A Novel Orientation Method for Nematic LCs by Using Magnetic Field Lines with Permanent Magnets and Electric Field for Assisting the Reorientation

Yoshihiro Aoyagi, Yuichi Saito, Yukihiro Kudoh, and Taiju Takahashi

Kogakuin Univ., 2665-1 Nakano, Hachioji, Tokyo 192-0015, Japan

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ABSTRACT

We proposed an LC orientation treatment method that was used by the magnetic field lines and the electric field for assisting the director reorientation. It was shown that a radial orientation could be obtained by performing this process with the vertical alignment cell in the initial state.

1 INTRODUCTION

It is widely known that the magnetic null method [1] which is one of the pretilt measurement methods using a uniform and strong magnetic field, as a useful technique combining a magnetic field and nematic liquid crystals (LCs). However, there is few reports that attracts much attention for an LC alignment technique with a magnetic field. For example, MOLCA method [2] has been proposed which is an LC alignment method using a magnetic field and a surface adsorption action on alignment films. In general, for controlling the LC alignment using the magnetic field, an electromagnet with pare of large size magnetic poles is required due to producing a uniform and strong magnetic field. There are few advantages to use the alignment method with the magnetic field, although the equipment is large, unfortunately.

LC materials are also applied to optical devices (such LC lenses, phase shifters, phase plates, and others) which are not required large area such LCDs. If the LC orientation treatment with the magnetic field is carried out to fabricate those small devices, the large electromagnet is not required. And, a small and a strong permanent magnet with neodymium can be available easily, recently. By using the magnetic field distribution induced by small magnet that varies greatly in the small area around the magnet, we expected that a novel LC orientation could be achieved. We propose a novel LC orientation method by using distribution of magnetic field lines and the applying electric filed to assist reorientation of the LC director in the cell. Mainly, the orientation method for a radial alignment of nematic LCs was attempted, in here.

2 PRINCIPLE OF RADIAL ORIENTATION

If the azimuth direction of the LC director was determined along the magnetic field lines from a small cylindrical neodymium magnet, a radial orientation of LC would be obtained. However, if the anchoring on the alignment film surfaces were strong, the LC directors could not be sufficiently controlled by the magnetic field. Therefore, it was prepared a vertically aligned cell. Because the azimuth anchoring was close to zero in the vertical alignment state, thus the tilted direction of the director was defined with the distribution of magnetic field lines when the assisted electric field was applied for tilting the director. Thus, LC materials with negative type were necessary for this experiment. From those process, this method could be thought a reorientation method to obtain the radial orientation. Incidentally, in order to maintain the obtained radial orientation even after removing the magnetic and the electric fields, a polymer stabilization method [3] with UV-curable liquid crystalline (UCL) monomer was employed. An outline of the process was shown in Fig. 1.

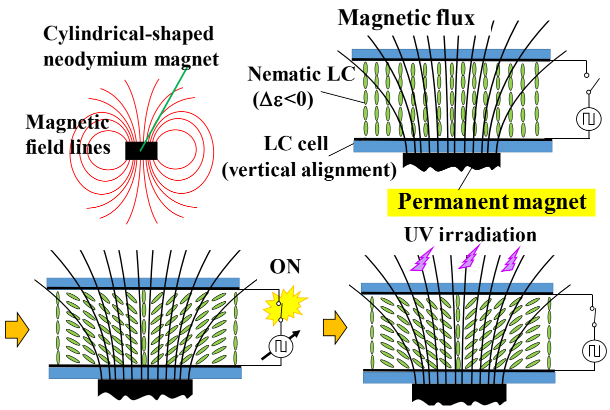

Fig. 1 Schematic model of the radial orientation treatment.

A small magnet was set on the outside of a vertically alignment LC cell, and the electric field was applied to assist the LC reorientation. Where, the slow increasing rate with the applying voltage from 0V was extremely useful to obtain a fine orientation LC texture, particularly in the vicinity of the threshold. When the voltage increased to an appropriate voltage, the UV light was irradiated for the polymer stabilization treatment with keeping the applied voltage. For example, the LC cell with the radial alignment would be used for an optical plate when the polymerization was strong, and the cell would be used for an LC lens since the tilt angle of LC directors could be controlled by the applying the voltage when the polymerization was weak. However, what kind of voltage distribution should be required in the cell to obtain the lens effect was another problem and did not discuss, in here.

