Photostability Evaluation of Liquid crystal Cell under a Focused Blue-Violet Laser Beam

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We report the optical writing in the liquid crystal (LC) cell with a photo-crosslinkable polymer alignment surfaces. Double-faced writing is successfully demonstrated in a guest-host mode LC cell by exposing the cell from both sides with an unpolarized UV light. Different LC alignment patterns are performed on both alignment substrates. Written images can individually be visualized when a polarizer is replaced in front of and behind the cell. Logical operations for two written images are also obtained when the LC cell is set between the polarizer and analyzer.

Keywords: Liquid Crystal, Photostability, blu-ray, alignment Polymer, Far Field Pattern.

1. Introduction
Photostability of liquid crystal (LC) materials and alignment layer is an important matter in affecting the lifetime of the LC devices. Therefore, the UV stability of LC mixtures have been reported[1-4] and the light induced degradation of LC cells have been investigated[5,6]. Recent years, the wavelength modulated in optical devices shifts from infrared ~ red to blue ~ violet wavelength due to the enhancement of diffraction properties, high density record in optical memory medias and the commercial production of blue-violet laser diodes. Therefore, LC gratings[7,8] and lenses[9,10] should also operate the blue - violet laser beam. Moreover, the projection type LC display (LCD) is needed a strong photostability by demanding higher backlight power and smaller LC device size. The shorter wavelength in the white light might mainly affect to the degradation of LC cells. Therefore, it is very important to evaluate the photostability of LC optical devices and LCDs for the blue ~ violet light. However, we need much time (a few days ~ a week) to evaluate the photostability by a conventional acceleration irradiation method. In addition, it is difficult to catch the beginning point of the degradation under the light irradiation.

In this work, we irradiated the LC cell with a focused blue - violet laser beam to reduce the photostability evaluation time. An interference far field pattern (FFP) pattern of the transmission laser beam was observed to detect the degradation in real-time.

2. Experimental
Figure 1 shows the schematic model of the laser beam irradiation and the FFP observation. We prepared a homogeneous LC cell using rubbed polyvinylalchol (PVA) and polyimide (PI: LX1400, Hitachi Chemical) films coated on the glass substrate with an indium-tin-oxide electrode. LC materials used in this study were 4-cyano-4'-n-pentylbiphenyl (5CB) and three LCs with high refractive index anisotropy; fluorinated LC mixture (MLC-2058, Merck), cyano LC mixture (E44, Merck), and cyano LC mixture containing tolane substances (MLC-6080, Merck). The cell thickness was 10 µm. The laser beam of 12 mW at 403 nm from the laser diode was focused on the LC layer through the lens of which numerical aperture was

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0.35. The LC cell temperature was about 20 °C under the laser beam irradiation. The transmission image of the laser beam, that is the FFP, was observed on the screen which was put 50 – 80 cm behind the cell. The LC alignment degradation was investigated using a polarizing microscope.

3. Results

Figure 2 shows the photographs of 5CB alignment degradation domain. The polarization direction of the laser beam was parallel to the LC director. Irradiation times were 20 min and 5 min in cells using PVA and PI film, respectively. The interference lines shown in Fig. 2(a) and 2(d) were observed, which shows the decrease of the optical retardation in the LC cell. The decrease of the retardation is caused by the increase of the LC tilt angle and/or the decrease of the birefringence by the photo decomposition. The clearing temperature $T_c$ (35.3°C) around the irradiation point did not change. Therefore, the increase of the tilt angle of 5CB is dominant for the decrease of the retardation. In addition, we could not observe any degradation in LC cells, when we irradiated empty cells with the focused laser beam for 1200 s and subsequently injected 5CB. We confirmed that the temperature of LC at the beam focus point was below $T_c$ under the irradiation, since the polarization plane of the transmission light was rotate about by 90° if we

Figures 3(a) show FFP pictures of the homogeneous LC cell which were prepared using MLC-2058 and PI alignment surfaces. The polarization direction of the laser beam was parallel to the LC director. The FFP immediately after the laser beam irradiation on the LC cell was the same as the laser beam image projected on the screen without the LC cell. The FFP with concentric fringes appeared after 30 s and we could not find the alignment degradation in the LC cell since the degradation point was too small to distinguish from rubbing scratches and particles. The FFP changed with the progress of the degradation of the LC alignment. The mean tilt angle at the center of the beam irradiation for 240 s was about 70°. The azimuth rotation of the MLC-2058 director on the PI surface was not observed. Figures 4 show experimental results of the LC cell using E44. The FFP started changing after a few seconds irradiation. The alignment degradation observed by the polarizing microscope was found after 30 s. The tilt angle at the center of the beam irradiation for 4 minutes irradiation was about 90°. These results indicate that the photostability of the E44 cell is lower than that of
the MLC-2058 cell. The azimuth rotation of the E44 director was also observed by the laser beam irradiation for more than 60 s.

Next, the cells were irradiated with the focused laser beam of which polarization direction was perpendicular to the LC director. The alignment degradation was confirmed after 300 s irradiation and the tilt angle at the center of the beam irradiation for 600 s was about 55° in both cells, as shown in Fig. 5(a) and (b). The light absorption anisotropy of the LC and the rubbed PI surface contributes to the polarization dependence on the photostability. The FFP of the MLC-2058 cell did not change, because only the tilt was up in the cell and the refractive index was ordinary index for the incident laser beam inside and outside the degradation domain as shown in Fig. 5(a). If the polarization direction is changed parallel to the LC direction for an instant by inserting a half wave plate or a 90° TN cell between the laser diode and the LC cell, the concentric FFP appears at that moment. On the other hand, the azimuth director of E44 rotated with simultaneously increasing the tilt angle. Therefore, the transmitted light at the degradation point showed an elliptically polarization state and the FFP changed, as shown in Fig. 5(b).

The FFP and the photo degradation of the LC cell using MLC-6080 are shown in Fig. 6. MLC-6080 contains tolane substances which are known as a low UV photostability material. The polarization direction of the laser beam is parallel to the LC director. When the LC cell was irradiated with the laser beam, the FFP rapidly changed and rings of the fringe were disordered as shown in Fig. 6 (a). It is found that the Tc around the beam focus point was dropped and the MLC-6080 was seemed to decompose, as shown in Fig. 6 (b). The PI layer was also damaged and was not fly any longer at the
the focused laser beam and measuring the time of FFP appearance. On the other hand, the correlation with the ranking obtained by irradiating with the He-Cd laser (325 nm) or with the white light from the Xe lamp (> 350 nm) was low.

5. Conclusions

We have investigated the photostability of the LC cell by irradiating the focused blue-violet laser beam. The LC alignment degradation is generated for a very short time typically within 10 minutes. The beginning of the degradation can sensitively be detected by observing the FFP. This technology is a useful tool to qualitatively estimate the photostability of the LC cell.

References