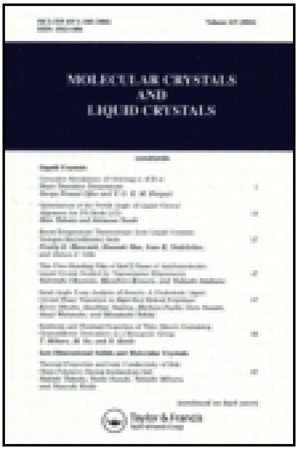

Molecular Crystals and Liquid Crystals Science and Technology. Section A. Molecular Crystals and Liquid Crystals

Publication details, including instructions for authors and subscription information:
http://www.tandfonline.com/loi/gmcl19

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Version of record first published: 24 Sep 2006

Mol. Cryst. and Liq. Cryst., 2001, Vol. 367, pp. 735-744
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Wide-Viewing Observation and High-Spatial Resolution Characterization of Rubbed Polyimide Film for Liquid Crystal Display

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Molecular orientation of rubbed polyimide (PI) film affects the quality of an LCD. It is necessary to characterize the molecular orientation of rubbed PI film in order to develop LCD. Recently, LCD panel size has been increasing while pixel size has been decreasing. For an advance of LCD, we have developed two techniques to characterize the molecular orientation of rubbed PI film. The first is a technique of the wide viewing. It visualizes the molecular orientation in the area of 5×10 mm with one snap shot. It is effective to rapidly characterize the molecular orientation in a producing process of LCD. The second is a technique of a high-spatial resolution. The spatial resolution is about 1 μm. It is effective to characterize the molecular orientation within a small area such as a pixel of TFT-LCD. We demonstrated the performance of two techniques by measuring the rubbed PI film.

Keywords: rubbing; polyimide; molecule; orientation; ellipsometry

Introduction

Molecular orientation of the rubbed polyimide (PI) film affects the initial orientation of liquid crystal molecule in LCD due to the intermolecular interaction. It is necessary to characterize the molecular orientation of the rubbed PI film for the development of the high quality LCD devises and the high yield of LCD manufacturing. Recently, reflection ellipsometry has been proposed for the evaluation of the rubbed PI film.[1] This method measures the polarization of the reflected light depending on the incident orientations. It has the high sensitivity as for the molecular orientation and the thickness of rubbed PI film.

Recently, LCD panel size has been increasing while pixel size has been decreasing. It has been difficult for the conventional ellipsometer to characterize the recent LCD panel. The measurement size of the conventional ellipsometer is about 1 mm. In order to characterize rubbed polyimide film on an actual LCD, the conventional ellipsometer needs much time for multi-point measurements.[2] And, the spot size of the conventional ellipsometer is too large to characterize one pixel of TFT-LCD. Two abilities of the high-spatial resolution and the wide-range characterization with high speed are demanded for the technique of the characterization for rubbed PI film of the recent LCD panel.

We have developed two techniques for the characterization of the rubbed PI film on actual LCD panel. The first is a technique of the wide-viewing and high-speed observation to characterize the uniformity of the molecular orientation of the rubbed PI film. It visualizes the in-plane distribution of molecular orientation with one snap shot of video image from a CCD camera. The observed area is 5×10 mm. The second is a technique of a high-spatial resolution to rapidly measure the molecular orientation of rubbed PI film within one pixel of TFT-LCD. The spatial resolution is about 1 μm and this technique does not need the mechanical rotation of the sample stage. It enables to measure the molecular orientation of the rubbed PI film within the one pixel of TFT-LCD with high speed.

We demonstrated the performance of two techniques by measuring the rubbed PI film. Rubbed polyimide film usually has optical anisotropy coming from polyimide- molecular orientation. Thus, we tried to characterize the molecular orientation of the rubbed film by observing anisotropy in polarization of reflected light in wide-viewing observation and high-spatial resolution characterization.

