Light Scattering of Ordinary Ray in Reverse Mode LC Cell Assisted by Micro Lens Effect

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ABSTRACT

We have propose a reverse mode LC cell prepared using a hole-patterened electrode substrate. Light scattering properties are obtained through the micro-lens effect with a short focal length and index mismatching between LC and polymer. Ordinary incident light can also be scattered by non-uniform electric field.

1 INTRODUCTION

Some types of reverse mode LC devices with the transparent off- and the scattering on-state have been proposed. In the LC and polymer composite system [1, 2], the incident light is scattered by refractive index mismatching between polymer and LC. Another reverse mode type is performed using micro-lens array system in which non-uniform electric field generated by a hole-patterned electrode causes the light scattering [3, 4]. The LC lens is basically operated by reorient homogeneously aligned liquid crystals with positive dielectric anisotropy. For the index mismatching type reverse mode cell, the homogeneouslly aligned cell shows low driving voltage and strong light scattering. However, the lens effect and index mismatching can be obtained by limiting to an extraordinary incident light.

In this study, we propose the light scattering LC cell prepared by combining the polymer composite and microlens array systems. A contribution of each light scattering mechanism is discussed and light scattering properties of ordinary incident light are clarified.

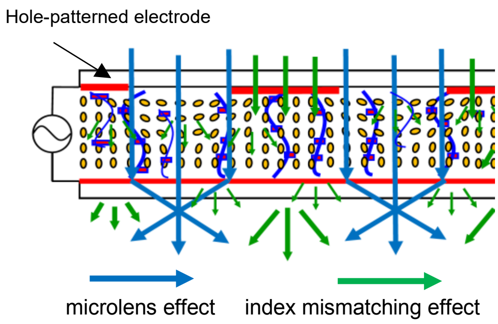

Fig. 1 Schematic model of scattering effect of combined cell.

2 EXPERIMENT

We used LC of MLC2136 (Δn=0.21, Merck) and diacrylate monomer of UCL-017 (DIC) mixture. The monomer of 5wt% was dissolved in the LC. A hexagonally arranged hole-patterned electrode was prepared. The diameter was 20 μm and the holes occupied 50% of the electrode area. We fabricated three type cells, "Type A" was a conventional LC and polymer composite type, "Type B" was the LC micro-lens array type, and "Type C" was a combination of Type A and Type B shown in Fig. 1. The cell thickness was set to 5 μm. The polymerization was carried out with the UV light (365 nm) of 20 mW/cm^2 for 300 s. An electro-optical property of the cell was measured using a laser diode of 635 nm and a silicon photodiode. The transmittance of 100% was defined as the light intensity detected without the cell. A collection angle of the scattered light was set to about 2°.

3 RESULTS

Figure 2 shows electro-optical properties in three types of reverse mode cells. The ordinary incident light is hardly scattered in Type A. On the other hand, Type B and C become hazy in the ordinary incident light although the scattering is weak. Type C has the strongest scattering of the extraordinary incident light and the driving voltage which gives the minimum

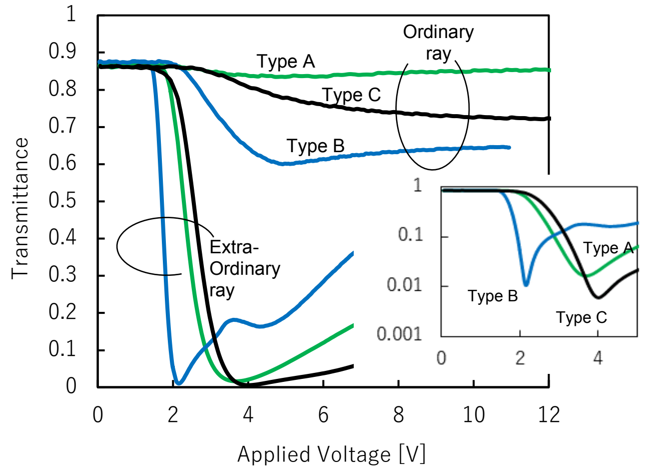

Fig. 2 Electro-optical properties of reverse mode cells.

transmittance is the highest in the three cells, as clearly shown in the inserted figure in Fig.2.

Figure 3 shows the light scattering pattern of extraordinary incident light in three cells by applying voltage of V_{90} and V_{10}. In Type A, the scattered light spreads perpendicular to the rubbing direction, that is, the polarization direction of the incident light, since the scattered light propagates and diffuses inside the cell. The theoretical focal length is estimated to be 50 μm in Type B, the focus point is out of the LC layer. Therefore, the scattered light isotropically spreads. The scattered light image in Type C has the characteristics of Type A and B, which indicates that two scattering mechanisms, refractive index mismatching and lens effects contribute to the stronger light scattering.

