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Electrooptic Response of a Nematic Liquid Crystal Membrane with Water Boundary

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A nematic liquid crystal is conventionally used in two glass substrates because it has fluidity. In this research, a nematic LC is sandwiched by water instead of the usual glasses and an influence of water on the LC is investigated. A texture of the membrane was observed by a polarizing microscope and an electrooptic response of the membrane was measured by a crossed polarizing optical system. It was found that there was variety of the responses depending on the penetrating position of the LC membrane.

Keywords Electrooptic response; lecithin; nematic liquid crystal; underwater

Introduction

Molecular dynamics of a liquid crystal is strongly influenced by its surface. So far, an electrooptic response of a ferroelectric liquid crystal (FLC) film with air surface was studied [1–4]. The FLC film with air surface had different characteristics from the film with conventional glass surface. In addition, Langmuir-Blodgett film with both a water-surface and an air-surface has been studied as well [5]. In this research, a nematic LC is sandwiched by water instead of the usual glasses and an influence of water on the LC is investigated. The nematic LC was made in a small water vessel. Because the liquid crystal has high surface tension underwater, it is difficult to make a thin film. To prevent a rounding of the LC, lecithin derived from eggs as a surface-active agent was employed [6,7]. The electrooptic response of this nematic LC membrane underwater was observed by a polarizing microscope and a crossed polarizing optical system. It was found that there was variety of the responses depending on the penetrating position of the LC membrane.

Experimental

A membrane of a nematic liquid crystal, 4-cyano-4′-pentylbiphenyl (5CB), was suspended by an edge of the hole of the polymer seat of 125 μm in thickness that exists in distilled water. A diameter of the hole was 5 mm. To prevent a rounding of the LC

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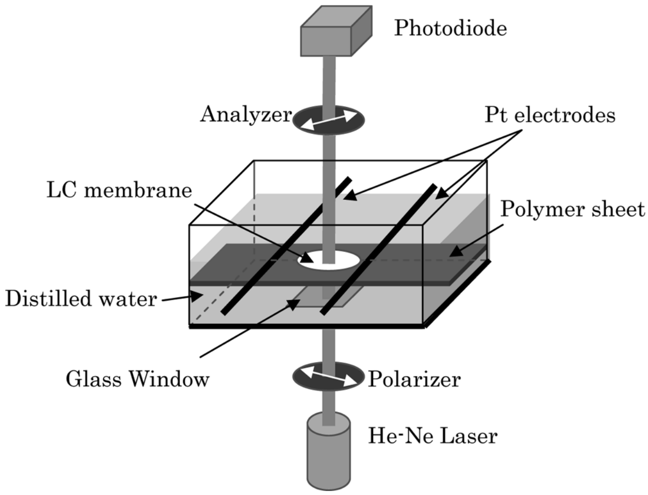

Figure 1. Experimental setup for electrooptic measurement.

due to its surface tension underwater, lecithin derived from eggs (Tokyo Kasei Kogyo Co., Ltd) as a surface-active agent (SAA) was employed. Lecithin is known as an amphiphilic molecule and can be a biocompatible SAA potentially. The lecithin added to distilled water at density of 0.01 wt% and its colloid suspension was produced by ultrasonic cleaner. The LC was put on the edge of the hole on the polymer sheet in the colloid suspension and it was spread by a spatula. Because the suspension scattered the light in optical measurements, the suspension was completely replaced with pure distilled water after the membrane fabrication. As a result, a nematic LC membrane underwater was fabricated in distilled water successfully.

Figure 1 shows a setup for an electrooptic measurement. Alternating sine wave voltage of amplitude 100 V was applied to the LC membrane by two platinum wires lying beside the LC membrane. An interval between the wires was 1 cm. A water vessel for an optical measurement had transparent glass window at its bottom. An electrooptic response of the LC membrane was measured using crossed polarizing optical system. The transmitted light intensity was transformed to voltage by a photodiode and observed by an oscilloscope. To measure a harmonics component of the response, a lock-in amplifier was employed. The response signal from the photodiode was measured by the lock-in amplifier directly and intensity of each harmonics component was estimated.

Results and Discussion

Figure 2 shows orthoscopic images of the LC membrane underwater. The LC membrane underwater was existed stably in not only a nematic phase but also in a solid and a liquid phase. Although it looks dark in liquid phase due to its isotropy, there was the membrane stably.

Figure 3 shows an orthoscopic image of the membrane under application of alternating voltage. There are inhomogeneity of light intensity in the membrane, that is, the molecular responses of the membrane have area dependence. To measure the

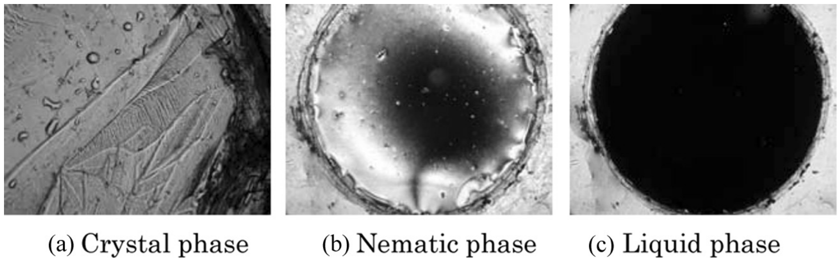

Figure 2. Orthoscopic images of the membrane underwater.