Incidentally, this alignment treatment could be repeated any number of times before the polymer stabilization treatment.

3 EXPERIMENTS

The vertical alignment film, SE-4811 (Nissan Chemi.), was formed on the glass substrate (20×25×1.1mm) covered with the ITO film was used for fabricating a sample cell. The cell thickness was 5 to 20 μm. The nematic LC with negative type, LC-A, doped with the UCL monomer was used. A cylindrical neodymium magnet with a diameter of 10 mm and a height of 10 mm was employed. (The central magnetic force was 360 mT through 1.1 mm glass substrate.) The applied voltage was a 10 kHz rectangular wave, the voltage was varied from 0 to 12 V. The polymerization was under applying 12 V of the voltage. Furthermore, in order to weaken the anchoring energy on alignment films, the alignment film surfaces were exposed to an atmospheric pressure plasma atmosphere with Ar gas before assembling the glass to cells.

4 RESULTS AND DISCUSSION

4.1 Cell Thickness Dependence

Both the magnetic and electric fields were applied to each cell in order to obtain the radial orientation. After that, the magnet was removed while 12 V of the voltage was kept applying. Then, a picture of each cell was taken. The polymerization treatment was not done. Figs. 2 (a)-(c) show photos of sample cells.

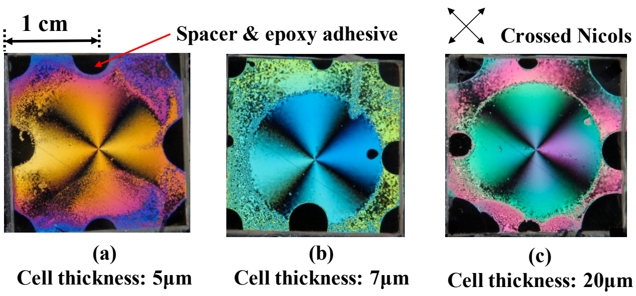

Fig. 2 Photos of the radial orientation depend on cell thickness. (under applying 12 V of the voltage, without polymerization treatment)

The optical extinction positions were observed along axes of crossed Nicols polarizers, and those positions were not changed when the cell was rotated between the polarizers. Thus, we confirmed that the radial orientation was realized. It can be seen that the LC texture showed in a random orientation pattern at where the influence of the magnetic field was weak or not exist, and the orientation quality was higher when the cell thickness was thicker due to less affected from surfaces.

4.2 Polymer Stabilization Treatment

The polymer stabilization treatment for memorizing the tilted direction of LC directors was carried out to obtain the radial orientation without the magnetic or electric fields. The tilt angle of the director could be controlled by applying the voltage when the magnitude of the polymerization treatment was weak. That is, it would be worked as a forcing function of the LC lens if this cell was applied to the LC lens. On the other hand, when the magnitude of the polymerization was strong, the radial orientation pattern was maintained without applying the voltage. For example, the stabilized cell could be functioned as a special wave plate.

The photo of the cell with the strong polymerization treatment state is shown in Fig. 3, as an example. The cell thickness was 20μm, the injected LCs was doped with 1.5 wt% of UCL, the UV irradiation energy was 1.0 J/cm^2. It can be seen the radial pattern was maintained without any applied voltage.

Incidentally, when the LCs doped with 0.5 wt% of UCL was injected, the weak polymerization cell was realized. We confirmed that the cell worked as expected.

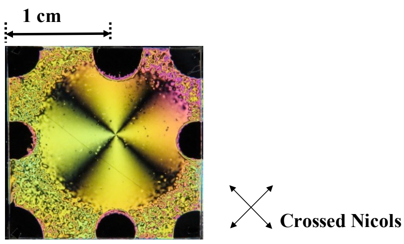

Fig. 3 Photo of the radial orientation after hard polymerization treatment. (without applying the voltage)

5 CONCLUSIONS

We proposed a novel LC orientation method for easily obtaining a radial orientation, which is difficult to achieve by rubbing treatment, using a commercially available permanent magnet and an applied electric field for assisting the director reorientation.

Applications to optical devices such as LC lenses are expected.

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