Japanese Journal of Applied Physics
Vol. 44, No. 7A, 2005, pp. 5117–5118

Brief Communication

Novel Photoaligned Twisted Nematic Liquid Crystal Cell

Dan Ding HUANG, Vladimir KOZENKOV, Vladimir CHIGRINOV, Hoi Sing KWOK, Hirokazu TAKADA[1] and Haruyoshi TAKATSU[1]

Centre for Display Research and Department of Electrical and Electronic Engineering, The Hong Kong University of Science and Technology, Kowloon, Hong Kong, P. R. China
[1]*Corporate R&D Division, Dainippon Ink and Chemicals Inc., Japan*

(Received December 18, 2004; accepted February 15, 2005; published July 8, 2005)

A novel photoaligned twisted nematic liquid crystal display (TN-LCD) cell is fabricated by one-step illumination with oblique nonpolarized UV light of an empty cell with azo-dye layers coated on indium tin oxide (ITO) substrates. If the incident angle is sufficiently large (>75°), the p-polarization of the light is more pronounced for the bottom azo-dye layer in comparison with that for the upper one. Thus, the photo-alignment of the 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. The method provides a new simple way of manufacturing photoaligned TN-LCDs. [DOI: 10.1143/JJAP.44.5117]

KEYWORDS: photoalignment, azo-dye, twisted nematic LC.

The photoalignment technique has been applied in twisted nematic liquid crystal displays (TN LCDs) for a long time and the LCD produced show excellent electrooptical performance.[1,2] In our previous studies, the azo-dye layers covered on indium tin oxide (ITO) substrates were normally exposed to a linearly polarized UV light. After the photo-alignment process, the ITO substrates were cured perpendicular to each other, to form a LC cell with a 90° TN alignment. In this paper, we propose a simple method of fabricating photoaligned TN LCDs by one-step illumination with oblique nonpolarized UV light of an empty cell with azo-dye layers on ITO coated substrates.

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°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 a 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 nonpolarized light. The ITO substrates that covered the azo-dye layers were first cured together to make an empty cell with a thickness of 5 μm. Secondly, a nonpolarized UV light was applied to expose the cell in oblique incidence. Figure 1 shows the scheme of the photoalignment process. The substrates were exposed to UV light in oblique incidence with a dosage of 5 J/cm^2. The light incidence angle was measured from the normal direction. It was varied from 5° to 75° in steps of 10°. After the UV illumination, the empty cell was filled in vacuum with liquid crystal MLC-6080 (from E. Merck) in a nematic phase. The LC optical anisotropy was $\Delta n = 0.2024$.

We found that, when UV alignment was absent or when the incident angle of UV alignment was less than 45°, no LC alignment was 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 nonaligned domain, which might be caused by shading at the glass edge. Nonpolarized UV light exposure under small incidence angles could not induce any LC alignment. In the range of 45°–70° incidence angle, nonpolarized UV exposure could lead to LC alignment with a pretilt angle on both substrates, which was observed as a homogeneous alignment. On the other hand, after passing through the upper substrate, the UV light became partially polarized, which could involve some weak polarization effects. This was the reason why there were some small twist domains.

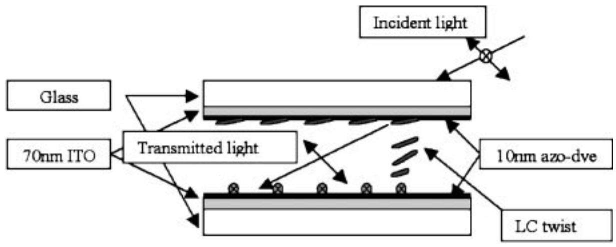

Fig. 1. UV exposure of empty LC cell by oblique nonpolarized UV light. The UV light at a high incidence angle is more p-polarized for the lower azo-dye layer than for the upper layer.

At the 75° incidence angle, the p-polarized light predominates, which results in a twisted alignment with an 88° twist angle; this is close to the twist angle usually observed in our previous experiments.[1,2] The twist angle of 88° was caused by the weak azimuthal anchoring energy of the SD-1 aligning layer. 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. The LC pretilt angles on both top and bottom substrates are nonzero, as was confirmed in our previous experiments.[1] The direction of the twist angle is defined by the handedness of the chiral dopant in MLC-6080, which was left in our case.

