(Polymer/Liquid Crystal) Composite Films with High Electric Charge Holding

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(Received July 22, 1999; CL-990648)

A (polymer/liquid crystal: LC) composite film with a high electric charge holding was prepared by a solvent-induced phase separation method. The (polydiisopropyl fumarate (Pdi-iPF)/TL205 (LC)) composite film sandwiched between two transparent electrodes exhibited highly stable electric charge holding over several hundreds seconds after the electric circuit connecting between the electrodes was opened. Reversible light transmission-light scattering switching upon an open circuit after the application of a pulse electric field and a short one, respectively, was achieved for the (Pdi-iPF/TL205) composite film.

The (polymer/LC) composite films have gained increasing interest because of their numerous potential applications as optical devices such as large-area flexible displays without polarizers, bright projections, light shutters, switchable windows and so on.[1-4] It is well known that the choice of LCs is critical in maintaining a high electric charge holding ratio which is required for an active matrix display mode. Since cyano-based LCs are difficult to maintain a high electric charge holding ratio compared with fluoro-substituted LCs, fluoro-substituted LCs have been used in an active matrix twisted nematic displays instead of cyano-based LCs.[5,6]

In this paper, the preparation method of the (polymer/LC) composite film with a high electric charge holding has been investigated in order to prepare the material for the light shutter driven with a very low electric power consumption.

Pdi-iPF supplied by Nippon Oil & Fats Co., Ltd. was used as the matrix for the (polymer/LC) composite film. After Pdi-iPF was purified by means of column chromatography (CC), the weight-average molecular weight, Mw and the polydispersity index, Mw/Mn were determined via gel permeation chromatography (GPC) with polystyrene standards. Mw of Pdi-iPF was 320000 and Mw/Mn was 1.87. The LC employed in this study was TL205 (Merck Co., Ltd.), which was a nematic mixture with a positive dielectric anisotropy. TL205 is suitable to use in an active matrix display because of its low electric conductivity. Pdi-iPF and TL205 were dissolved in a solvent such as toluene for the preparation of the composite films. The weight ratio of Pdi-iPF/TL205 was 20/80 and the initial concentration of solution was about 10 wt%. The solution was bar-coated on an indium tin oxide (ITO)-coated poly(ethylene terephthalate) (PET) film with a doctor-blade under Ar purge gas. The solvent was evaporated at the natural rate under the atmospheric pressure and at room temperature. The thickness of the composite films was controlled to be about 5 and 10 μm. The film specimens were dried at 393 K for 30 min after being dried at room temperature for 72 h. The phase-separated structure of the composite films was investigated by means of the scanning electron microscope (SEM) as mentioned in the previous paper.[7] In order to evaluate an electric charge holding phenomena of the composite films, light transmittance changes upon an open circuit after the application of a pulse electric field and a short one were measured. The composite films were sandwiched between two ITO-coated PET films. He-Ne laser (wavelength: 632.8 nm) was used as an incident light source. The measurement of the transmitted light intensity through the composite films without any polarizers was carried out with a photodiode and a digital storage oscilloscope. The transmitted light intensity was not normalized by the intensity of the incident light through a blank cell, that is, the resultant transmittance of the cell included that of the substrates.

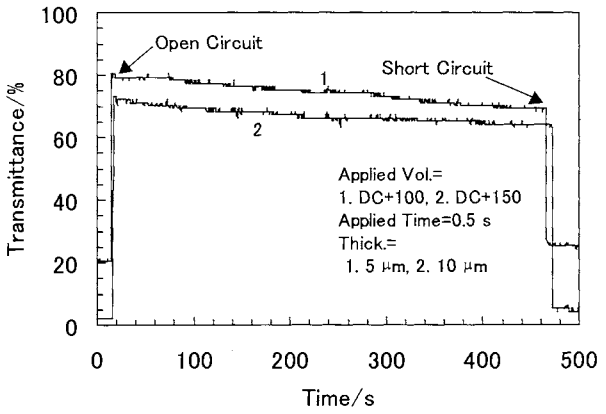
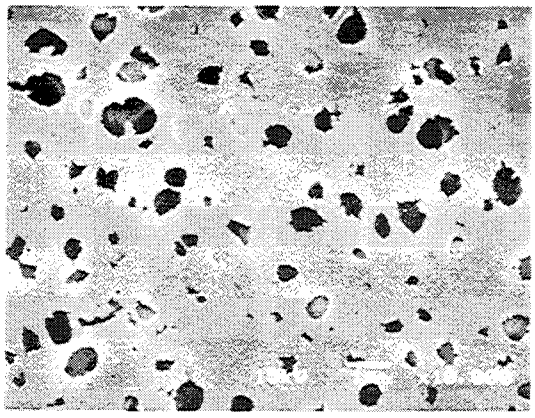
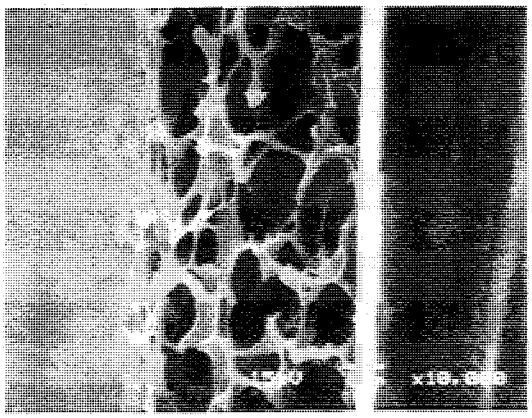


