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# Alignment of Liquid Crystal on the Conductive Pyrolyzed Polyimide Langmuir-Blodgett Films

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Highly conductive pyrolyzed polyimide Langmuir-Blodgett (LB) films showed good aligning properties for a twisted nematic liquid crystal. Static and dynamic alignment properties of the LB films were similar to those of rubbed polyimide films on ITO electrodes.

Recently, we have reported that Kapton-type polyimide Langmuir-Blodgett (LB) films show a conductivity of 300 S/cm after pyrolysis at 1000 °C.[1] These films are stable over months, which is advantageous to application to the electronic devices. Polyimide LB films which are precursors of pyrolytic polyimide (PPI) LB films have been studied also for aligning liquid crystals.[2-4] It is reported that the liquid crystals align parallel to the dipping direction without rubbing treatments. In this paper, we report the aligning properties of liquid crystals on the conductive PPI LB films which can be used as the transparent electrodes for liquid crystal cells.

The precursor polyimide LB films were prepared according to the method of Kakimoto *et al.* on quartz substrates.[5] Biphenyl-type polyamic acid (Fig. 1, U-WANISU-A) purchased from Ube Kosan Ltd. was used as a starting material for constructing LB films. The reproducibility of Y-deposition was improved compared with the Kapton-type polyamic acid. The pyrolysis was achieved by heating the films under nitrogen atmosphere at 1000 °C for 60 min. The thickness of 75-layered films was determined by the stylus method to be 138 nm (1.84 nm/layer) for the polyamic acid LB film, 46 nm (0.61 nm/layer) for the polyimide LB film and 19 nm (0.25 nm/layer) for the PPI LB film, respectively. The thickness per layer of the PPI LB film is smaller than that of graphite (0.335 nm/layer), indicating that a part of the material evaporated during the pyrolysis. The loss of the material, however, was much smaller than that of the Kapton-type polyimide LB film whose thickness is 0.06 nm/layer after the pyrolysis. The conductivity of the film was measured in a direction parallel to the dipping direction by a dc 4-probe method using evaporated gold electrodes formed on the film surface with a gap distance of 8 mm. The conductivity of the PPI LB film increased with an increase in layer number, saturating at about 100 S/cm for samples of more than 11 layers.

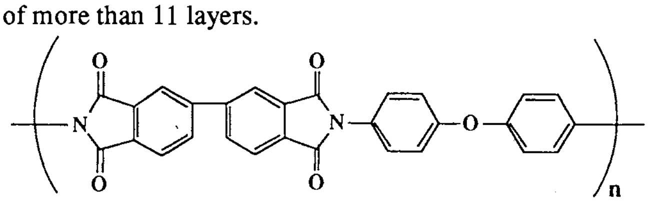


Fig. 1. Chemical structure of polyimide.

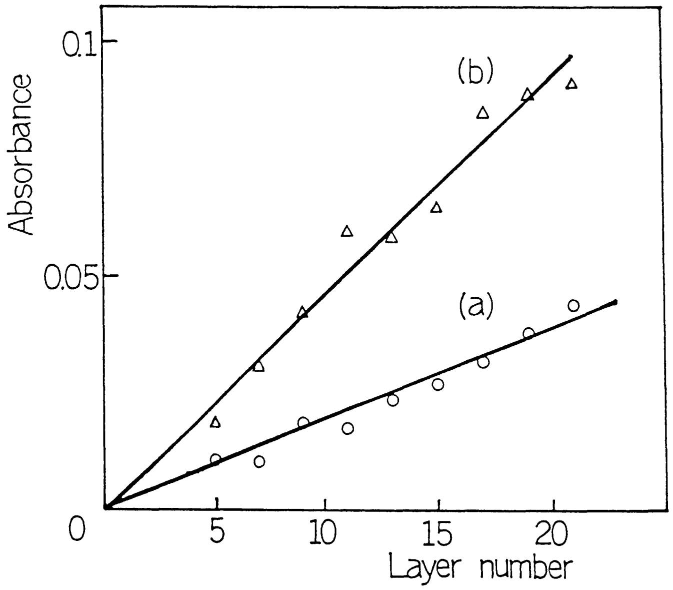


Fig. 2. Relationship between layer number and absorbance maxima of polyimide (a) and pyrolyzed polyimide LB films (b).

