Fabrication of Liquid Crystal Cell with Phase Separated Composite Organic Film

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For liquid crystal displays, it is ideal that the birefringence of liquid crystal medium does not vary in whole visible light region. Although the wavelength dispersion of the birefringence can be made small by utilizing an optical phase difference film, the precise control is needed for attachment of the film. In this study, in order to realize the phase-separated composite organic film (PSCOF) structure for the fabrication technology of liquid crystal display without external attachment of the film, we research in detail the fabrication condition of PSCOF liquid crystal cell. In this research, we used lots of alignment film and UV curable monomer materials. As a result, it is found that the most important factor for the realization of a uniform PSCOF structure is the wettability of liquid crystal materials to the alignment film and monomer materials to ITO surface.

Keywords: liquid crystal, PSCOF, polymerization, wettability,

1. Introduction

The phase-separated composite organic film (PSCOF) method has attracted considerable attentions because of its applications in lots of novel liquid crystal displays (LCDs)\textsuperscript{2–5)} and photonics devices\textsuperscript{5,6)} with a unique internal polymer/LC bilayer structure. PSCOF structure is fabricated by irradiating with UV light and initiating the polymerization reaction on one side substrate of a cell containing a solution of LC and photocurable monomer. The spatially nonuniform rate of polymerization\textsuperscript{7)} can be realized by a gradient of UV intensity along the substrate normal. The intensity gradient is produced by strong UV absorption of LC medium. As a result, a bilayer structure of polymer/LC can be obtained with the polymer layer on the substrate closer to the UV source, as shown in Fig. 1. The optic axis of the LC layer can be controlled by an alignment film on the LC side substrate. This unique internal structure provides the devices with a strong resistance to mechanical deformations. With the PSCOF technology, flexible plastic LCDs, microlens arrays, and single-substrate devices have been fabricated.\textsuperscript{2–6)}

The electrooptical performance and mechanical robustness of PSCOF devices depend on their internal polymer structure and morphology. Therefore, in order to design and optimize the device performance, and further to fabricate the PSCOF structure, it is important to understand the phase separation process of polymer/LC. Qian \textit{et al.}\textsuperscript{8)} calculated the essential features of this process by using a simple one-dimensional model and predicted that the formation of PSCOF is a result of nonuniform UV illumination caused by the strong UV absorption, slow polymerization and phase separation of the LC and prepolymer mixture. However, these factors are necessary but not sufficient conditions. In fact, PSCOF structure cannot be obtained easily and a polymer-dispersed structure is usually formed. In this research, we focus on the wettability and investigate the influence of monomer materials and alignment films on the formation of PSCOF structure.

![Fig. 1 Scheme of PSCOF structure.](image-url)
2. Experiment Details

2.1 Alignment film dependence

E7 (Phase sequence: Cryst. (-10°C) N (60°C) Iso.) and 5CB (Phase sequence: N (34.8°C) Iso.) were used as the liquid crystal sample. NOA65 (NORLAND) which is a UV curable adhesive was added to E7 at 50wt%. The rubbing alignment film of RN1199, SE150, IPS-A, IPS-B (Nissan Chemical Industries), AL1254 or AL3046 (JSR) was coated on the one side of glass substrate in a cell, and the cell gap was set 4µm. The polymerization of NOA65 was carried out by UV irradiation (310nm, 2µW/cm², 120min at 90°C) from the side of bare ITO glass substrate which was not coated with the alignment film. The texture in the cell was observed with a polarizing microscope. In order to investigate the effect of wettability on PSCOF structure, the contact angle was measured.

2.2 Monomer materials dependence

E7 doped with 50wt% Monomer D, E or F (Osaka Organic Chemical Industry) was prepared. The miscibility of E7 and these monomers is not well. RN1199 was used as alignment film. The texture was observed after UV irradiation (310nm, 2µW/cm², 120min at 90°C). Furthermore, the contact angle of the monomers to ITO and RN1199 was measured.

3. Results and Discussion

3.1 Alignment film dependence

Figure 2 shows microscopic textures, which were observed at the room temperature, in the cells fabricated using E7 and NOA65 after UV irradiation. It is found that uniform alignment structures are obtained in the cases of RN1199 and IPS-B alignment films. The direction of LC molecular orientation is in accordance with the rubbing direction of the alignment film. On the other hand, in the cases of other alignment films, the macroscopic phase separation in cell plane is observed and the isotropic situation remains in almost whole area even at the room temperature. It is guessed that since the UV irradiation was performed in the isotropic phase at 90°C, a random molecular alignment can be maintained in a polymer-dispersed situation. Furthermore, Fig.3 shows microscopic textures in the case of 5CB. The same results were obtained. Thus, PSCOF structure can be obtained only by using RN1199 and IPS-B.

