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Electrooptic Response of Reflective Liquid Crystal Cell

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Abstract

The electrooptic properties of the reflected light in a reflective mode, 45°-twisted nematic liquid crystal (TNLC) cell were investigated in the voltage regions near and away from the Freedericksz transition threshold. The measured reflectivity away from the threshold voltage (V_{th}) could not be described by the model which assumes a constant tilt angle as well as a linearized distribution of twist angle across the cell, although the data are well fitted near V_{th}. We found that in the voltage region away from V_{th}, the model considering the distributions of the tilt angle and the twist angle should be applied for the calculation of the reflectivity. The director-axis distributions were obtained from the numerical integration of the Euler-Lagrange equation.

Keywords : reflective liquid crystal cell, electro-optical property, Solc filter, Euler-Lagrange, director-axis deformation

1. Introduction

Liquid crystals(LC) have attracted strong interest due to their various applications such as liquid crystal display, spatial light modulator, portable television, notebook computer etc. A lot of studies have been proposed on the operation method of LC cell and on the improvement of performance of LC materials [1,2]. In particular, the reflective mode of operation has been studied more because it has advantages over the transmissive mode in the cell thickness and the response time [3].

The voltage-dependent reflectivities near V_{th} could be described by the model describing the TNLC as a fan-type Solc filter [4], but the reflectivities away from V_{th} could not be described by it. In this paper, to predict correctly the electrooptic response of LC cell under a higher voltage than V_{th} as well as near V_{th}, we did calculate the distributions of the tilt angle and the twist angle through the numerical integration of the Euler-Lagrange equation associated with them.

2. Experiment

A reflective mode, 45°-twisted liquid crystal cell was made using E7 liquid crystal. The LC cell was made to have a cell gap of 4.2 μm. To apply the electric field for LC directors, an indium tin oxide (ITO)-coated glass plate and an aluminium(Al)-coated glass plate were used as the front and back electrodes. The rubbing method was used to align LC directors in a particular direction. The resultant alignment layers had a thickness of 800Å. The front and the back alignment layers were attached so that the twist angle between them was 45°.

The voltage-dependent reflectivities were measured in the voltage regions near and away from the Freedericksz transition threshold. They were measured for two polarization directions of analyzer: parallel (∥) and perpendicular (⊥) to the polarization direction of incident beam. The polarization direction of incident beam was parallel to the rubbing direction of front alignment layer.

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3. Results and Discussion

The reflectivities (R ∥ and R ⊥) measured for two polarization states of analyzer are shown in Fig. 1 (open circles). In the R1 region, there are slight variations from their zero voltage reflectivities depending on the thickness of the LC layer. If the operating voltage was increased to the R2 or R3 region, both R ∥ and R ⊥ exhibit larger variations. To know whether the voltage-dependent reflectivity data can be described by the model which assumes a constant tilt angle as well as a linearized distribution of twist angle across the cell [4,5], we compared R ∥ and R ⊥ data withthe predictions (dotted lines) obtained using the model. The R ∥ and R ⊥ data in the R1 and R2 regions agree fairly well with those obtained by the linearly twisted model, except that the R ∥ data in the R1 region show an oscillatory behavior deviating from the expected curve. This oscillatory behavior is thought to be due to the multiple reflection between the front and the back surfaces of LC cell. However, in the R3 region, both R ∥ and R ⊥ deviate a lot from predictions by the linearly twisted model. It is quite reasonable that the voltage dependency of the tilt angle can not be expressed by equation proposed in the Ref. 5 under a higher voltage than V_{th}. Other possible reason is that there are distortions of uniformly twisted structure under a higher voltage than V_{th}. That is, the LC cell can not be regarded as a fan-type Solc filter any more.

