Polarizer Free Reverse-Mode Liquid Crystal Gels with Super Twisted Orientation

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Abstract

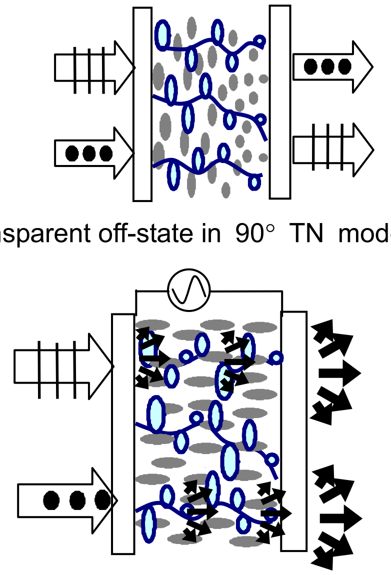
Reverse-mode films of anisotropic gels with 270° super twisted molecular orientation have been prepared based on nematic liquid crystal MLC-6080 and a small amount of reactive mesogen RM-256. The samples with a contrast ratio of about 8 and a driving voltage less than 8 V have been obtained. The driving voltage was reduced to 4 V by lowering power of UV irradiation used to polymerize the reactive mesogen.

1. Introduction

The reverse-mode gels show a transparent off-state and a light scattering on-state. They were primarily prepared by Hikmet using conventional LC with a positive dielectric anisotropy and photosensitive liquid crystalline diacrylates [1]. Shortly thereafter, the reverse-mode films were proposed on the base of LCs with negative dielectric anisotropy or dual-frequency LCs [2-4]. These gels however demonstrated high driving voltage and low contrast ratio because of poor dielectric and refractive index anisotropies. As a result of the subsequent optimization of materials, it was possible to reduce controlling voltage and slightly improve electro-optic contrast [5-7]. However, the contrast remained to be rather low (≈2) in the absence of a polarizer. It was caused by parallel configuration of LC cells. In this configuration, the incident light polarized perpendicular to a long axis of gel molecules is practically not scattered. To weaken strong angular dependence of light scattering, we have proposed to use samples with 90° twisted and 270° super twisted orientation [8]. We have demonstrated that super twisted configuration is more favorable from the viewpoint of contrast and its angular uniformity in case of polarized light. This work takes a step towards optimizing the parameters of such systems. By changing reactive mesogen (RM) in the composites we achieved a contrast value of about 8 at driving voltage of only 6-8 V. We also study influence of photo-polymerization conditions on the electro-optic performance of the gels.

2. Experimental

We used reactive mesogen RM-256 as a network forming polymer and nematic LC MLC-6080 ($\Delta\varepsilon$=+6.8, n_e=1.707, n_o=1.506, T_{NI}=95°C) as a LC host. Both compounds were obtained from Merck. The reactive mesogen was dissolved in the LC at concentration of 5 wt %. A chiral dopant ZLI-811 from Merck was also added to obtain the pitch length of about 17 μm to twist the LC orientation up to 270°. The mixture was sandwiched between two glass substrates coated with rubbed polyimide film whose rubbing directions were perpendicular to each other. The gap between two substrates was 10 μm. The cell was irradiated with UV light of 20 mW/cm^2 for 5 minutes to polymerize the reactive mesogen keeping the twisted molecular orientation state, as schematically shown in Fig. 1(a). The electro-optical properties were measured using a laser diode generating at 635 nm and a silicon photodiode. The frequency of the applied voltage was 1 kHz. The collection angle of scattered light was about 2°. The transmittance of 100 % was defined as the light intensity detected without the cell.



(a) Transparent off-state in 90° TN mode

(b) Scattering on-state in 270° STN mode

Fig.1. Schematic models of molecular orientation in twisted LC gel films.