Figure 4 and Table 1 show the contact angle measured at 90°C: Fig.4 is the time dependence and Table 1 is the value after 60s from dropping. It is found that LC materials are more wettable to alignment films than NOA65. Moreover, in the difference of the contact angle between the alignment films, the wettability of LC materials to RN1199 and IPS-B is relatively well. Therefore, it is thought that the good wettability of LC materials to alignment film is important to fabricate PSCOF structure. The LC molecules can be biased to the alignment film surface during UV photocure in the case of better wettability, and then the two-layer phase separation of polymer/LC can be realized after UV photocure.

On the other hand, as compared 5CB with E7, it is
found that the contact angle required to form PSCOF structure is different between LC materials used. Table 2 shows the contact angle of E7 and 5CB to ITO surface. It is found that the wettability of 5CB is better than that of E7. Therefore, it is concluded that the difference of the contact angle between the alignment film and ITO is an important factor to realize the PSCOF structure.

![Image of AL1254](image1)

![Image of AL3046](image2)

![Image of RN1199](image3)

![Image of SE150](image4)

![Image of IPS-A](image5)

![Image of IPS-B](image6)

Fig. 3 Texture observation (5CB).

![Image of AL1254](image7)

![Image of AL3046](image8)

![Image of SE150](image9)

![Image of RN1199](image10)

![Image of IPS-A](image11)

![Image of IPS-B](image12)

Fig. 4 Contact angle (E7, 5CB and NOA65)

### Table 1 Contact angle to several alignment films (after 60s)

<table>
<thead>
<tr>
<th></th>
<th>E7(°)</th>
<th>5CB(°)</th>
<th>NOA65(°)</th>
</tr>
</thead>
<tbody>
<tr>
<td>AL1254</td>
<td>2.61</td>
<td>3.47</td>
<td>11.69</td>
</tr>
<tr>
<td>AL3046</td>
<td>3.88</td>
<td>5.65</td>
<td>12.35</td>
</tr>
<tr>
<td>RN1199</td>
<td>2.40</td>
<td>3.15</td>
<td>10.84</td>
</tr>
<tr>
<td>SE150</td>
<td>2.74</td>
<td>3.58</td>
<td>11.37</td>
</tr>
<tr>
<td>IPS-A</td>
<td>2.68</td>
<td>3.41</td>
<td>10.99</td>
</tr>
<tr>
<td>IPS-B</td>
<td>2.20</td>
<td>2.18</td>
<td>10.65</td>
</tr>
</tbody>
</table>
3.2 Monomer materials dependence

Figure 5 shows microscopic textures and phase transition temperature in the cells fabricated using E7 and Monomer D, E or F, which is acrylate. It is found that a uniform two-layer separation can be obtained in the case of Monomer D and F. However, in the case of Monomer F, the phase transition temperature is much lower than that of E7, and thus, the polymer/LC phase separation is not completed. The miscibility of E7 and all monomers used in this research is not well. Therefore, it is concluded that the ease of the phase separation is not sufficient to fabricate PSCOF structure.

<table>
<thead>
<tr>
<th>Monomer</th>
<th>ITO(°)</th>
</tr>
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<tbody>
<tr>
<td>E7</td>
<td>16.86</td>
</tr>
<tr>
<td>5CB</td>
<td>11.90</td>
</tr>
</tbody>
</table>

Table 2 Contact angle to ITO (after 60s)

From these results, it is found that a uniform two-layer phase separation of polymer/LC can be obtained in a small contact angle of the monomer such as Monomer D to ITO surface. On the other hand, the poor wettability of monomer to ITO may suppress the formation of PSCOF structure. Therefore, it is concluded that the good wettability of monomer to ITO surface is also important to fabricate PSCOF structure.

Figure 6 and Table 3 show the measurement results of the contact angle in Monomer D, E and F.

Table 3 Contact angle of monomers (after 60s).

<table>
<thead>
<tr>
<th>Monomer</th>
<th>RN1199(°)</th>
<th>ITO(°)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Monomer D</td>
<td>6.21°</td>
<td>9.72°</td>
</tr>
<tr>
<td>Monomer E</td>
<td>10.86°</td>
<td>14.56°</td>
</tr>
<tr>
<td>Monomer F</td>
<td>12.42°</td>
<td>13.38°</td>
</tr>
</tbody>
</table>

4. Conclusions

In the case of good wettability of LC materials to alignment film and monomer to ITO surface, a uniform two-layer phase separation of polymer/LC can be obtained. Therefore, the wettability is an important factor to fabricate PSCOF structure.
Acknowledgments

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References