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O3 Surface Interaction Effects on Anisotropic Phase Separation for Plastic LCDs

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We studied surface interaction effects on anisotropic phase separation induced by photopolymerization of liquid crystal and polymer composite as wetting properties are changed. . By experiments and numerical simulation, we can explain qualitatively the the morphologies of anisotropic phase separation of liquid crystal and polymer composites. This result can be applied to stabilizing liquid crystal mode for flexible LCD display applications.

1. Introduction

Recently flexible display technology is widely being studied and developed. Among them, for plastic LCD application, polymer and liquid crystal composite systems were extensively studying. There are several ways of stabilizing the polymer and liquid crystal composite by UV irradiation such as polymer dispersed liquid crystal mode(PDLC)[1], polymer stabilized liquid crystal mode(PSLC)[2] and pixel-isolated liquid crystal mode(PILC)[3,4]. PDLC has many advantages in fabrication and polarizer free display application but there are still severe drawbacks such as large driving voltage, low contrast ratio and slow response time. PSLC or polymer network liquid crystal mode is studied for the purpose of optical switching devices and display. They also can give stabilized liquid crystal mode on flexible substrates, but due to their relatively high threshold voltage, noticeable hysteresis and inadequate low contrast ratio , there are still obstackles in application to display devices. For PILC mode, they have novel electrooptic properties which has almost same as those in normal LC. In fabrication of PILC, there occur two kinds of anisotropic phase separation. First, by applying UV irradiation through patterned photomask, spatially modulated polymer wall structure can be generated. And next, weak UV exposure can generate anisotropic phase separation of remaining polymer and LC along the substrate normal direction[Figure. 1]. One of the major key issues in PILC mode is optimized conditions for anisotropic phase separation normal to the glass substrate. We report here the effects of surface interaction between surface alignment layer and liquid crystal molecules or prepolymer molecules on anisotropic phase separation.

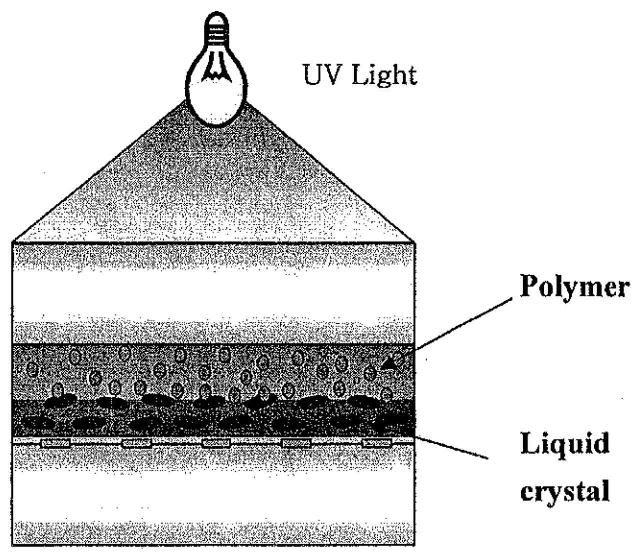

Fig. 1 Schematic diagram of PSCOF.

2. Sample Preparation

The materials used in this study were LC17 as liquid crystal , UV curable optical adhesives NOA 72,73 (Norland), and SK 9 (Summers Laboratories) as prepolymers. These prepolymers were a mixture of a monomer, an oligomer, and a photoinitiator. For the alignment layers, we used Nylon 6(Sigma Aldrich) and RN1286 (Nissan). The alignment layers were spin coated on one glass substrate followed by rubbing to achieve homogeneous LC alignment. LC/polymer mixture (LC 70wt%) were introduced into the empty cell by capillary method. Anisotropic photopolymerization was achieved by weak UV irradiation of 0.7mW/cm2 during 1hr.

3. Results and Discussion

3.1 Microscopic and SEM Observation

Fig 2. shows the microscopic image and scanning electron microscopic image of liquid crystal and polymer composite of several optical adhesives using N6 alignment layer after UV photopolymerization. LC + NOA72 shows uniform texture and optical birefringence under the crossed polarizers like normal ECB mode while LC+SK-9 shows droplet like texture, non switching and no rotational anisotropic view under crossed polarizers. LC+NOA73 morphology is rather intermediate. From Fig. 2(b), the SEM images explain clearly microscopic texture. The defect structure in microscopic image is due to by droplet formation of polymers.

