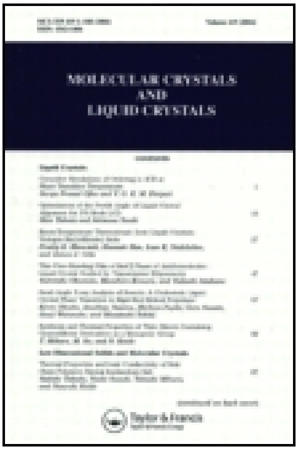

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Orientation Patterning of Liquid Crystals by UV-Irradiated Polysilane Oriented Films

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*We prepared a highly oriented thin film of the simplest polysilane, poly(dimethylsilylene) (PDMS) by friction transfer method. It had an ability of aligning liquid crystals. A liquid crystal, 4-cyano-4′-**n**-pentylbiphenyl (5CB) sandwiched between oriented PDMS layers was uniformly oriented. The molecular axis of 5CB lay in parallel to the direction of PDMS chains. PDMS films could be easily photooxidized by UV light irradiation. 5CB between UV-irradiated PDMS oriented in the different manner from that between non-irradiated PDMS. The PDMS orienting films could be patterned by irradiation with a shadow mask and the orientation of 5CB induced by them was patterned.*

Keywords: friction transfer; liquid crystals; orientation; patterning; polysilanes; UV-irradiation

INTRODUCTION

Liquid crystal alignment layers are necessary for display application of liquid crystals. Rubbed polymer films are most used as the alignment layer in industry. Alternative alignment layers are investigating.

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Friction-transferred polymer film is a candidate because the film has an ability of alignment of other materials. Especially, poly(tetrafluoroethylene) (PTFE) is investigated intensively. The friction-transferred PTFE was reported to act as a liquid crystal alignment layer [1]. We have studied friction-transferred films of other polymers, *e.g.*, polysilanes. The simplest polysilane poly(dimethylsilylene) (PDMS) also has an ability of aligning other molecules [2–5]. Moreover, polysilanes are easily decomposed by ultraviolet (UV) light irradiation, and photodegradation is applied to lithography [6]. Surface relief grating of polysilane using of photodegradation was studied as a liquid crystal alignment layer [7]. We already reported that patterning of orientation of friction-transferred polysilane by UV-irradiation and that UV-irradiation control the induced orientation of vacuum deposited oligosilane on the polysilane layer [8]. In this study, we show friction-transferred polysilane can be applied to the liquid crystal alignment layer and patterning by UV-irradiation.

EXPERIMENTAL

In this study, a polysilane, PDMS (Nippon Soda Co., Ltd.), and a nematic liquid crystal, 4-cyano-4′-*n*-pentylbiphenyl (CB5) (Tokyo Kasei Kogyo Co., Ltd.), were used. PDMS oriented films were prepared by the friction transfer method as follows: A pellet was compressed from the powder. The pellet was press and slid on a clean substrate, whose temperature was kept at 250°C, under vacuum and then a PDMS thin layer deposited on the substrate. Glass and Si wafer (for IR measurements) were used as substrates. UV irradiation was carried out by a xenon lamp with a power of 100 W (LAX100, Asahi Spectra Co., Ltd.) The wavelength range was limited between 300 and 400 nm. A polarizing microscope and Infrared (IR) spectroscopy were used for observation of the orientation of the liquid crystal. The IR spectra were measured with Biorad FTS-175C spectrometer with a KRS-5 wire-grid polarizer.

RESULTS AND DISCUSSION

The friction-transferred layer of PDMS had an ability of orienting liquid crystals. The texture of the nematic liquid crystal CB5 inserted into the friction-transferred PDMS was observed by a polarizing microscope. Figure 1(a) shows polarizing micrographs of CB5 between two parallel friction-transferred PDMS under the cross-polarization condition. The transmission light intensity at the area between PDMS was changed homogeneously on rotating the sample. The light