We have evaluated the degree of light polarization for the UV light passing through the upper substrate in comparison with that in the case of the bottom one, as shown in Fig. 2. According to optical light-tracing calculation,[3] the transmitted beam is strong in the p-polarization parallel to the plane-of-incidence and weak in the s-polarization perpendicular to the plane-of-incidence; i.e., the transmitted beam is partially polarized. The ratio of the s-state to p-state light transmittance T_s/T_p decreases as the incident angle of UV light increases, and is lower for the SD-1 layer on the bottom substrate in comparison with that in the case of the upper one. The photoaligned TN cell made by this new method exhibits a good electrooptical performance, comparable to

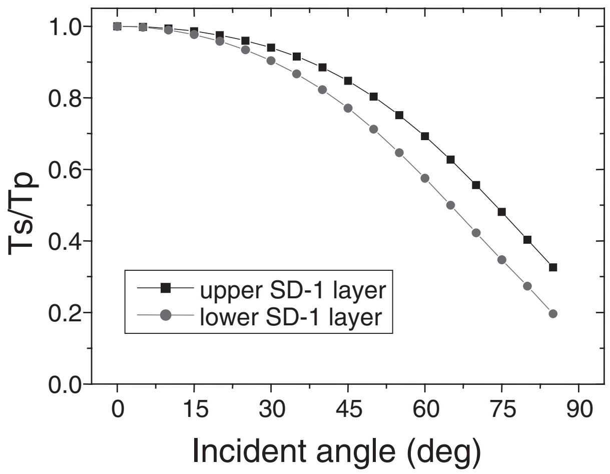

Fig. 2. Simulation results of ratio of polarization T_s/T_p for LCD cell illuminated as shown in Fig. 1. p-Polarized light is more pronounced for the bottom (below) substrate than for the upper one for large light incident angles.

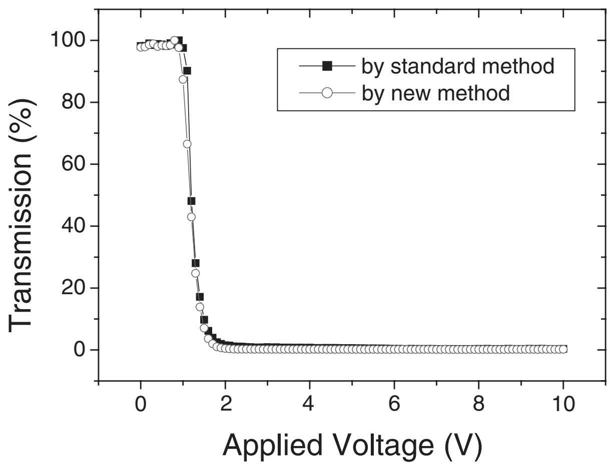

Fig. 3. Electrooptical performance of TN cells fabricated by new method, in comparison with that of cell fabricated by standard rubbing method.

that of TN cells fabricated conventionally, as shown in Fig. 3.

We have also repeated our experiment with one-step illumination by nonpolarized light for a cell filled with LC instead of an empty LC cell at an angle of 80°. The LC was injected into the LC cell in a nematic phase, which has no alignment or twist alignment. After the UV exposure, we observed a homogeneous LC alignment instead of a twist alignment if the energy of UV-exposure was sufficiently high (more than $10\,J/cm^2$). At the same time, a twist LC alignment was also observed by one-step illumination of the empty cell at the same oblique exposure angle of 80°, but with a low exposure energy (about $5\,J/cm^2$). These experiments clearly show that, LC interaction with the surface significantly affects not only anchoring energy and LC pretilt angle, but also even the LC configuration itself. We believe, that the predominance of p-polarized light in the bottom azo-dye layer with respect to that in the upper one is no longer observed in the case of having an LC layer between them, because the refractive index of the LC layer is close to that of the azo-dye layer. In this case, the polarization effect, taking place for large incident light angles due to the difference in refractive index between the two neighboring optical media, disappears.[3)]

This research was partially supported by RGC grants HKUST6102/03E and HKUST6149/04E.

1) V. Chigrinov, E. Prudnikova, V. Kozenkov, H. Kwok, H. Akiyama, T. Kawara, H. Takada and H. Takatsu: Liq. Cryst. **29** (2002) 1321.
2) V. Chigrinov, A. Muravski, H. S. Kwok, H. Takada, H. Akiyama and H. Takatsu: Phys. Rev. E **68** (2003) 061702.
3) E. Hecht: *Optics* (Addison-Wesley, Reading, MA, 2002).