Extended Abstracts of the 2009 International Conference on Solid State Devices and Materials, Sendai, 2009, pp659-660

Evaluation of 5CB Liquid Crystal Molecules on SiO_2 Alignment Layer by Simultaneous Surface Plasmon Resonance and Optical Waveguide Spectroscopy

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1. Introduction

In recent years, liquid crystal (LC) displays have been practically used in notebook computer, monitors, and so forth. However, LC displays still have some reliability problems. For example, the phenomenon called "Image-sticking", which causes the afterimage when displayed for a long time, is one of the typical problems. Although it is known that the problem is due to the impurity ions inside the LC cell [1], and the interfacial interaction of LC molecules and alignment layers, the mechanism has not been clearly understood. Therefore, effective evaluation methods of interfacial phenomenon are desired.

Recently, simultaneous surface plasmon resonance (SPR) and optical waveguide spectroscopy (OWS) technique has been used for the evaluation of LC molecules [2],[3]. This technique allows in-situ observation for LC tilt angles from near the alignment layers to the inside the LC cell.

In this study, we report on the evaluation of tilt angles of LC molecules near the surface of SiO_2 alignment layers and in the whole cell when constant voltages are applied. Surface plasmon resonance spectroscopy and waveguide mode in attenuated total reflection configuration are used to monitor the property of LC molecules orientation on the surface and the bulk.

2. Simultaneous Surface Plasmon Resonance (SPR) and Optical Waveguide Spectroscopy (OWS)

Fig.1 shows the simultaneous surface plasmon resonance (SPR) and optical waveguide spectroscopy (OWS) set-up for the investigation of the LC cell. When the incident light is totally reflected, evanescent wave generates at the e metal thin film/LC interface. If the wavenumber of the evanescent wave coincides with the SP wavenumber, SP is resonantly excited. The reflectivity is attenuated at the excitation angle of SPR. When the sample is thick enough such as LC layer in this experiment, waveguide propagates inside the sample at some incident angles [4]. The reflectivity is attenuated at these angles because a part of incident light becomes into propagating light wave. This can be observed as multiple dips in the attenuated total reflection (ATR) angular dependence property (See Fig.2). A number of sharp dips shown in the low-angle region are due to the waveguide and a wide dip shown in the higher-angle region is due to the excitation of SP. The dip angles and depths depend on the thickness and dielectric constant of the samples. Tilt angles of LC molecules are determined by theoretical curve fitting to the experimental results on the assumption of dielectric constant of the LC molecule. Since SPR and OWS properties depend on the tilt angles of LC molecules near the surface of the alignment layer and inside cells, respectively, both information can be obtained at the same time.

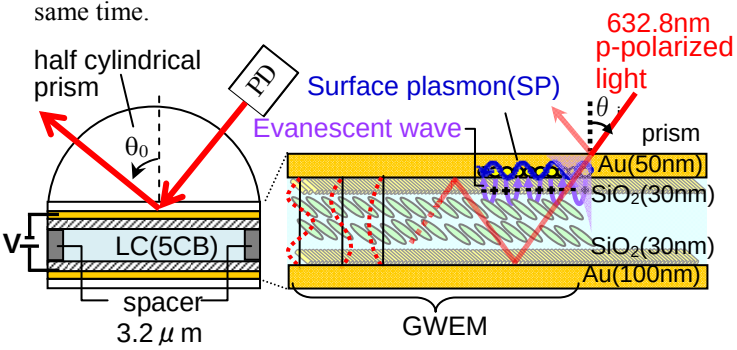


Fig. 1 The ATR set-up with LC cell and the schematic sketch of the excitation of SPR and GWEM

3. Experimental Section

Sample structure and set up for the measurement

The sample structure consisted of Au (50nm) / SiO_2 (30nm) / LC / SiO_2 (30nm) / Au (100nm). SiO_2 alignment layers were obliquely evaporated on both Au surfaces. 4-cyano-4'n-pentylbiphenyl (5CB, Merk JAPAN) was used as the LC molecule, and the cell gap was about 3μm. The LC cell was attached to the flat side of the half cylindrical prism (S-LAH60 : n=1.8294, Ohara Inc.) with index matching oil as shown in Fig.1. The sample was mounted on a θ-2θ stage for the angular measurements.