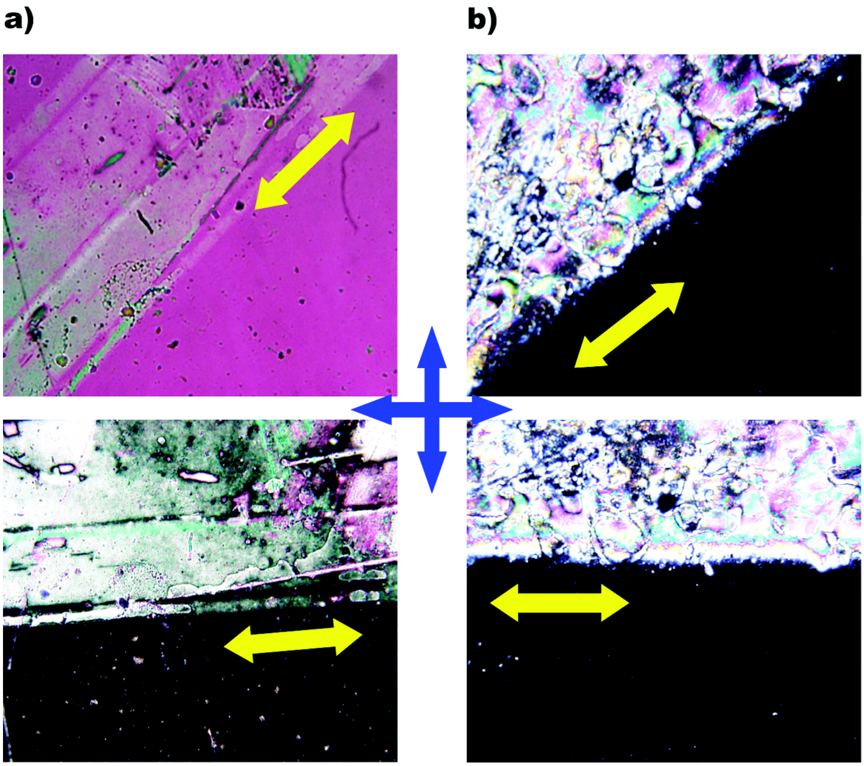

FIGURE 1 Polarizing micrographs of (a) CB5 between non-irradiated PDMS, and (b) CB5 between UV-irradiated PDMS. Allows and a crossed allow show the friction direction of PDMS and the direction of polarizer, respectively. The upper left half areas of photographs represent the CB5 between bare glasses.

intensity was strongest when the friction direction of PDMS was set 45° against the polarizer direction. 5CB was homogeneously oriented by PDMS layer.

Polysilanes are easily decomposed by UV irradiation. On UV-irradiation the characteristic absorption and luminescence are diminished in the spectra. This is the result of scission of the main chain and oxidation. UV-irradiated PDMS film lost orientation and the morphology of the film changed [8]. Figure 1(b) shows the texture of CB5 between UV-irradiated PDMS layers. The transmission light was dark and did not change with the angle of the polarizer. The orientation of the CB5 induced UV irradiated PDMS was different manner from that between non-irradiated PDMS.

Molecular orientation of 5CB was evaluated by polarized IR measurements. The polarized IR spectroscopy is a powerful tool for evaluation of molecular orientation. 5CB has some orientation-sensitive bands [9]. The transition moments of the bands at 2227 cm^{-1} (CN stretching) and 1606, 1494 cm^{-1} (CC stretching of biphenyl ring) are

