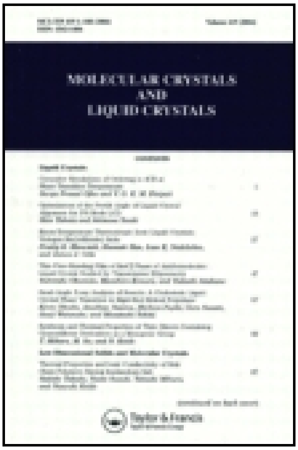

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Multi-Domain Alignment Films of Polystyrene/Polyimide of Liquid Crystals

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Multi-Domain Alignment Films of Polystyrene/Polyimide of Liquid Crystals

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Composite films of polystyrene/polyimide onto ITO glass prepared with disperse domain of polystyrene in the polyimide matrix align liquid crystals in multi-domain by single rubbing process. The size of the polystyrene domain was controlled by varying the rpm of spin coating and weight ratio of polystyrene in polyimide film. When the films were rubbed, polyimide forced liquid crystals to orient to a rubbing direction, while polystyrene forced to the perpendicular direction. After the rubbing process, multi-domain structured films aligned the liquid crystals with various directors.

Keywords: LCD alignment; multi-domain; phase separation; rubbing

INTRODUCTION

In liquid crystal displays, narrow viewing angle is one of the shorthand to compete with other flat panel displays. Many methods have been investigated to overcome the viewing angle problem, such as amorphous TN[1], multi-domain alignment[2], optical compensation[3], in-plane switching method. However, multi domain alignments using polyimide with several treatment of rubbing require another photoresist procedure because of added rubbing process.

In this paper, we report two component multi-domain structure using polystyrene/polyimide polymer as an alignment of liquid crystal. It is known that polyimide has an ability to orient liquid crystals to the same direction of rubbing[4] and that polystyrene has the same ability but in the opposite direction[5]. Polymer alignment film with multi-domain structure also improve the properties of the alignment such as pretilt angle[6] and thermal stability. With this surface structure of composite film, we can align the liquid crystals to various directions with a single rubbing process.

EXPERIMENTAL

Poly(amic acid), the precursor of SE150 polyimide (Nissan Co.), was mixed with polystyrene (LG Chem.) with various weight ratio in co-solvent of *N,N*-dimethylacetamide (DMAc). The structure of the SE150 polyimide and polystyrene were shown in Figure 1. By observing the transmission of a light through the mixed solutions of the SE150 polyimide and polystyrene at various composition in DMAc, the domain of liquid separation in ternary diagram was obtained at 25°C. The mixed solutions of polystyrene/poly(amic acid) with various concentrations were spin-coated at a speed of 2000rpm on the ITO glass. And the coated films were cured at 200°C for 1hr. Domain formation of the cured films were observed by microscope and the immiscibility of two polymers was confirmed by a differential scanning calorimetry (DSC). The DSC thermograms were obtained by using a Du Pont Instrument 910 from 35°C to 350°C at a heating rate of 10°C/min under nitrogen environment. The cured films were rubbed by slightly contacting with a rubbing cloth of velvet (Yoshikawa Co.) at a rotating speed of 800 rpm of the cylinder. After assembling cell with two ITO substrates coated with the films, nematic liquid crystal (E7, Merck Co.) was filled by the capillary force. The gap between two ITO substrates was hold by inserting a 6μm polyethyleneterephthalate (PET) film. The structure of multi-domain alignment and the texture of liquid crystals in the cell were observed by a polarized microscope.

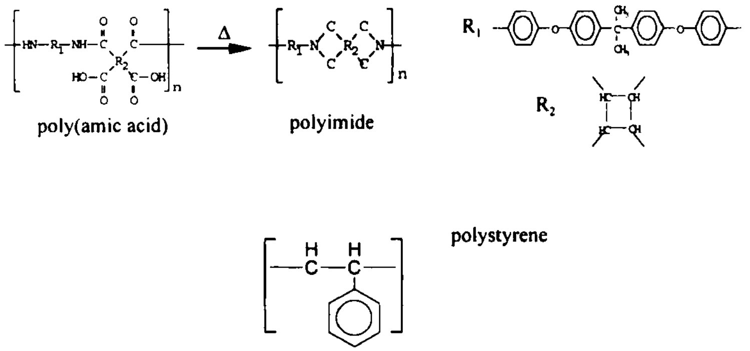

FIGURE 1. Structure of polyimide and polystyrene.

RESULTS AND DISCUSSION

The solutions of poly(amic acid) in DMAc and polystyrene in DMAc were easily mixed at 25°C. The mixed solutions of 1, 2, and 3 wt.% of poly(amic acid) and polystyrene in DMAc showed a homogeneous phase through all the range of weight ratios of two polymers, while the mixed solutions of 4 and 5 wt.% showed a phase separation in some weight ratios at room temperature. Figure 2 shows the ternary phase diagram of polystyrene/ poly(amic acid)/DMAc system. Relative weight ratio of polystyrene to poly(amic acid) in the solutions remained unchanged during the process in Figure 2. The ternary diagram show the phase separation in most composition ranges except very low concentrations of the mixed solutions.

The spin coating process can be operated along Two kinds of process are possible in making an alignment film; arrow a represents that spinning starts with a dispersed solution and arrow b with a miscible solution.