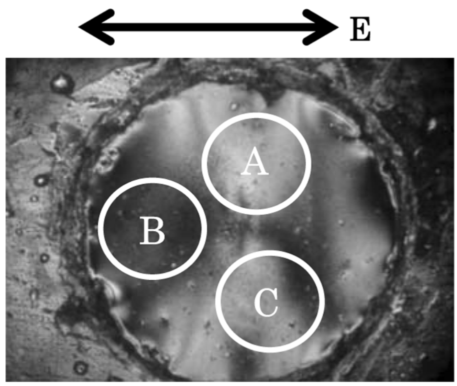

Figure 3. The membrane and light penetrating areas.

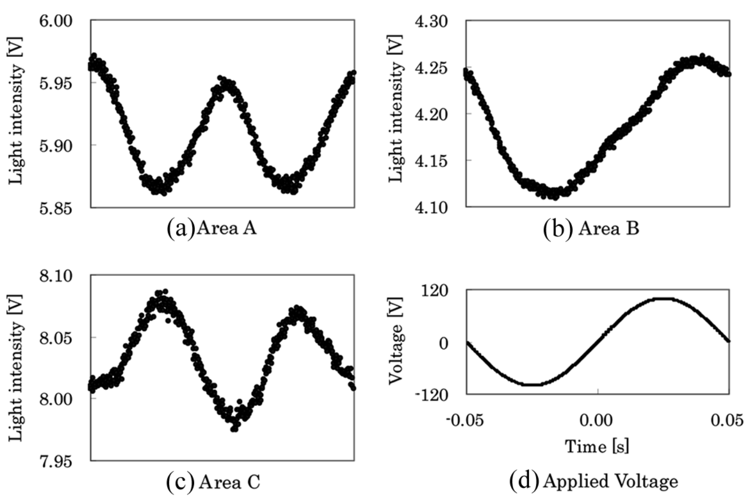

Figure 4. Electrooptic response.

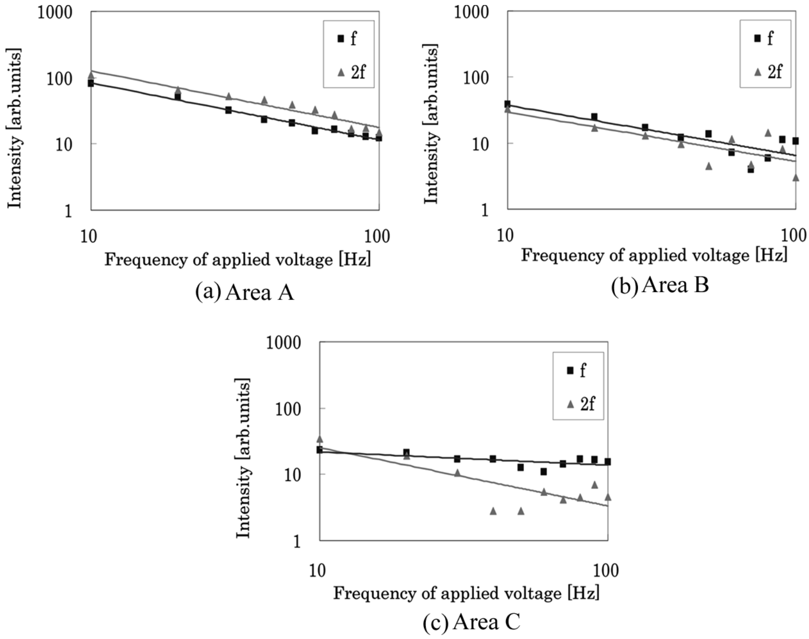

Figure 5. Harmonic components of the response.

electrooptic response precisely, a penetration area of the laser beam was limited to three different areas A, B and C. Figure 4 shows electrooptic responses of the each area to the applied voltage of 10 Hz in frequency. It was found that there was variety of the responses depending on the position on the membrane. That is, a second harmonics was dominant in the response of area A and C, in contrast, a fundamental was dominant in the response of area B.

Figure 5 shows the intensities of the fundamental and the 2nd harmonic components of the response measured with the lock-in amplifier. The frequency of the applied voltage was changed from 10 Hz to 100 Hz. The second harmonics are larger than the fundamentals in whole range of frequency in area A. Although there is some dispersion in a high frequency range, the fundamentals are larger than the second harmonics in area B. In the area C, a ratio of the second harmonics to the fundamentals becomes smaller, as the frequency become higher.

Normally, a nematic LC has no polarity and an electric field induced molecular reorientation is due to dielectric anisotropy of the molecule. The second harmonics component that is observed in the measurements can be explained by the normal feature of the nematic. On the other hand, the big fundamental component is especially observed in area B. In a word, the possibility for the nematic liquid crystal underwater to have the polarity is shown. The liquid crystal molecule is asymmetry, and has a head and a tail. Because a head of a certain molecule and a tail of a neighboring molecule are pairs, the polarity is not observed usually. In the case of the underwater, either head or tail might arrange to the water side, and the polarity appears. However, a reason why the response is different according to the place on the membrane is not found yet. A shape of the round membrane might be related.

Summary

This work can be summarized as follows. The electrooptic response of the LC membrane underwater has been measured. The three different types of the electrooptic response were observed. The area A has the second harmonics component as dominant in whole frequency range. The area B has the fundamental component as dominant in whole frequency range. The area C has the dominant second harmonics component at low frequency.

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