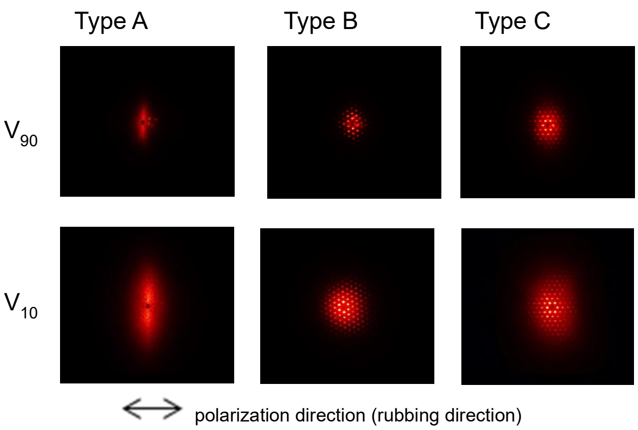

Fig. 3 Light scattering patterns in three cells by applying voltage of V_{90} and V_{10}.

Figure 4 shows polarized optical microscope (POM) images in three cells by applying voltage of V_{90} and V_{10}. The rubbing direction is parallel to one of the polarizer. A linear polarization state is preserved even if the incident light is fully scattered in Type A. On the other hand, the light leakage is observed in Type B. Electric field lines generated inside of the hole-patterned electrode is radially formed. Therefore, the twisted LC reorientation can be obtained at the edge of the holes, which causes the light scattering of the ordinary ray shown in Fig. 2. The light leakage is also observed in Type C by applying the voltage of V_{10}.

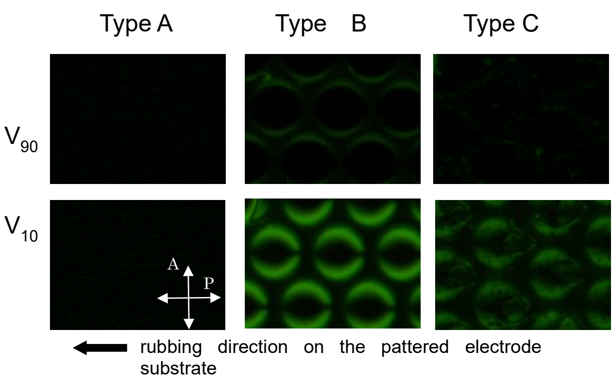

Fig. 4 POM images in three cells by applying voltage of V_{90} and V_{10}.

Next we have tried to improve the light scattering property in the ordinary incident light. We prepared the LC of RDP-A1872 ((Δn=0.29, DIC). The LC was sandwiched between substrates with the hole- patterned electrode. The hole diameter was 30 μm and the cell thickness was 19 μm. The positioning of the holes on both substrates were not particularly performed. The ordinary incident light is scattered stronger than that in the Type B cell shown in Fig .2, since the twisted LC reorientation generated around both side of the substrate. Applying this cell structure to the Type A cell, stronger light scattering of the natural incident light can be expected.

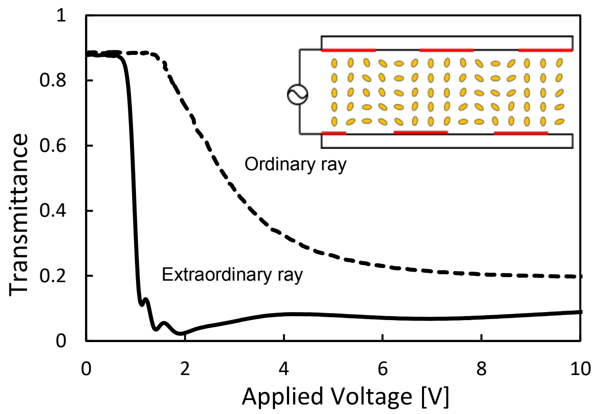

Fig. 5 Electro-optical properties in the LC cell with hole-pattered electrode on both side of the substrates.

4 CONCLUSIONS

Light scattering properties in three type of reverse mode cells, the refractive index mismatching type, and micro-lens array type, and the combination type, have been investigated. The short focal length of the LC lens effect by using hole-patterned electrode substrate contributes to increase the light scattering in the conventional index mismatching type cell. Moreover, the ordinary incident light is also scattered by the hole-pattered electrode. Light scattering of the natural incident light can be improved by using hole-patterned electrode substrate on both sides.

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