cm^2. The incident angle was varied from 5° to 75° in step of 10°. We found that, when the incident angle was less than 45°, there was no alignment observed; the incident angle between 45° ~ 65° could result in a homogeneous alignment with small twist domains; the 75° incident angle leads to a perfect twisted LC alignment with a small non-aligned domain, which might be caused by shading at the glass edge.

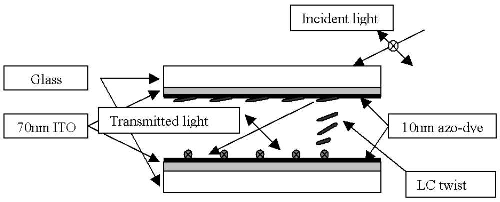

Figure 1. UV exposure of empty LC cell by oblique non-polarized UV light. The UV light at high incidence angle is more *P*-polarized for lower azo-dye layer, than for the upper one.

RESULTS AND DISCUSSION

At the 75° incidence angle, the *P*-polarized light predominates which results in a twisted alignment with 88° twist angle, i.e. close to the twist angle usually measured in photo-aligned TN LC cells [1-3]. The twisted LC alignment occurs because the azo-dye layer supports the LC orientation perpendicular to the UV light polarization, i.e. along the direction of the light on the upper cell substrate and perpendicular to the P-polarized light on the lower substrate (Fig.1).

We have evaluated the degree of light polarization for the UV light passed through the upper substrate in comparison with the bottom one, as shown in Fig. 2. The transmitted beam is strong in *P*-polarization parallel to the plane-of-incidence and weak in *S*-polarization perpendicular to the plane-of-incidence i.e. partially polarized (Fig.2). The ratio of the *S*-state to *P*-state light transmittance T_s/T_p decreases for the higher angles of incidence of UV light and is lower for the SD-1 layer on the bottom substrates in comparison with the upper one (Fig.2).

When making a cell by using a substrate with a certain ITO mask and another ITO substrate, the oblique UV non-polarized light at 75° incidence would lead to twisted LC alignment in ITO area and homogeneous alignment in areas without ITO. Fig. 3 shows the photo of the cell with a HKUST logo, obtained by this method.

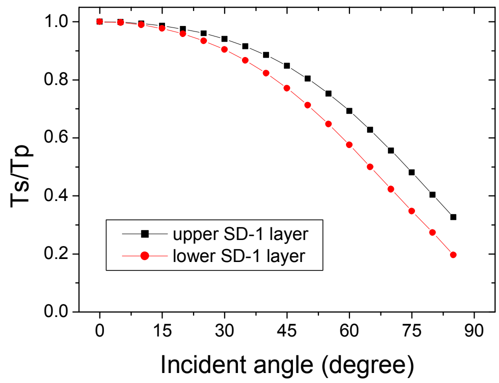

Figure 2. The ratio of the polarization T_S/T_P for LCD cell illuminated as shown in Fig.1. P-polarized light is more pronounced for the bottom (below) substrate, than for the upper one for high light incident angles.

Figure 3. Photograph of the cell with a HKUST logo, made by non-polarized UV light exposure at the angle of 75^0. Black regions have homogeneous alignment in crossed polarizers (no ITO layers on both substrates). White regions exhibit twisted alignment by the method shown in Fig.1.

Twisted LC alignment in ITO areas appears white and homogeneous alignment in no-ITO area appears black in crossed polarizers. According to our calculations, a layer of ITO could not affect the light polarization so much. There might be other reasons to explain the phenomenon, which needed to be studied further.

We have also repeated our experiment with one-step illumination by non-polarized light for the cell filled with LC instead of empty LC cell at the angle of 80^0. We observe a homogeneous LC alignment instead of twisted alignment, if the energy of UV-exposure was high enough (more than 10 J/cm^2). At the same time twisted LC alignment was also observed by one-step illumination of the empty cell at the same oblique exposure angle of 80^0, but small exposure energy (about 5J/cm^2). These experiments clearly show, that LC interaction with the surface drastically affects not only anchoring energy and LC pretilt angle, but even the LC configuration itself. We believe, that the predominance of *P*-polarized light in the bottom azo-dye layer with respect to the upper one is no longer observed in case of LC layer between them (Fig.1), as the refractive index of LC layer is close to the refractive index of azo-dye layer.

ACKNOWLEDGEMENTS

This research was partially supported by RGC grant HKUST6102/03E.

CONCLUSION

The new way of TN-cell cell preparation of TN-cell by one-step illumination of non-polarized light of the empty cell with the subsequent filling of the cell with LC is proposed. The exposure angle should be high enough (about 75^0) or more and LC cell substrates have to be covered with ITO. The variation of this procedure (no ITO in one or two substrates) and/or the exposure of the cell filled with LC results in a homogeneous LC alignment. The formation of the twist orientation may take place probably by special polarization conditions of the light at high angles of incidence (P-polarization at the bottom azo-dye layer predominates in comparison with this one in the upper azo-dye layer) and azo-dye molecules tend to align perpendicular to the light polarization.

Consequently, LC directors on the top and bottom substrates become also perpendicular. The novel method of twist-cell preparation is simple and easy to use for LCD production.

REFERENCE

[1] V. Chigrinov, E. Prudnikova, V. Kozenkov, H. Kwok, H. Akiyama, T. Kawara, H. Takada, H. Takatsu, *Liq. Cryst.*, **29**, 1321 (2002).

[2] Vladimir Chigrinov, Elena Prudnikova, Vladimir Kozenkov, Hoi Sing Kwok, Hidenari Akiyama, Tatsuo Kawara, Hirokazu Takada, and Haruyoshi Takatsu, *J. of SID*, **11/3**, 579 (2003).

[3] Vladimir Chigrinov, Anatoli Muravski, Hoi Sing Kwok, Hirokazu Takada, Hidenari Akiyama and Haruyoshi Takatsu, *Phys. Rev. E*, **68,** 061702-1 (2003).

[4] V.A.Konovalov, V.G.Chigrinov, H.S.Kwok, H.Takada and H. Takatsu, *Jpn. J. Appl. Phys.,* **43,** 261 (2004).