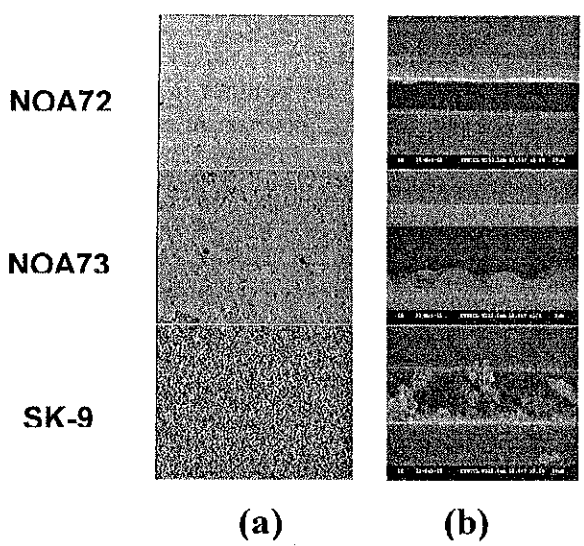

Fig. 2 Miccroscopic and SEM image for N6 alignment layer

Figure. 3 shows PSCOF morphologies for the same couple of LC and polymers except alignment layer RN1286. Comparing to Fig. 2, the LC+SK-9 is almost same, but NOA 72 and 73 shows different . However, NOA73 on N6 texture is rather similar to NOA72 on RN1286. The SEM image also exhibit same cross sectional structure. We think the NOA 72, and 73 have similar bulk property but SK-9 has quite different. And we further thought the change of alignment layer means change of surface interaction.

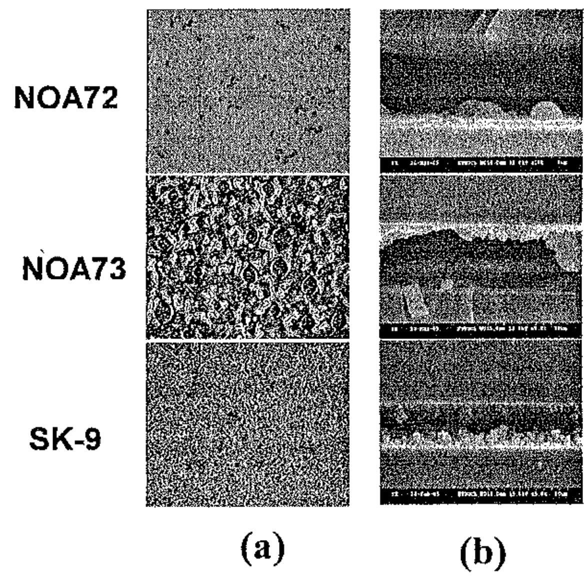

Fig. 3 Miccroscopic and SEM image for RN1286 alignment layer

With these experimental results and contact angle experiments which was previously reported[4], we perform the numerical simulation for this system.

3.2 Simulation Results

To describe the 1-dimensional polymerization induced phase separation, we use 1-dimensional kinetic model[5]. The detailed mathematical formals are in the Ref. 5. Among the formular, we modified the prepolymer current term to include surface interaction effect. For the simplicity, we assume exponentially decaying surface potential form with same characteristic length. Hence finally modified current term of prepolymers can be written as follow in dimensionless variable.

$$J_{\phi} = -\psi \frac{\partial \phi}{\partial z} + \phi \frac{\partial \psi}{\partial z} - \chi \phi \psi \frac{\partial \psi}{\partial z} - \phi \psi \frac{\partial V}{\partial z}$$

where V has the following form

$$V = h\exp(-z/\delta)$$

h is the surface interaction difference between prepolymer and liquid crystal and z is the coordinate whose axis is perpendicular to substrates. We carried out numerical simulation by using finite difference method. The mixing ratio is same as experiment (LC:polymer = 7:3). The concentration profiles before UV irradiation for various h are shown in Figure. 4. These results show surface wetting property of liquid crystal and prepolymer mixture on alignment layer. In this calculation, we set alignment layer position as z=0. Figure. 5 is the resultant concentration profiles after UV irradiation. Irrespective of surface interaction parameter h, there is bulky separation of liquid crystal and polymer layer. The generation of LC and polymer boundary can be understood as follow. Liquid crystal molecules strongly absorb 350nm UV light. Hence for the first time prepolymers near illuminated glass substrate undergo polymerization and prepolymers near cured polymers are joined due to by entropic driving which results in moving liquid crystal

