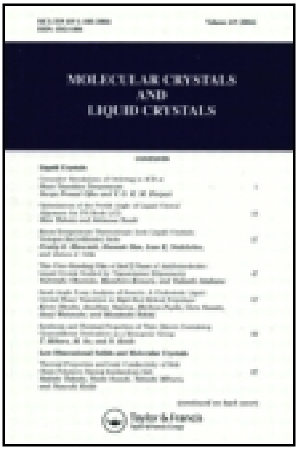

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PERFORMANCE OF SHORTER PERIODICAL DOMAIN OF NEMATIC LIQUID CRYSTAL INDUCED BY ELASTIC WAVE PROPAGATION

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Performance of Shorter Periodical Domain of Nematic Liquid Crystal Induced by Elastic Wave Propagation

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The light diffraction properties of a shorter periodical domain, which is caused by an elastic wave propagating along one of two glass plates composing a liquid crystal cell, are described. The shorter periodical domain is controllable for the application of an electric field to the liquid crystal cell. The response time of the disappearance of the shorter periodical domain decreases with increasing the applied voltage. On the other hand, the response time of the domain formation is independent of the applied voltage. These response times agree quantitatively with those of the birefringence electrooptic effect. The domain disappearance by applying the voltage to the liquid crystal indicates the Freedericksz transition.

Keywords: nematic liquid crystal; elastic wave propagation; periodical domain; light diffraction

INTRODUCTION

The acoustooptic (AO) effect of nematic liquid crystals has been reported by using a surface acoustic wave (SAW) excited by an interdigital transducer (IDT).[1-3] The operation frequency of the SAW device is limited in a pass-band related to the SAW velocity and the periodicity of the IDT.

We have been reported an acoustooptic effect of a nematic liquid crystal, which is induced by an elastic wave propagating along one of two glass plates composing a liquid crystal cell.[4] In such a case two types of periodical domains have been observed under the existence of elastic wave. We have recently studied that the longer periodical domain is related to the velocity of the elastic wave in the liquid crystal cell.[5] On the other hand, the shorter periodical domain is independent of the carrier frequency of the elastic wave and influenced by the orientation direction of the liquid crystal molecules and the layer thickness of the liquid crystal.

In this paper, we investigate a light diffraction property of the shorter periodical domain induced by the elastic wave. The characteristics of the disappearance and formation of the shorter periodical domain are described by applying and removing a voltage to the liquid crystal layer. In the present study, the use of a Lamb wave device is incorporated for the elastic wave propagation. The Lamb wave propagates in a thin glass plate, which is available for multiple-mode operation.[6] The Lamb wave in a liquid-loaded substrate with a liquid layer, in the form of a leaky wave, is mode-converted to a longitudinal wave into the liquid layer.[7,8]

EXPERIMENTAL PREPARATION

Figure 1 shows a schematic structure of a liquid crystal cell and an interdigital transducer (IDT) used in the present study. The IDT is used for exciting an elastic wave (Lamb wave), in a 230μm-thick piezoelectric ceramic plate (TDK, 101A) cemented on a 1.1mm-thick glass plate (Corning, 7059). The poling axis is in the thickness direction. The IDT has an interdigital periodicity of 400μm and seven-electrode-finger pairs. A liquid crystal sample is sandwiched between two indium-tin-oxide (ITO) coated glass plates. A homogeneous alignment was obtained by using glass plates whose surfaces were coated with polyimide (JSR, AL1254) and rubbed unidirectionally. The liquid crystal compound used in this study was ZLI-

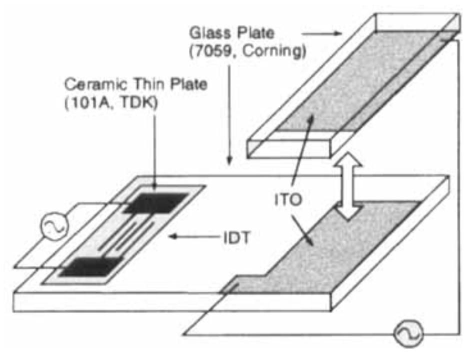

FIGURE 1 Schematic structure of a liquid crystal cell and an IDT.

1132 (Merck), which shows the nematic phase in the temperature range from -40℃ to +71℃. The thickness of the liquid crystal layer ranged from 4 to 6 μm.

Figure 2 shows an experimental setup used in this study. In the light diffraction measurement, no polarizer was used and the diffracted light was detected by a photodiode, which was rotated around the cell. On the other hand, two polarizers were used in the birefringence electrooptic measurement and the transmitted light through the cell was monitored by the photodiode, where two polarizers were set on the angle of ±45∞ from the orientation direction of the liquid crystal. The elastic wave was excited by the application of a sine voltage wave (9.5MHz) to the IDT. The applied voltage to the liquid crystal was a rectangular wave (1kHz).