A correct knowledge of the director-axis distribution within the LC layer for various voltages can help us to better describe the voltage-dependent reflectivities under a higher voltage than V_{th}. Thus, we calculated the director-axis distribution through the numerical integration of the Euler-Lagrange equation [6]. Figure 2 shows the distributions of the tilt angle and the twist angle for various normalized voltages between 1 V_{th}

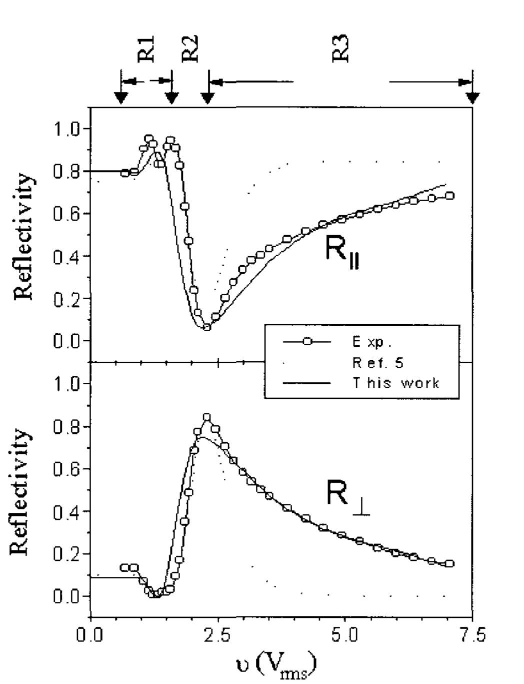

Fig. 1. Reflectivity as a function of the applied voltage for two polarization directions of analyzer. (∥ or ⊥ symbol designate that the analyzer is parallel or perpendicular to the incident polarizer.)

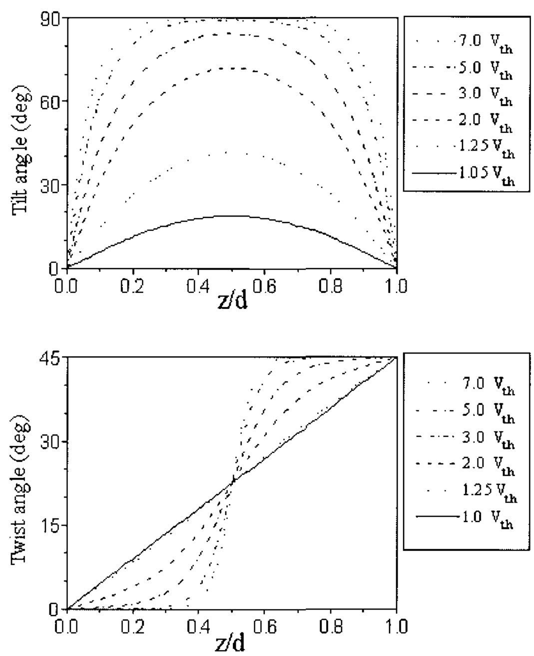

Fig. 2. Tilt angle (top) and twist angle (bottom) as a function of the normalized distance for various normalized voltages. (d and z are the distance from the aligning surface and the cell gap, respectively.

and 7 V_{th}. As is expected, the tilt angle doesn't have the voltage dependency given by Ref. 4 but shows a distribution that has a maximum value at the center between the front and the back electrodes. Moreover, as the voltage is increased, uniformly twisted structure is found to be distorted. Next, we estimated the reflectivity using the tilt angle and the twist angle calculated from the Euler-Lagrange equation. These reflectivities are designated by solid lines in Fig. 1. Our theoretical values fit fairly well to the experimental data under a higher voltage than V_{th}, while the linearly twisted model describes only the experimental data near V_{th}.

In conclusion, we found that the simplified model describing the TNLC as a fan-type Solc filter can describe only the reflectivities near V_{th}, and under a higher voltage than V_{th}, the complete model including the distributions of the tilt angle and the twist angle should be applied. The distributions of the tilt angle and the twist angle were obtained from the numerical integration of the Euler-Lagrange equation associated with them.

Acknowledgments

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