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Akira Baba [a], Futao Kaneko [a], Kazunari Shinbo [a], Keizo Kato [a], Satoshi Kobayashi [a] & Takashi Wakamatsu [b]

[a] Niigata University, Ikarashi 2-8050, Niigata, 950-21, Japan

[b] Ibaraki National College of Technology, Nakane 866, Hitachinaka, Ibaraki, 312, Japan

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AKIRA BABA[a], FUTAO KANEKO[a], KAZUNARI SHINBO[a], KEIZO KATO[a], SATOSHI KOBAYASHI[a] and TAKASHI WAKAMATSU[b]
[a]Niigata University, Ikarashi 2-8050, Niigata 950-21, Japan; [b]Ibaraki National College of Technology, Nakane 866, Hitachinaka, Ibaraki 312, Japan

Tilt angles of liquid crystal molecules, 5CB, have been investigated in the liquid crystal cells with the polyimide (PI) LB alignment films on the aluminum electrodes using the attenuated total reflection (ATR) measurement. The ATR properties were evaluated from the surface plasmon polariton (SPP) and the guided wave excitation modes (GWEM) when various DC voltages were applied to the cell. The tilt angles of the liquid crystal molecules were calculated by fitting the theoretical ATR curves to the experimental ones using a three layers model. Furthermore, the electric field intensities in the cell were calculated at several incident angles.

Keywords: ATR; nematic liquid crystal, SPP, GWEM; PI LB film

1. INTRODUCTION

Evaluating behavior of liquid crystal molecules in cells is very important in order to improve and to develop the cells. Recently attenuated total reflection measurements have been used for evaluation of liquid crystal molecules[1,2]. Aluminum films on the prisms have been scarcely used in the ATR measurements since the ATR properties are not as sensitive as silver[2]. Nevertheless, the SPP using aluminum films on the prisms can enter deeper into the cell than the case using silver, and some information inside the cell

can be obtained. Furthermore, various LB films can be easily deposited on the aluminum films[3]. In this paper, tilt angles of liquid crystal molecules, 5CB, were evaluated on rubbing-free aligning layers of polyimide (PI) LB films[4] on aluminum films from the ATR properties when various DC voltages were applied to the cells.

2. EXPERIMENTAL DETAILS

Figure 1 shows the Kretschmann configuration and the liquid crystal cell used in the ATR measurements. The half-cylindrical prisms (HOYA SF6, n=1.79882) were used for the ATR measurement. PI LB[5] films were deposited on aluminum films as the rubbing-free aligning layers. The thickness of the liquid crystal layer in the cell was 5360 nm. Reflectivities in the ATR measurement were measured at an interval of 0.1° as a function of the incident angles of a He-Ne laser at 632.8 nm when various DC voltages were applied to the cell at 25℃. The nematic liquid crystal was 4-cyano-4'-n-pentylbiphenyl (5CB: Merck Japan co.). The details are shown in Fig. 1.

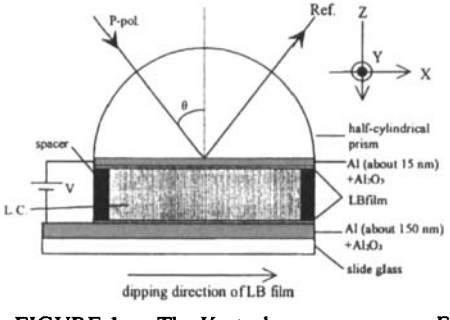

FIGURE 1 The Kretschmann configuration in the ATR measurements and the liquid crystal cell.

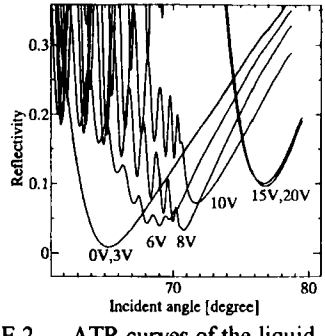

FIGURE 2 ATR curves of the liquid crystal cell at various voltages.