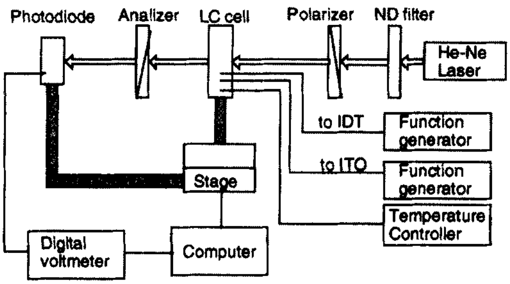

FIGURE 2 Experimental setup for measuring light diffraction and a birefringence electrooptic effect.

RESULTS AND DISCUSSION

When the elastic wave propagates in the liquid crystal cell, a periodical domain is recognized in the liquid crystal texture. Figure 3 shows a series of polarizing micrographs of the liquid crystal textures under the elastic wave propagation and the electric field application to the liquid crystal cell. Figure 3 (a) shows the liquid crystal texture when the elastic wave does not propagate and the electric field is not applied to the liquid crystal. A unidirectional alignment is recognized in this figure and the bright state is achieved because the angle between the direction of the molecular alignment and the polarizer is 45∞. Figure 3 (b) shows the liquid crystal texture under the elastic wave propagation. The periodical domain is clearly recognized in this figure. It has been reported that the direction of this domain is perpendicular to the rubbing direction and the periodicity of this domain increases

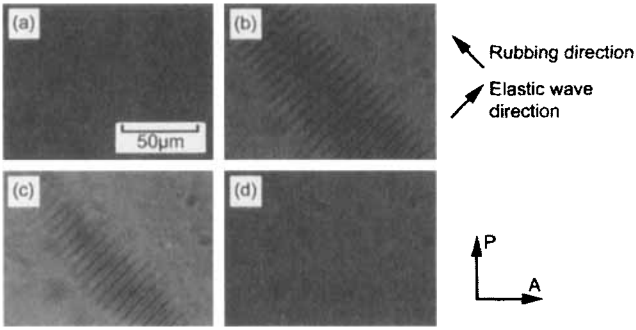

FIGURE 3 Polarizing micrographs of nematic liquid crystal texture. (a) is under no elastic wave and no applied voltage. (b)-(d) are under elastic wave propagation excited by applying a sine voltage (9.6MHz, 14V) to IDT. (b) is under no applied voltage. (c) and (d) are under applications of 1V and 2V rectangular wave (1kHz) to the liquid crystal, respectively. See Color Plate XIV at the back of this issue.

with the liquid crystal layer thickness. The liquid crystal textures shown in Figures 3 (c) and (d) are obtained under the electric field applied to the liquid crystal during the elastic wave propagation. The periodical domain is maintained under the application of the electric field below a threshold level, as shown in Figure 3 (c). While, for the electric field beyond the threshold level, the periodical domain disappears, as shown in Figure 3 (d), where the molecular orientation is parallel to the electric field direction and the birefringence to the incident light disappears.

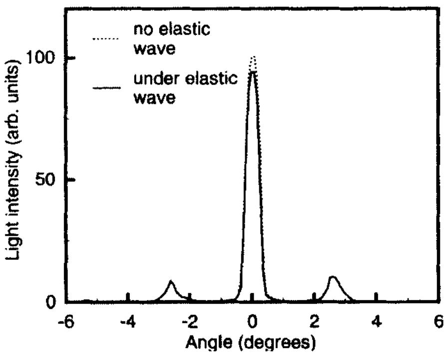

FIGURE 4 Observed angular dependences of transmitted and diffracted light intensities under no elastic wave and elastic wave propagation (9.5MHz, 14.5V).

Figure 4 shows the observed angular dependences of the transmitted and diffracted light intensities trough the liquid crystal cell under the conditions with and without elastic wave propagation. Under the existence of the elastic wave propagation, the diffraction peaks are recognized at ±2.61°. The diffraction angle corresponds to the first order diffraction peak, which is consistent with the value from the periodical length and the wavelength of the light source.

In the nematic liquid crystal with positive dielectric anisotropy, the liquid crystal molecules are reoriented in the direction of the applied electric field beyond the threshold level of the field. As shown in Figure 3, the light diffraction disappears by the application of the electric field to the liquid crystal. This indicates that the light diffraction is controllable by the electric field to the liquid crystal. Figure 5 (a)

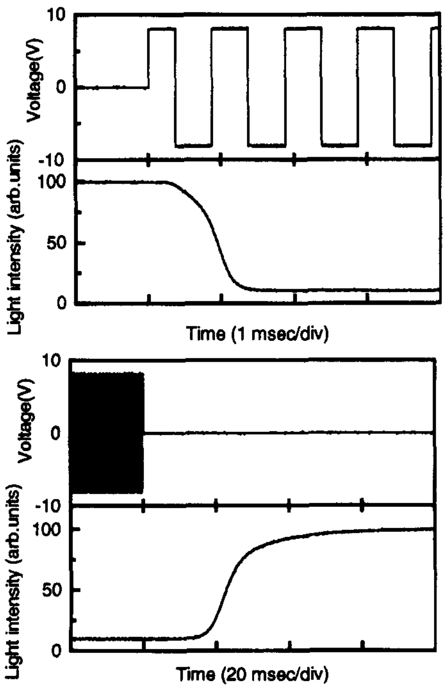

FIGURE 5 Observed waveforms of applied voltage and diffracted light intensity (a) for application and (b) for removal of square wave voltage.