Technique of wide-viewing observation

Figure 1 shows an outline of the system to visualize the in-plane distribution of the molecular orientation of rubbed PI film. A light from the white light source is expanded by a collimating system (CS) and one wavelength is selected by a interference filter (IF). The selected wavelength and the bandwidth are 533 nm and 15nm respectively. The expanded light is reflected from a sample after passing through a polarizer (P) and a quarter wave plate (QW). A sample stage rotates mechanically to tune sample orientation to observe in-plane distribution of anisotropy of sample. Following the reflection, the light passes through an analyzer (A). The intensity of the light after passing through analyzer depends on its polarization. Finally, the light is passed through

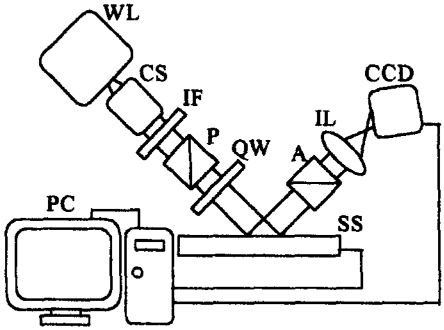

Figure 1. Schematic of the measurement system for the wide-viewing observation. WL: White light source, CS: Collimating system, IF: Interference filter, P: Polarizer, QW: Quarter wave plate, SS: Sample stage, A: Analyzer, IL: Imaging lens, CCD: CCD camera, PC: Computer.

an imaging lens (IL) and imaged by a Charge-Coupled Devices (CCD) camera. In this system, the observable area and the lateral spatial resolution are about 5×10 mm and 10 μm. The lateral spatial resolution is equal to the pixel size of the CCD camera, and the visualizing rate is 5-10 frame/s. We prepared PI films containing two areas of rubbing and non-rubbing on one Si substrate for the demonstration.

Result

Figure 2 shows snap-shots of the sample image obtained from some incident orientations. The area with an arrow in Figure 2 is rubbed and the area without the arrow in Figure 2 is not rubbed. The direction of the arrows shows the rubbing orientation. The azimuth angle of polarizer and analyzer is set and fixed by null ellipsometly for the non-rubbing area at the 0° of the incident orientation.[3] The incident angle and the fixed azimuth angle of P, C and A were 70°, 13.5°, 45.0° and –

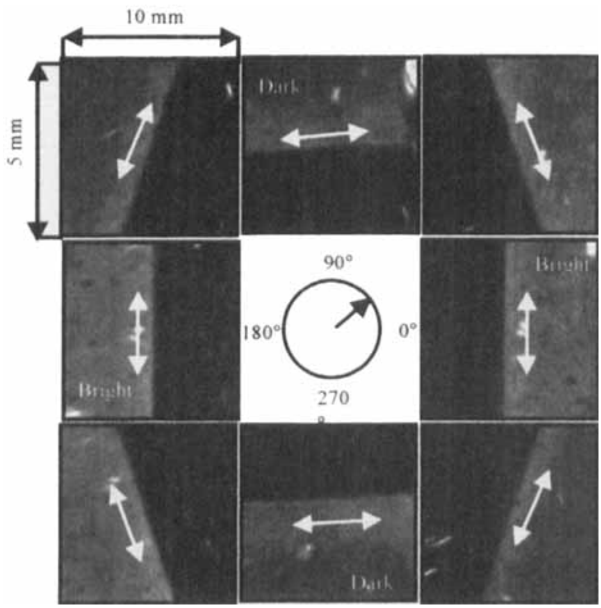

Figure 2 Snap shots of video-image of the PI films having both areas of rubbing and non-rubbing. The images were taken from each incident orientation from 0° to 360° every 45°. The area with an arrow is rubbed area and the area without the arrow is not rubbed one.