Figure 2 shows the absorbance of the polyimide LB film at 365 nm and the PPI LB film at 270 nm as a function of layer number. Each absorbance was proportional to the layer number. In-plane spectral anisotoropy was evaluated by using polarized light. The ratio of the absorbance of the polyimide LB films with monitoring light polarized parallel and perpendicular to the dipping direction was 1.1 on the average. This suggests that a part of the polyimide chains align parallel to the dipping direction. No in-plane anisotoropy was observed for the PPI LB films.

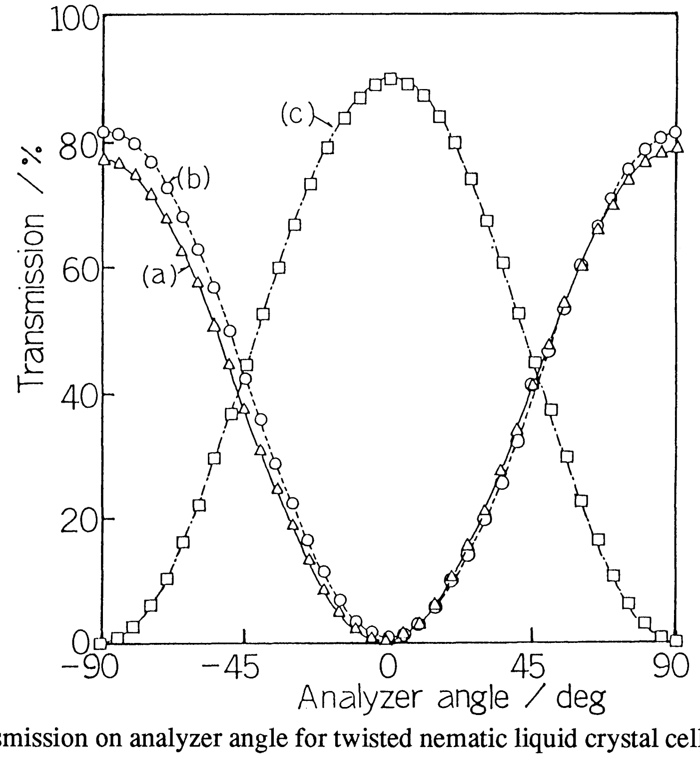


Fig. 3. Dependence of transmission on analyzer angle for twisted nematic liquid crystal cells of pyrolyzed polyimide LB films (a) and rubbed polyimide films (b) and vacant quartz cell (c).

To examine the static alignment properties of a liquid crystal on the PPI LB film, two quartz plates on which the PPI LB films were formed were assembled with globular spacers of 9 μm in diameter between them in such a manner that the LB films should be facing with their dipping directions perpendicular to each other. In case of electrooptic response measurements, 7.5-μm sheets were used instead of globular spacers. The assembled cell was filled with a liquid crystal (Merck E-7), and was viewed between the polarizer and analyzer under a halogen lamp using a Nikon P-1 microscope. The polarizing direction of the polarizer was parallel to the dipping direction of the LB film on the polarizer side. The polarizing direction of the analyzer was rotated for evaluating the static alignment of the liquid crystal without applying voltage. Dynamic alignment properties of the liquid crystal were examined by applying 50 Hz ac voltage with the polarizing direction of the analyzer parallel to that of the polarizer.

Figure 3 shows the static alignment properties of the liquid crystal on the PPI LB film compared with commercially available rubbed polyimide film. The cells consisting of the PPI LB film and the rubbed polyimide film showed contrasts of 132 and 110, respectively, indicating similar properties of the two films. The mechanism of the alignment of the liquid crystal in the LB film case is not clear at present since the film showed no in-plane anisotropy in the polarized UV-visible spectra. Studies are now in progress on the morphology and alignment properties of the PPI LB films using atomic force microscopy and other optical spectroscopy.