3. Results

Figure 2(a) shows transmittance vs. voltage curves for the 90° twisted LC gel film. In the off-state, the film is very clear without a polarizer, and appears dark and bright between parallel and crossed polarizers, respectively, since the polarization plane of

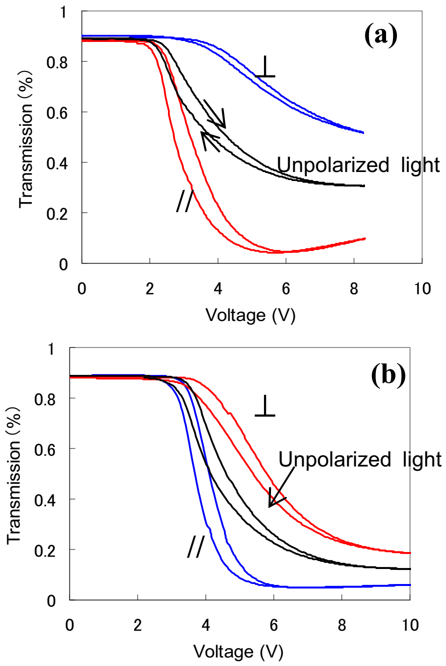


Fig.2. Electro-optical properties in (a) 90° TN and (b) 270° STN gel films.

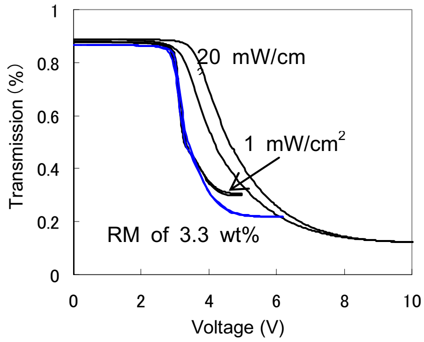
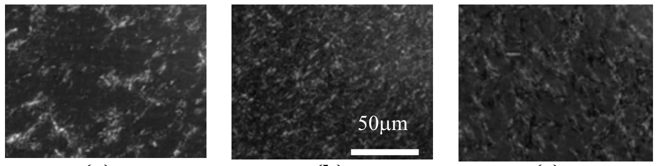


Fig.3. Eelectro-optical properties of unpolarized light in 270° STN gel films.



(a) (b) (c)

Fig.4. Transparent microphotographs of 270°STN gel films in crossed polarizers. UV irradiation powers are (a) 1 mW/cm^2, (b) 20 mW/cm^2 and (c) RM of 3.3wt%.

the incident light rotates at almost 90° as observed in a conventional twisted nematic LC cell in Mauguin's regime. Upon voltage application to the film, LC molecules reorient parallel to the applied field. For the light polarized along the rubbing direction on the entrance side of the substrate, the refractive index mismatch between the LC and RM increases near the entrance side of the film Moreover, the incident light polarized perpendicular to the rubbing direction goes through without rotation of the polarization plane. Then the refractive index mismatch occurs near the exit side of the film and the light is scattered. However, the scattering is weaker than that of the light polarized parallel to the rubbing direction. Therefore, the contrast ratio of the unpolarized incident light is low (≈ 3).

Figure 2(b) shows the transmittance vs. voltage curves for the 270° twisted LC gel film. The incident light polarized perpendicular to the rubbing direction on the entrance side of the substrate is scattered stronger than that in the 90° twisted film, since the refractive index mismatch occurs near the exit side of the substrate as well as in the middle of the film, as shown in Fig. 1(b). Therefore, the contrast ratio of the unpolarized incident light increases to about 8. It is noteworthy that this high value of contrast is reached at rather low values of driving voltage (6-8 V).

It has been earlier reported that the weaker UV irradiation in the polymerization process reduces the driving voltage in the homogeneously aligned LC gel films [3]. Therefore, we tried to make the twisted films by irradiating the mixtures with UV light of 1 mW/cm^2 for 100 minutes. As a result, the driving voltage reduced to 4 V. The lower concentration of RM to 3.3wt% also decreases the driving voltage. A hysteresis width also became very small. Transparent microphotographs are shown in Fig. 4. LC domains become larger due to slower polymer network formation and low RM concentration. These results indicate that the large LC domains make a reorientation of nematic LCs easier, since interaction between polymer and LC surfaces becomes weaker. However, simultaneously, the light scattering in the on-state is weakening too that results in contrast ration of only about 3~4. This suggests that further optimization of such samples is needed. It should involve optimization of the ratio of LC and RM components, exposure conditions and thickness of the gel films.

4. Conclusions

We demonstrate improved performance of the reverse mode films of LC gels with 270° STN orientation. The value of electro-optic contrast 8 in combination with the controlling voltage of 6-8 V is obtained. This improvement is achieved by using reactive mesogen RM-256 from Merck as a polymer component of the gels. It is shown the opportunity of further improvement of the performance of such a system.

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