61.6° respectively. Detected intensities are different between rubbed and non-rubbed area as shown in Figure 2. The brightness on the rubbing area varied according to the incident orientation. Optical anisotropy of rubbed area is clearly observed in the dependence of detected intensity of sample orientation as shown in Figure 3. As for the image of the non-rubbing area, it is dark in all incident orientation. This shows that the optical anisotropy in the non-rubbing area does not exist. It is concluded that the in-plane distribution of molecular orientation of rubbed PI film can be rapidly characterized with snap

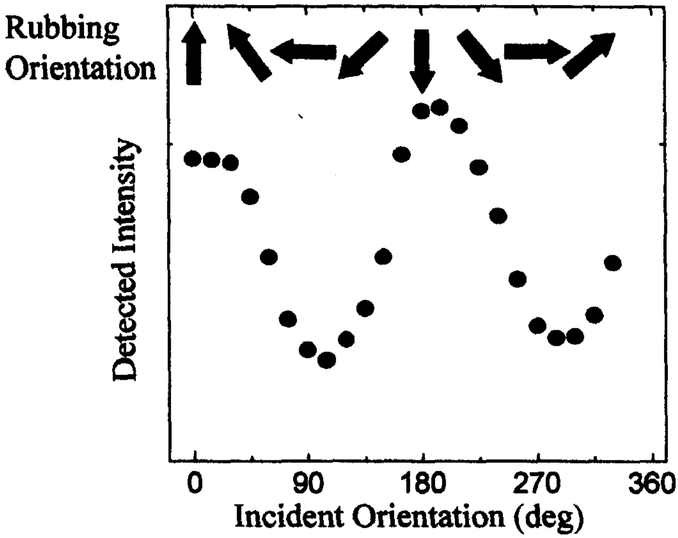

Figure 3 Dependence of detected intensity on the incident orientation on one point of the rubbed area.

shots of video image from CCD camera by our technique. We consider that the result of our experiment is the first step to in-line characterization of rubbed polyimide film on the manufacturing process of LCD.

Technique of high-spatial resolution

Figure 4 shows the outline of the measurement system used to rapidly characterize the molecular orientation of the rubbed PI film within one pixel of TFT-LCD. After the coherent light beam from a laser is expanded by a beam expander (BE), it passes through the polarizer (P) and the quarter wave plate (QW). The coherent light beam is focused

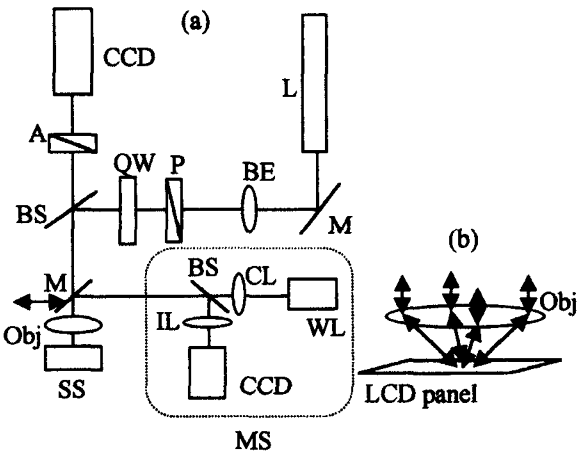

Figure 4 Outline of the measurement system for high-spatial resolution. L: Laser, M: Mirror, P: Polarizer, QW: Quarter wave plate, BS: Beam splitter, Obj: Objective lens, SS: Sample stage, A: Analyzer, CCD: CCD camera, WL: White light, CL: Condenser lens, IL: Imaging lens, MS: Microscope unit.

by a high numerical aperture microscope objective. The focused light rays impinge on the sample surface. The spot size of convergent beam is about 1μm. It is much smaller than the size of one pixel of TFT-LCD. The reflected light beam becomes parallel through the same objective. After passing through the analyzer (A), a cross-sectional distribution of the reflected light was detected by a CCD camera. The position of each pixel in the CCD camera corresponds to the incident angle and azimuth orientation of the incident beam (Figure 4(b)). An microscope unit sharing the objective lens is used to decide a lateral position for the measurement. The polarization of the incident light to the objective lens is circular polarization. Figure 5 shows that the distortion of circular polarization by the objective lens is equivalent in all incident orientations to the sample. Its distortion is caused by large