Figure 1. Time dependence of the light transmittance for the (Pdi-iPF/TL205) composite films after applied the electric field of dc +100 or +150 V for 0.5 s.

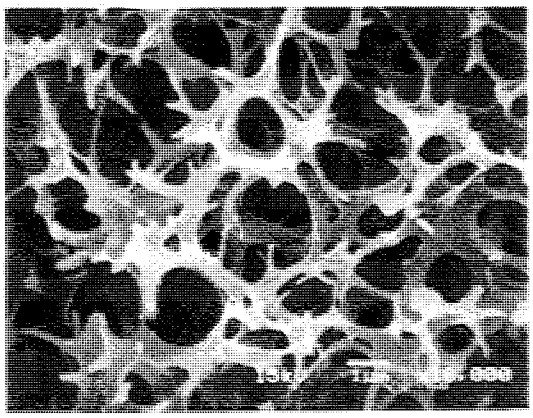
Figure 1 shows the time dependence of the light transmittance for the (Pdi-iPF/TL205) composite films after dc electric field of 100 and 150 V were applied to the composite films for 0.5 s and turned off. The (Pdi-iPF/TL205) composite films exhibited the remarkably stable light transmittance for the time period more than 500 s when the electric circuit was opened after the application of a dc electric field for 0.5 s. These results apparently indicate that the temporary memory of transparent state can be realized, maybe due to a high electric charge holding after an open circuit. Therefore, in order to maintain the transparent state in the composite film, the continuous application of an electric field is not required. This means that the light valve operations can be made with an extremely low electric power consumption by using this type of



(a) Surface facing surface



(b) Cross section



(c) Substrate facing surface

Figure 2. SEM micrographs of the (Pdi-iPF/TL205) composite film after extraction of TL205 with methanol.

composite film. This phenomenon might be due to the asymmetric formation of the thin Pdi-iPF surface which takes a role of an insulator. This will be discussed later. When the electric circuit was shorted, the (Pdi-iPF/TL205) composite films exhibited instantly a light scattering state as shown in Figure 1. The (Pdi-iPF/TL205) composite film also exhibited a reversible light transmission-light scattering switching upon an open circuit after the application of a pulse electric field and a short one, respectively. The appearance of this phenomenon was independent of the thickness of the composite film as shown in Figure 1.

Figure 2 shows the SEM micrographs of the matrix Pdi-iPFs after extraction of TL205 with methanol. The TL205-rich phase might be embedded in the dark holes shown in Figures 2(a), (b) and (c) and the bright parts might correspond to the Pdi-iPF-rich phase. The composite film exhibited the phase-separated structure, in which an entirely continuous TL205 phase was embedded in a three-dimensional Pdi-iPF network as shown in Figures 2(b) and (c). It is clear that the surface of the (Pdi-iPF/TL205) composite film was mainly composed of the Pdi-iPF thin layer although some small holes was found in the surface of (Pdi-iPF/TL205) composite film as shown in Figure 2(a). On the other hand, the Pdi-iPF layer was not found for the substrate facing surface of the (Pdi-iPF/TL205) composite film as shown in Figure 2(c). Namely, Figures 2(a) and (c) apparently show the asymmetric phase-separated structure with the different surface morphologies. The formation of the asymmetric surfaces with the Pdi-iPF and TL205 rich phases would promote an increase of the electric charge holding ratio of the composite film because the insulated thin layer of the Pdi-iPF can trap the ions conducting through the composite film.

In conclusion, the memory time of transparent state in the composite film during the open circuit period after application of a pulse electric field can be remarkably improved by controlling the phase-separated structure of the composite film. This result indicates that this type of composite film can be applied to the new material of light shutter driven with a very low electric power consumption.

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