shows the observed waveforms of an applied field to the liquid crystal and the light intensity of the first order diffraction. It is confirmed that the disappearance of the light diffraction is caused by the application of the square voltage wave. On the other hand, observed waveforms of diffracted light intensity for the removal of the applied square voltage wave is shown in Figure 5 (b), where the increase of the diffraction intensity is recognized. These results support that the light diffraction is controlled by the application and removal of the square wave voltage to the liquid crystal. The rise and decay times in the waveforms are defined as the time from the instant of the voltage removal to 90% of the light intensity change and the time from the instant of the voltage application to the 10% of the light intensity change, respectively.

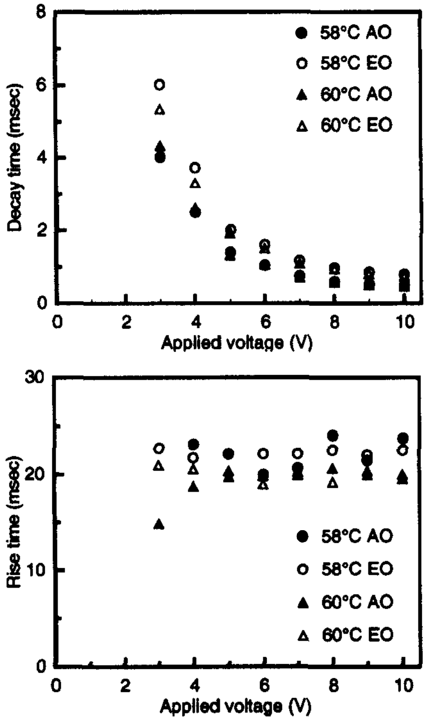

FIGURE 6 Applied voltage dependences of (a) decay time and (b) rise time of light diffraction and birefringence electrooptic effect.

Figure 6 shows the rise and decay times of the light diffraction as a function of the applied voltage to the liquid crystal. To compare with the birefringence electrooptic (EO) effect, the rise and decay times of the birefringence EO effect are also shown in this figure. The decay time corresponding to the disappearance of the shorter periodical domain decreases with increasing the applied voltage. The rise time corresponding to the formation of the shorter periodical domain is independent of the applied voltage. In these results, the decay and rise times of the light diffraction are similar to the tendencies in the birefringence EO effect, respectively.

We investigated the disappearance process of the shorter periodical domain while varying the amplitude of the applied rectangular voltage to the liquid crystal increased. Figure 7 shows the light intensities of the first order diffraction and the birefringence

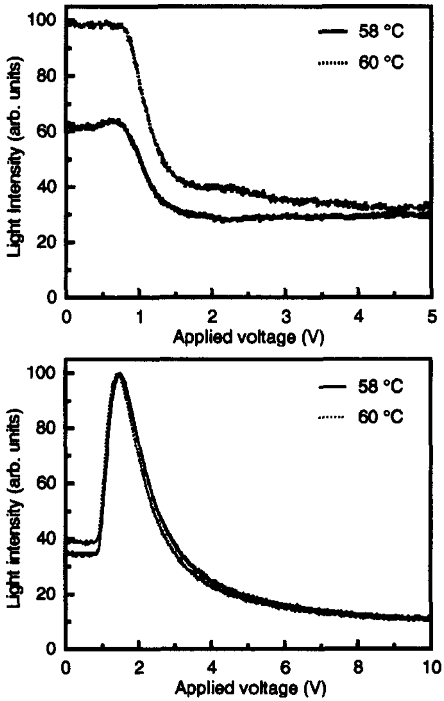

FIGURE 7 Light intensities of (a) light diffraction and (b) birefringence electrooptic effect as function of applied voltage to liquid crystal.

EO effect as a function of the applied voltage to the liquid crystal. The diffraction intensity kept at a high level below 1V decreases with increasing the applied voltage. Beyond 3V, the light intensity is held at a certain level. In the birefringence EO effect, a similar response is observed, as shown in Figure 7(b). The threshold voltage in the light diffraction is lower than that in the birefringence EO effect. This phenomenon is interpreted as the Freedericksz effect.[9] The disappearance of the shorter periodical domain by voltage application to the liquid crystal also indicates the Freedericksz transition.

CONCLUSION

The light diffraction properties of a shorter periodical domain induced in a nematic liquid crystal cell were investigated. The light diffraction of the shorter periodical domain is controllable for the application of the electric field to the liquid crystal. The response time of the disappearance of the shorter periodical domain decreased with increasing the applied voltage to the liquid crystal cell, which the response time of the formation was independent of the applied voltage. These response times are the same order as those of the birefringence EO effect. The disappearance of the shorter periodical domain by applying the voltage to the liquid crystal is related to the Freedericksz transition.

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