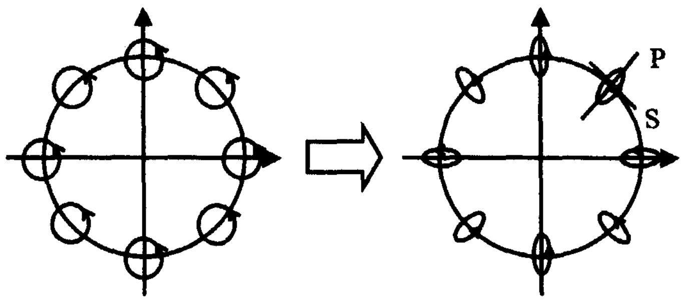

Figure. 5 Distortion of circular polarization by the objective lens.

refraction of light for the objective with high numerical aperture. But, due to the symmetry of the distortion of the circular polarization, we can observe the change of the polarization of the reflected light for rubbed PI film from all incident orientations at the same time. Compared with the incidence of the linear polarized light to the objective, this enables to decrease the measurement time.[4] Moreover, the incidence of circular polarization enhances the sensitivity of the measurement due to the incidence of the polarization with both p-component and s-component to the sample. The polarization of reflected light is determined by using the rotating analyzer method.[3] As a sample for the demonstration of this technique, an actual TFT-LCD panel was prepared. The actual TFT-LCD was separated and washed by solvent for this experiment.

Result

Figure 6 shows the phase shift of the reflected polarized light as function of the incident orientation. It clearly shows that the phase shift of the reflected light polarization depends on the incident orientation

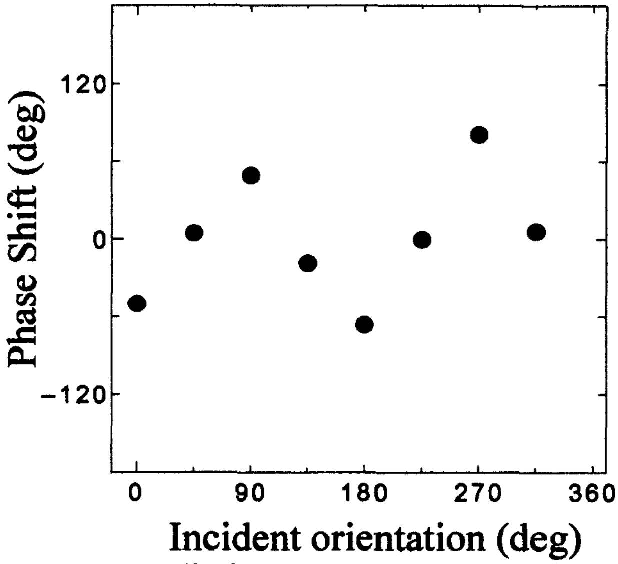

Figure 6 Phase shift of the reflected light as function of the incident orientation

due to the optical anisotropy for the molecular orientation. The large phase shift was caused by an influence of a residual liquid crystal molecule on the actual TFT-LCD panel. The measurement time was 30 sec in case of using a mechanical stepping-motor for rotating the analyzer. Its measurement time is shorter than the method of incidence of linear polarized light.[4] This result shows that this technique enables the characterization of rubbed PI film with high spatial resolution and high-speed without the mechanical rotation of the LCD panel.

Summary

We proposed two techniques to characterize rubbed PI film. The first has the advantage of being to be observe in-plane distribution of molecular orientation of rubbed PI film in wide area with high speed. This is effective in detection of a defect of the rubbed PI film in a producing process of LCD. The other has the advantage of high-speed characterization with the high-spatial resolution below the one pixel of TFT-LCD. This is effective in the characterization of the rubbed PI film inside a restricted small-area on LCD, for example the characterization of the LCD having small pixel-size for a projector and the LCD having wires inside a pixel. We demonstrated the performance of these techniques by using rubbed PI film. These techniques promise effective development and production of high-quality LCD devices.

Acknowledgments

The authors would like to thank Mr. Tajima, and Drs. Yoneda, Shiotani and Tsujide for their encouragement throughout this work.

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