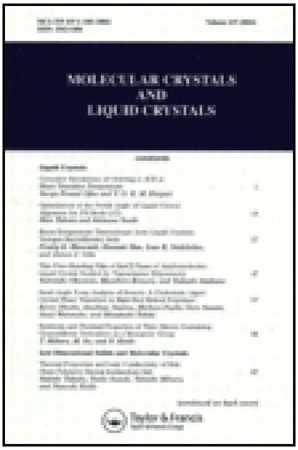

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Modulated Microdomain Switching of Nematic Liquid Crystals

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Modulated Microdomain Switching of Nematic Liquid Crystals

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Modulated microdomain switching of nematic liquid crystals have been investigated. This display mode used for light switching of micron-sized domains regions using a complicated electric field with special mesh electrode structures. Under He-Ne laser irradiation, contrast ratio was 22:1 for homeotropic alignment cell and transmittance change was no dependent of incident polarization condition. Under white light illumination, the contrast ratio was 4.3:1.

Introduction

Nematic liquid crystals have fascinated us for its flexibility. As a result of investigation, many kinds of display modes have been invented.[1-15] Recently, photolithographic technique has been applied to the patterning of the electrode and domain formation. We had investigated a microdeflection liquid crystal display modes with zigzag fashioned electrode structure[16] and scattering display modes with in-plane electrode structure. [17] During these investigations, we have considered that a scattering display mode would be realized in these special electrode structure and position controlled domain regions. In this paper, we have investigated a modulated microdomain switching (MMS) of nematic liquid crystals which uses "micron-sized" multi-domain region for a light switching.

Proposal and experiment

A characteristic of the proposed display mode is light scattering using "micron-sized" multi-domain regions. Recent display modes used several ten microns sized multi-domain structure for the purpose of a wide viewing angle, whereas these multi-domains are insufficient for scattering. In the polymer-dispersed liquid crystals, several micron-sized droplet is used and scattering characteristics is excellent. However, position control of droplet is difficult. We consider that light switching, *i.e.*, scattering, polarization conversion, diffraction, deflection and so on, will be realized using the liquid crystal cell structure with "micron-sized" periodical domain structure.

For example, switching characteristics of electric field using periodical electrode structure, are as follows: Any of homogeneous, homeotropic, tilt and hybrid alignment structure could be applied. Electrode structure under study is shown in Fig.1. Basic repetition area is dotted region. In order to obtain a complicated electric field, special mesh structures combined with the mesh and oblique line were used. Molecular alignment of liquid crystal between electrode intersection parts is identical to conventional cell and another part shows complicated and oblique electric field. Therefore, non-uniform "micron-sized" multi-domain structure could be realized. Electrode material was indium tin oxide, where the electrode width of 3 μm and the distance L was 30 μm.

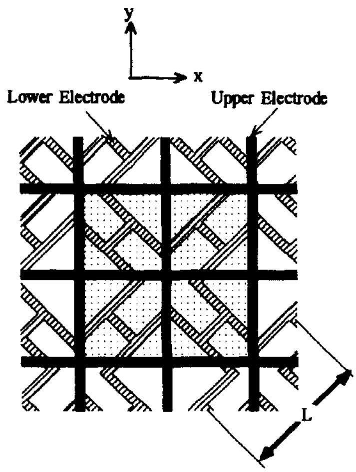

Figure 1. Electrode structure

Prior to experiment, potential distribution in vacuum was calculated using Laplace's equation. In experiment, the characteristics of five-micron thick cell was shown. Initially alignment state was uniform state. Here, homeotropic alignment (ODS-E: Chisso), where surface-anchoring energy was relatively small, was shown. The liquid crystal used was GR-63 (Chisso, dielectric anisotropy $\Delta\varepsilon$ =13.9, birefringence Δn=0.1574). Light source was He-Ne laser and tungsten lamp of white light. Transmittance versus voltage (Tr-V) characteristics was measured using computer-controlled system with photodiode for He-Ne laser irradiation, luminance meter for white light illumination and digital multi-meter. The response characteristics were evaluated under application of 16Hz at the repetition cycle of two seconds with one second ON/OFF repetition.

Three dimensional potential calculation

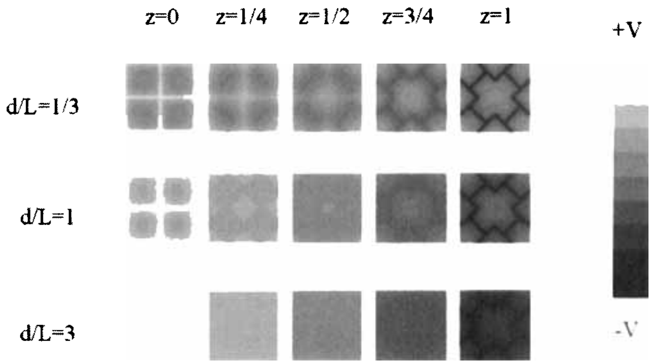

Figure 2. The potential distribution with thickness in vacuum.