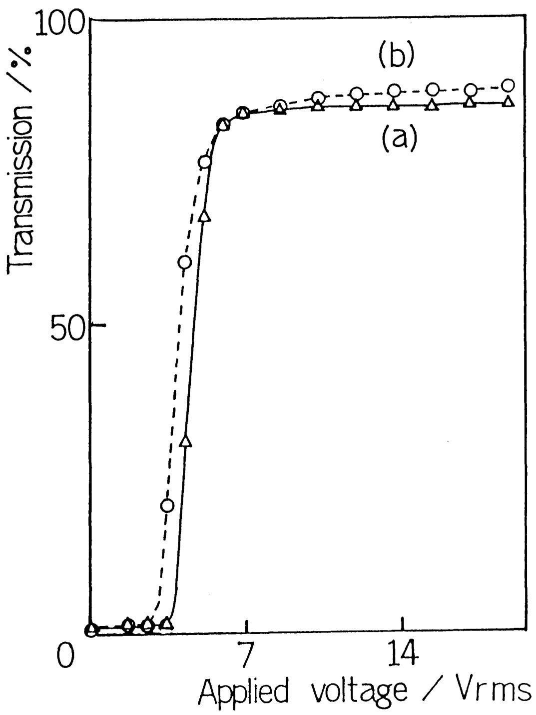


Fig. 4. Dependence of transmission on applied voltage for twisted nematic liquid crystal cells of pyrolyzed LB films (a) and rubbed polyimide film (b).

Dynamic behavior of PPI LB film cell was examined. Figure 4 shows the change in the transmission of the liquid crystal cell using the PPI LB films and the rubbed polyimide films by varying applied voltage.[6] For the latter case, ITO was used for electrodes. Both cells showed a threshold voltage of 3 Vrms (Vrms = effective voltage) and the transmission became constant above 5 Vrms. The contrast was 78 and 67 for the LB film and the rubbed polyimide cell, respectively. Electrooptic response of the two cells was measured by switching the applied voltage every two seconds. No significant difference was observed between the two cells as is shown in Fig. 5. The switching times in the "on" and the "off" directions were 200 and 200 ms for the LB film cell and 100 and 200 ms for the rubbed polyimide cell, respectively.

In summary, the PPI LB films are effective for the alignment films and transparent electrodes for nematic liquid crystal cells. The LB films of this type will be useful also as a semiconducting alignment film for ferroelectric liquid crystal cells [7,8] since they are very thin and transparent with their conductivity controllable by the pyrolysis temperature.[9]

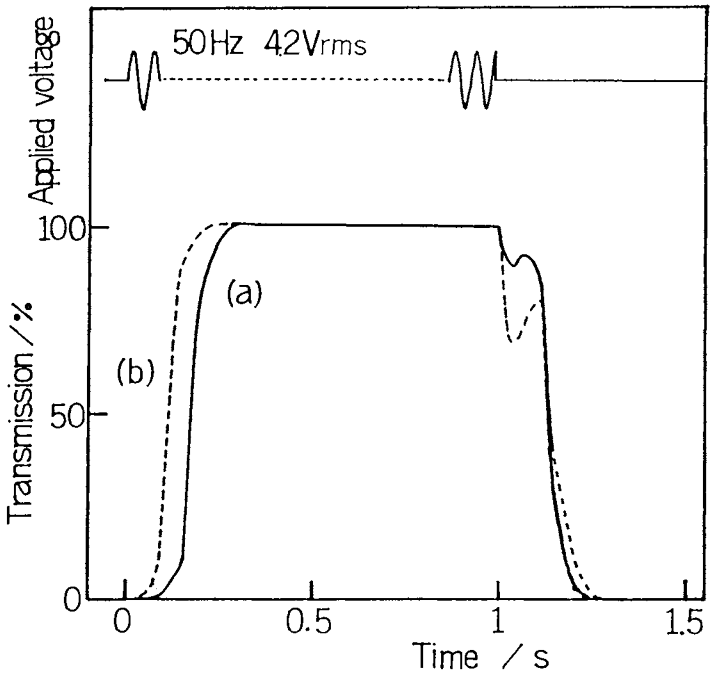


Fig. 5. Electrooptical response of twisted nematic liquid crystal cells using pyrolyzed polyimide LB film (a) and rubbed polyimide fiim (b).

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6)When the electric field was applied to a virgin PPI LB film cell or to the cell left for several minutes without electric field, some defects were observed under microscope and the response time was slow. These defects should be the disclination probably due to a small pretilt angle. After several tens of seconds, the cell responded reproducibly.

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