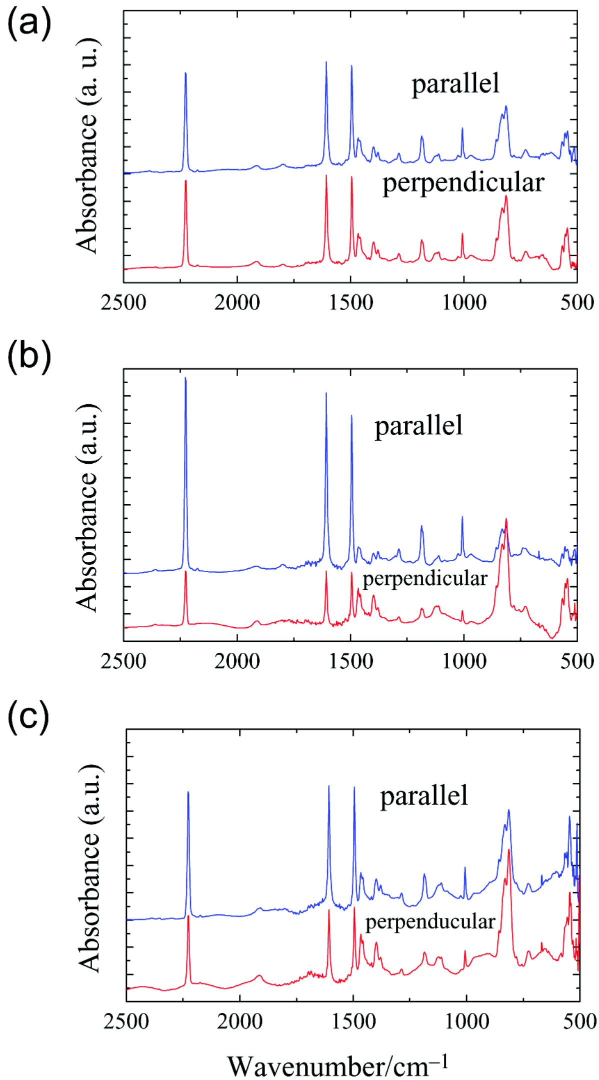

FIGURE 2 Polarized IR spectra of (a) Si/CB5/Si, (b) Si/PDMS/CB5/PDMS/Si, and (c) Si/UV-PDMS/5CB/UV-PDMS/Si.

parallel to the long axis of biphenyl ring. The band at 813 cm^{-1} (out-of-plane bending of biphenyl ring) is polarized perpendicular. Figure 2 show the polarized IR spectra of 5CB between 3 different substrates, Si wafer, friction-transferred PDMS on Si wafer, and UV-irradiated PDMS on Si wafer. The spectra of 5CB between friction-transferred PDMS (non-irradiated) (Fig. 2(b)) show stronger dichroism than the other spectra. In Figure 2(b) the parallel band (2227, 1606, 1494 cm^{-1}) are stronger in the spectrum with parallel polarization to the friction direction. This suggests that the CB5 molecules aligned in the friction direction, *i.e.*, the chain direction of PDMS. The dichroic ratio D is defined by absorption A as follows:

$$D = (A_{\parallel}/A_{\parallel}(iso))/(A_{\perp}/A_{\perp}(iso)),$$

where (*iso*) means isotropic. The absorbance at 813 cm^{-1} was used for perpendicular band. Dichroic ratio of 5CB between non-irradiated PDMS is 6.36 (for 2227 cm^{-1}) and 5.46 (for 1606 cm^{-1}). On the other hand, dichroic ratio of the 5CB between UV-irradiated PDMS is 1.65 (for 2227 cm^{-1}) and 1.53 (for 1606 cm^{-1}). In-plane orientation of the 5CB between UV-irradiated PDMS remains little and it shows a small dichroic ratio.

Because UV-irradiated PDMS induced the different orientation of 5CB from that induced non-irradiated PDMS, patterning of orientation should be possible by partial UV-irradiation. Figure 3 exhibits the polarized micrographs of 5CB between PDMS layers irradiated with a shadow mask. The transmission light of non-irradiated area is changed with the angle of polarizer. On the other hand the

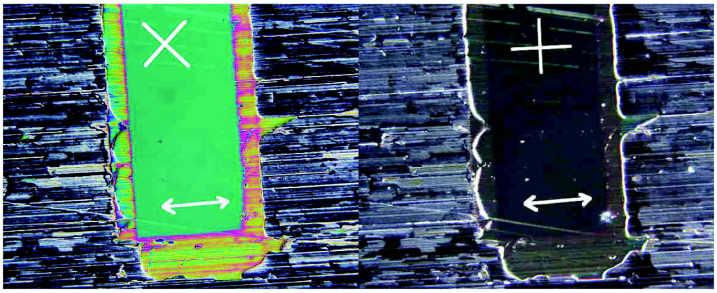

FIGURE 3 Polarized optical micrographs of 5CB sandwiched between UV-patterned PDMS layers under the cross-polarization condition. The shadow mask width was 0.35 mm. Central areas have not been irradiated. White crosses and arrows show the polarization direction and the orienting direction, respectively.

UV-irradiated area is dark and independent of the direction of polarizer. The induced orientation by friction-transferred PDMS can be patterned by UV-irradiation.

CONCLUSION

The friction-transferred layer of PDMS aligned a liquid crystal 5CB. The molecular axis of 5CB aligned in the PDMS chain direction. The friction-transferred PDMS films could be patterned by UV-irradiation with a shadow mask and the orientation of 5CB induced by them was patterned. The friction-transferred PDMS films could be used as "patternable liquid crystal alignment layers."

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