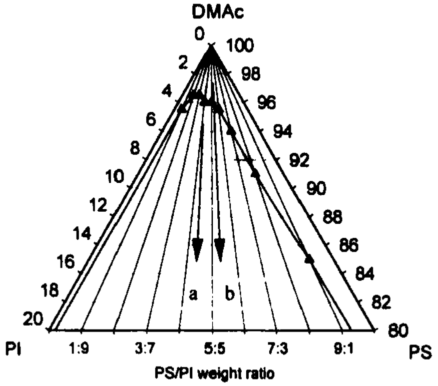

FIGURE 2. Phase diagram of polystyrene/poly(amic acid)/DMAc system; experiments were done along operating lines of relative weight ratio; a: with disperse solutions, b: with miscible solutions.

The coated films were cured at 200°C for 1 hr and the surface structures were not changed with curing temperature. Hydrophobic polystyrene domain in the hydrophilic poly(amic acid) matrix on hydrophilic ITO glass has formed by the evaporation of the solvent during spin coating process. In DSC thermogram, T_g of polystryrene was not shifted even at mixed film.

The morphology of the spin-coated films are observed as the initial solution concentrations, polymer compositions, spin speeds, temperature, and humidity. In path b, the mixed solutions of 1, 2, and 3 wt.% of polymers in the miscible region reaches to immiscible phase during the spin coating process. These films showed the irregular aggregation of submicron particles at the high amounts of polystyrene. Figure 3 shows the microscope image of the mixed films on ITO glass before filling the nematic liquid crystal. In Figure 3, the mixed films (5:5) of 5 wt.% showed a circular domain of polystyrene in polyimide matrix. The size of the polystyrene domain was varied with weight ratio of polystyrene to polyimide as well as initial concentrations of the solutions.

(a) (b) (c) (d) (e)

FIGURE 3. Microscope image of the mixed films of polystyrene and polyimide; (a) 1:9, (b) 2:8, (c) 3:7, (d) 4:6, (e) 5:5 (5 wt.% solution).

Figure 4 shows the average domain size of spin-coated films with weight fraction of polystyrene. The average diameter of polystyrene domain in 1:9 of polystyrene-polyimide film was in the range of several μm and those of 5:5 reached to 5-30μm.

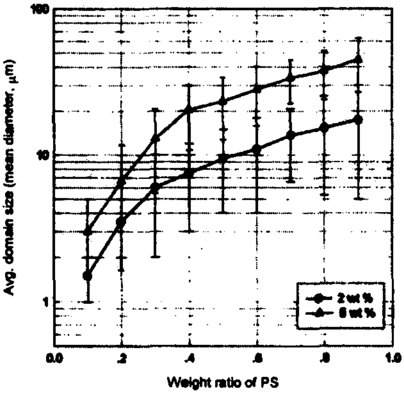

FIGURE 4. Average domain size of polystyrene/polyimide spin-coated films with weight ratio of polystyrene; ● : 2 wt.%, ▲: 5 wt.% solution.

The speed of spin coating also affected the average size of polystyrene domain because the spin coating process consists of dispensing large amount of the mixed solution and abrupt evaporation of the solvent. In Figure 5, the domain size distribution at a spin speed of 500 rpm was wide and the morphology showed some aggregations of polystyrene phase. As the spin speed increased, the uniform polystyrene domain was randomly distributed in the polyimide matrix.

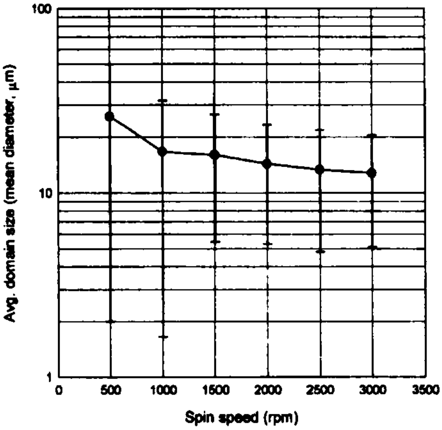

FIGURE 5. Average domain size of 5:5 polystyrene/polyimide (5 wt.%) spin-coated film with speed of spin coating.

ITO glass coated with the cured films were rubbed with velvet and the substrates were assembled to make a TN cell. Nematic liquid crystal (E7) was filled into the cell at room temperature to prevent relaxation of polystyrene whose glass temperature is about 110°C. Figure 6 shows the crossly polarized microscope pictures of the cells made of the alignment films of 5:5 sample. Figure 6 (a) is the picture of texture of liquid crystals whose direction of rubbing was the same as that of polarizer in the microscope. Liquid crystals anchored by polystyrene domain appeared black in the picture, because the orientation of liquid crystals in the domain was different from that of liquid crystals in polyimide matrix.

(a) (b) (c)

FIGURE 6. Crossly polarized microscope pictures of TN cells with PS/PI alignment; (a) 0°, (b) 45°, (c) 90° rotation to first polarizer.

The structure of the liquid crystal molecules in the cell are similar to that of ideal amorphous TN-LCD[1], which can improve the viewing-angle characteristic of TN-LCD[7]. Our simple calculation by 4×4 matrix method was quite identical to the report. It is obvious that some different orientations were built at polystyrene domain, while others are aligned to rubbing direction of polyimide. As a result, we could make a surface structure of polymer films which induce some different orientations of liquid crystal by a single rubbing process. It is our proposal to apply this multi-domain system to wide-viewing-angle technology of LCD with rubbing process.

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