3. RESULTS AND DISCUSSION

ATR properties of the liquid crystal cell

Figure 2 shows the experimental ATR curves in the region of the resonant angles of the SPP when various DC voltages were applied to the cell. From the theoretical ATR curves, the shifts of the resonant angles to the higher

angles by the applied voltages indicate that the refractive index in the cell increase, that is, the tilt angles of the liquid crystal molecules increase. The results exhibit that the ATR measurements are sensitive to behavior of liquid crystal molecules in the cell.

Evaluation of the tilt angles

The ATR curves at 0, 3, 15 and 20 volts have only the large dips due to the SPP excitation. The calculation was carried out assuming a uniform tilt angle of the liquid crystal molecules in the cell. The theoretical values due to the SPP excitation agreed with the experimental curves. The tilt angles of the liquid crystal molecules on the PI LB film were obtained from these results to be 8° at 0 and 3 volts and to be 90° at 15 and 20 volts. The small vibrations of the reflectivities due to the guided wave excitation were observed in the region of the resonant angles of the ATR curves at 6, 8 and 10 volts. Assuming that the tilt angles of the liquid crystal molecules were uniform in the cell, all energy of the incident laser beam was transferred to the excitation of the SPP and any GWEM in the cell could not exist in the region of the resonant angles. Therefore, a simple model was proposed that the liquid crystal molecules in the cell were composed of three layers, that is, the two layers near the aligning layers had a lower refractive index, and the middle layer had a higher one. The theoretical curves were calculated and were fitted to the experimental ones. Fig.3 shows an example of the ATR curves. In the calculation, the thicknesses of the two interface layers and the middle layer were assumed to be 180nm and 5000nm, respectively. The tilt angles of the molecules in the three layers were obtained from the fittings of the curves. The tilt angles in the interface layers and the middle layer were evaluated to be 33° and 90° at 6 volts, 44° and 90° at 8 volts and 50° and 90° at 10 volts, respectively.

Calculation of the electric fields in the cell

The electric field intensities in the cell were also calculated. Figure 4 shows the electric field intensities in the cell at the incident angles of 65.2°, 69.4° and 72.0°, shown in Fig.3. The calculation exhibited that the electric fields due to the excitation of the GWEM in the middle layer of the cell were enhanced by the excitation of the SPP.

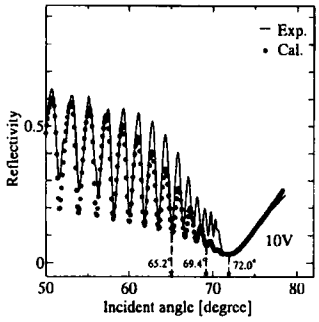

FIGURE3 The calculated dotted curve assuming a three layers structure model and the experimental ATR curve of the liquid crystal cell at 10 volts.

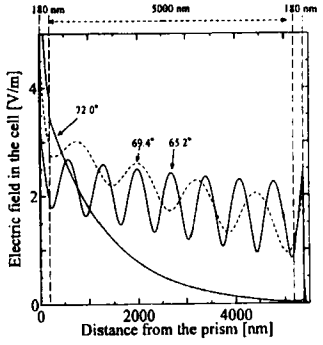

FIGURE 4 Calculated electric fields in the cell at the incident angles of 65.2°, 69.4° and 72.0° shown in Fig.3.

4. CONCLUSIONS

The behavior of the liquid crystal molecules was evaluated in the cell with the rubbing-free aligning layers of the PI LB films on aluminum films using ATR measurements when various DC voltages were applied to the cells. The properties caused by the excitation of the surface plasmon polariton and the guided wave excitation modes were observed in the ATR curves. The electric field intensities were enhanced not only near the surface of the LB aligning layer due to the surface plasmon polariton but also in the middle layer due to the guided wave excitation modes. The ATR measurement is one of useful techniques for evaluating behavior of liquid crystal molecules and LB aligning layers.

References

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