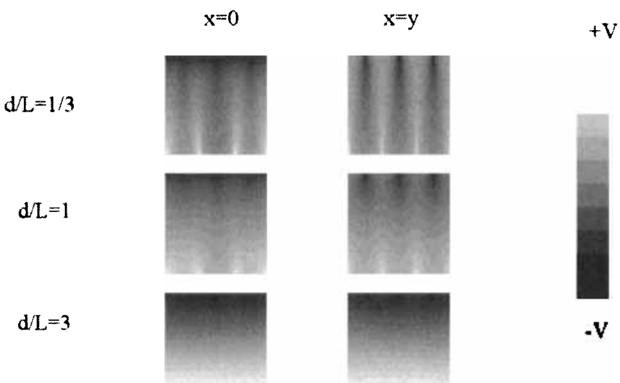

Figure 3. Cross sectional views of the potential distribution in vacuum.

In order to obtain a guide for electrode distance and cell thickness, the potential distribution in vacuum was calculated. The applied voltage of upper and of lower electrode was $+V$ and $-V$, respectively. The cell thickness was fixed at d and the ratio d/L was selected among 1/3, 1 and 3.

The potential variations with thickness were shown in Fig.2 and cross sectional views of the potential are shown in Fig.3, for basic repetition region. The x-direction was parallel to the upper electrode line and the line $x=y$ is inclined by forty-five degrees from the x-axis. When the ratio d/L was larger than three, the potential changed gradually and equi-potential line was almost parallel to substrate plate, like an ordinary cell structure. On the other hand, when the ratio d/L was smaller than 1/3, the existence of the electrode greatly influenced the potential distribution and the voltage at the middle of the cell was superimposed between upper and lower electrodes. From Fig.3, the potential distribution changed greatly by cell thickness position. From the above-mentioned discussion, it is expected that the liquid crystal will be disordered and field-induced disclination will appear in thinner cell. In further thinner cell, however, horizontal component of electric field will be enhanced and switching mode will change to an in-plane switching. Therefore, there exists an optimum cell thickness.

<u>Experimental results</u>

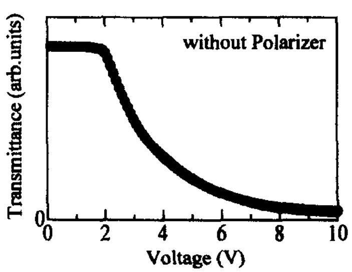

Figure 4. Tr-V characteristics
(He-Ne laser)

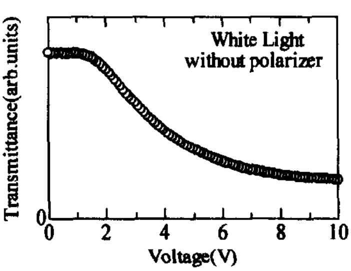

Figure 5. Tr-V Characteristics
(White light)

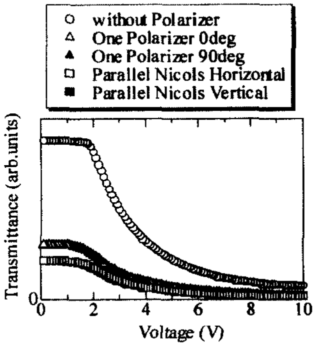

Figure 6. Tr-V Characteristics with varied polarization condition

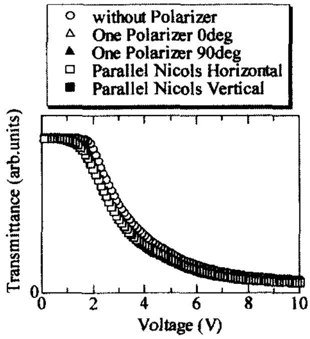

Figure 7. Normalized Tr-V characteristics

Transmittance versus voltage characteristics of the cell without polarizer under He-Ne laser irradiation is shown in Fig.4. Contrast ratio was 22:1. Figure 5 also shows the Tr-V characteristics of the cell without polarizer under white light illumination, whereas the contrast ratio was 4.3:1. Figure 6 shows the Tr-V characteristics for various polarization conditions. Figure 7 also shows normalized Tr-V characteristics. The transmittance has decreased by inserting the polarizer, however, there was no polarization direction dependence. The characteristics were almost identical even after the normalization. Under crossed polarizers, optical transmittance increased with increase in the applied voltage, however, maximum optical transmittance was only as low as 1.2% at 3.5V compared to that of parallel polarization condition. Therefore, polarization state conversion was small in this device configuration.