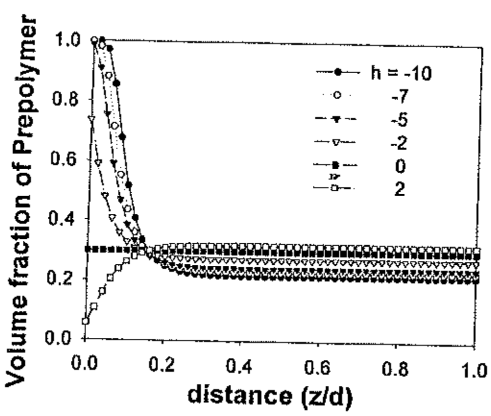

Fig. 4 Concentration profiles of prepolymers as distance z for various surface interaction

molecules towards alignment layer substrate. As a result liquid crystal molecules aggregated on alignment layer substrate which was opposite to illuminated substrate and there exist sharp boundary between liquid crystal molecules and polymers . For the case of NOA72 and 73 can be understood in this way. However for the case of SK-9, there was no intrinsic change of morphologies as change of alignment layer. This is due to by different bulk properties, for example, fast polymerization of low mean field diffusion coefficient. And in this case the polymer dispersed structure can be generate[5].

In Fig. 5, surface concentration of polymers are different for different surface interaction h. Large h gives large amount of surface concentration. In Fig. 2 and 3, the amount of polymers near alignment layer can be understood by wetting properties of polymers on alignment layer.

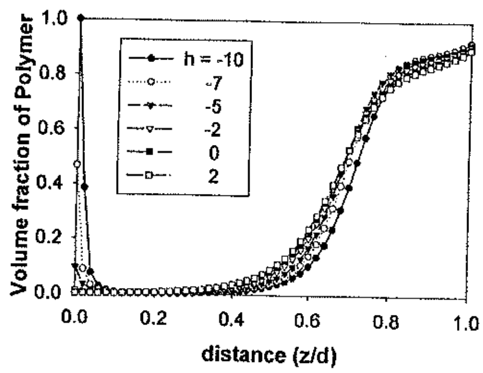

Fig. 5 Concentration profiles of polymers as normalized coordinate after polymerization.

4. Conclusion

We investigated the surface wetting effects on PSCOF morphology. By experiment and numerical simulation, we can conclude that polymeric wetting property on alignment layer plays a crucial role in PSCOF morphology. This result can be directly applied to the display devices using polymer microstructure. For the application of plastic LCD, more stabilized liquid crystal modes on flexible substrates are requested. To do that, one of good candidate is pixel-isolated liquid crystal mode whose electrooptic properties such as V-T curve and response time are almost same as normal liquid crystal sample. Our result can be applied to optimize and fabricate pixel-isolated liquid crystal mode

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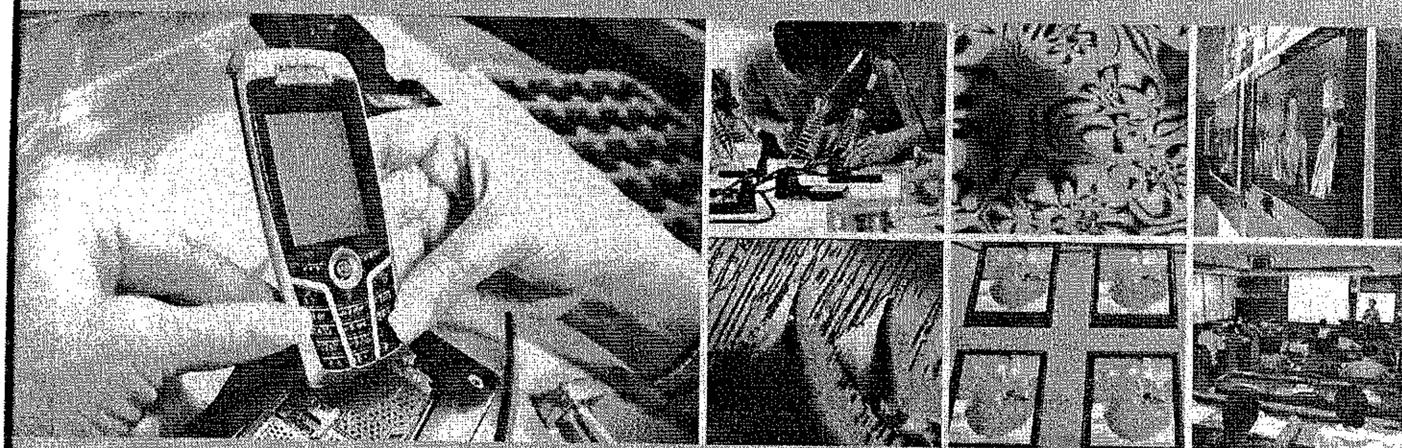

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