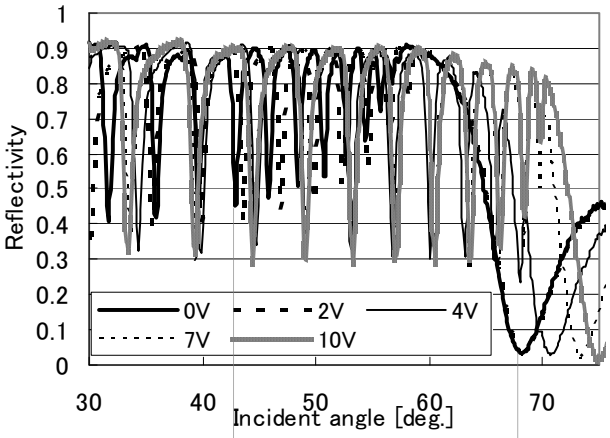
4. Results and Discussion

Evaluation of the LC alignment

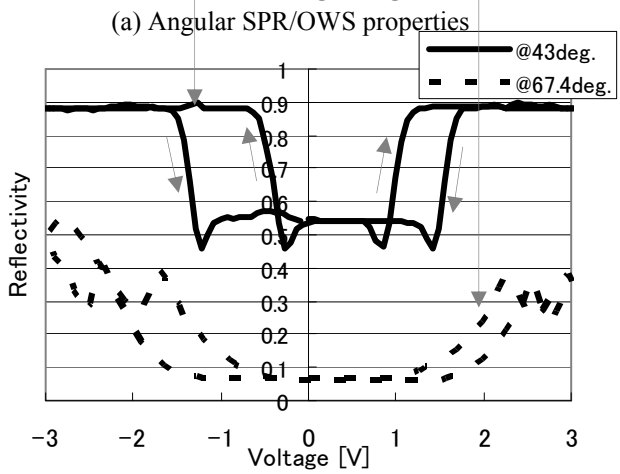
First, the angular properties were measured at constant applied voltages, 0, 2, 4, 7, 10V at room temperature (RT), as shown in Fig.2(a). The SPR dip, which depended on the tilt angle of LC molecules adjacent to the surface of the alignment layer, was observed at around 68° at 0V, and the dip was shifted to higher angles with the increase of applied voltages. This shift indicates an increase of the tilt angle near the surface, i.e. horizontally aligned LC molecules gradually tilts toward vertical direction.

OWS dips, which depended on the tilt angles of LC molecules in a whole cell, were changed at 0 to 4V as the LC molecules tilt toward vertical direction, and then the dips were almost constant at above 4V. As shown in this Figure,

OWS dips changed at low applied voltages, while SPR dip changed at above 4 V.



(a) Angular SPR/OWS properties



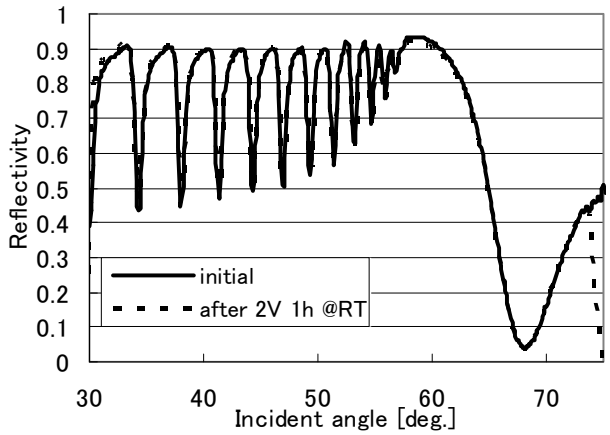
(b) Kinetic property (-3 to 3V at 10mHz for 1cycle)

Fig. 2 SPR/OWS properties with applied voltages

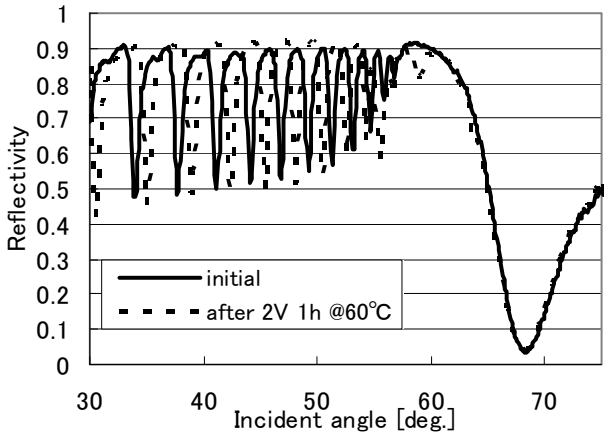
In order to further study the change of the tilt angles with applied voltages, the kinetic properties were measured at fixed incident angles of 43° and 67.4° while the voltage, triangular wave, was being applied from -3 to +3 V at 10mHz for 1cycle. As shown in the result of Fig. 2(b), the reflectivity of the GWEM dip at 43° increased at around 1V, while SPR dip at 67.4° did not increased up to 2V. This is because of the anchoring force of the SiO_2 alignment layers.

LC alignment property after applying the voltage

In order to study the "Image-sticking" effect, angular SPR/OWS properties were measured after applying the voltage at 2V for one hour at RT and 60 ºC. Fig.3 shows the angular properties measured before and after applying the voltage. In both cases, the SPR dip was almost constant, indicating the tilt angle near the surface is stably moved back to initial state after applying the voltage. On the other hand, the OWS dips at 60ºC were obviously changed after applying the voltage, while the dips were constant at RT. This indicates that the "Image-sticking" problem was generated when the cell was heated. The results show that the LC molecules inside the cell did not move back to initial state due to the constraint force



(a) before and after applying the voltage (2V) 1h at RT



(b) before and after applying the voltage (2V) for 1h at 60 ºC

Fig. 3 Angular SPR/OWS angular properties

5. Conclusions

In conclusion, the alignment properties of LC molecules showed a different behavior between inside of the cell and near the interface. These results were obtained by simultaneous surface plasmon resonance (SPR) and optical waveguide spectroscopy (OWS) technique. In addition, we observed the LC alignment properties after applying the voltage which related to the "Image-striking" effect. The theoretical fitting was also carried out in order to obtain the alignment profile of LC molecules. As demonstrated in this report, this technique should provide the useful information to understand the phenomena for LC displays at the interface.

References

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