The optical light pattern change under He-Ne laser irradiation was shown in Fig.8. The diffraction pattern corresponding to repetition

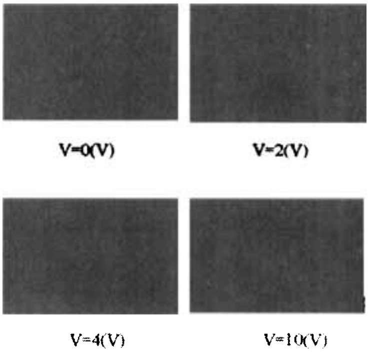

Figure 8. Optical light pattern change
See Color Plate XIV at the back of this issue.

periods of the electrode were observed without applied voltage. With increased in the voltage, the numbers of diffraction spots increased and light intensity of the direct beam also decreased. There were many small spots due to alignment mismatching between opposite electrodes. Optical micrographs of the observed cell under crossed polarizer are shown in Fig.9. Without applied voltage, both upper and lower electrodes are observed. With increased in the voltage, refractive index modulation due to orientational deformation of liquid crystal molecules occurred and optical focusing and dispersion were also observed. Under white light illumination, direct view of the transmittance decreased by applying voltage.

The optical response characteristics under the application of voltage with rectangular burst waveform are shown in Fig.10. The transmittance response increased with hump and the transmittance showed small ripple. Figure 11 shows response time versus voltage characteristics. In a similar manner

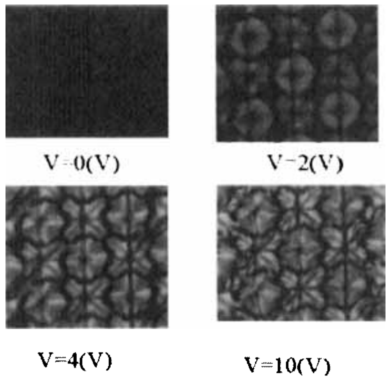

Figure 9. Optical micrographs
See Color Plate XV at the back of this issue.

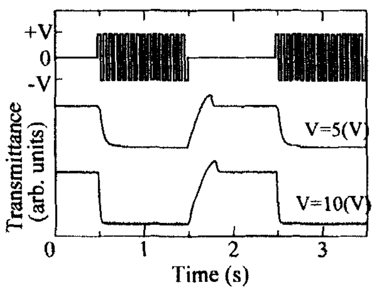

Figure 10 . Optical response of the cell without Polarizer

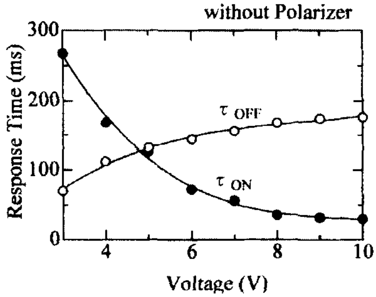

Figure 11. Response time characteristics

that of conventional twisted nematic cell, the rise time decreased and the fall time increased slightly with increase in the voltage. Response times of ON and OFF states were 61ms and 146 ms, respectively, at 5V. These values were longer than that of conventional display mode.

The viewing angle characteristics under He-Ne laser irradiation are shown in Fig.12. The parameters V_{100} $-V_{20}$ shows the applied voltage that the transmittance shows 100-20% under direct view condition. The viewing angle characteristics were symmetric against the whole viewing directions. The transmittance at V_{100} was flat with varied viewing angle, while there was larger viewing angle dependence between V_{80} and V_{40}. In the Tr-V characteristics, threshold voltages, defined as the voltage at the transmittance decreased to 90 % of the maximum, decreased with increase in the viewing angle. From these results, the domain structures in the liquid crystal cell appeared clearly in applied lower voltage.

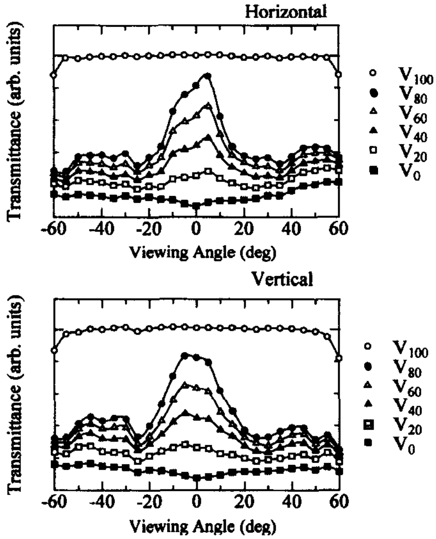

Figure 12. Viewing angle characteristics.

Conclusion

We have presented "micron-sized" micro-domain switching in the nematic liquid crystal cell. Up to date, the characteristics are insufficient for actual liquid crystal display. Further investigation about the electric field distribution and smaller domain fabrication will improve electro-optical characteristics.

Acknowledgment

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