Improved Nucleation and Transition in Optically-Compensated-Bend Displays by Plasma Beam Treatments

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1. Abstract
Optically compensated bend mode (OCB-mode) LCD is promising for next generation displays. Reduction of warm-up time in liquid crystal molecules are desired to improve the disadvantages brought forth by the OCB mode displays. The present technique is a useful approach to reducing the splay-to-bend transformation time by atmospheric pressure plasma beam treatments. The novel process method shorten the overall transition time. We proved that the number of the nucleus sites of liquid crystal cell has increased more than 6 times and 45%~74% reduction in warm-up time than the control sample. We maintained the original optical properties and response time about 5ms for the OCB mode LCD.
keywords : OCB, warm-up time, nucleus

2. Introduction
Since liquid crystal devices are characterized by low driving voltage, low power consumption, light weight, low production cost, no radiation. so, it has been broadly applied to TV set and monitor that is more popular than the traditional CRT (Cathode Ray Tube) monitor. However, conventional TN-mode LCD have a viewing angle problem that results in degradation of the contrast ratio or gray scale inversion, and they are unsuitable for displaying motion pictures because of their slow response speed. OCB-mode displays have been introduced as electro-optical binary switching devices that offer a wide viewing angle but also remains good photoelectric properties at low temperatures. The response time is 10 faster times than the traditional TN-LCD. However, OCB-mode requires a transition of the liquid crystal from an initial splay state to bend state configuration before it's operation. It needs to apply a higher voltage or it takes a long warm-up time to transform to the bend state as shown in Fig. 1. This is a disadvantage of the OCB-mode displays. One of most important our aims is the reduction in warm-up time. A splay to bend transition in the OCB-cell is produced in two steps (1) formation of bend nuclei and growth. However, there are some problems in creating the transition; nucleation is uncertain, and the transition area growths slowly. The purpose of this study is to found a method of creating the transition nucleus. In earlier studies, A small dark region represents an irregularity that occurred in the LC alignment probably due to the existence of a spacer. This region acted as a bend nucleus. The number of transition nucleus accelerated the efficiency of bend transition in OCB. In order to realize a shorter transition time, we successful induced the partial liquid crystal arrangement irregularity and increase in the number of transition nucleus sites for shortening the overall transition time by atmospheric pressure plasma beam to bombard PI film. The pi-cell is constructed by a pair of substrates rubbed in
parallel angle$^{7,8}$.

![Diagram](image)

**Fig. 1.** When we applied a voltage splay and bend state in the parallel rubbing cell

3. **Experimental**

The sample of the experiment was a glass plate with an ITO membrane sputtered on the surface. Taking this structure as the substrate, spread a layer of horizontal alignment PI (5560) material as the lower alignment layer. In this experiment, an ITO membrane with a thickness of 1000Å was sputtered onto the surface of a glass plate. The glass plate served as a substrate. Then, cut ITO glass into 2cm x 2.5cm. Wash basic plate after cut, then, blow it dry with nitrogen gun and put basic plate in SWIENCO TYPE PM490 Spin-coater to coat PI alignment film. Horizontal alignment layer with a low pre-tilt angle at 6° was used. Place the glass substrate on the spin-coater for spin coating. In the first stage, the spinning speed is 500rmp in 10sec thus the alignment layer material could be evenly coated; in the second stage, the spinning speed is set to 2000rmp in 20sec to obtain a consistent thickness in the layer. After the coating, place the substrate on a hot plate and soft bake it at a temperature of 80°C for 80sec, excess water and solvent would evaporate. Then place the substrate on a pre-heated hot plate and hard bake it at a temperature of 180°C for 60min, let alignment layer be solidified to a thickness of 100nm. Following this regulate the alignment of the alignment layer by rubbing. The average rubbing speed is 30mm/s, the speed of the roller is set to 300rpm, the rubbing depth is set to 0.300mm, the rubbing angle must be zero (enter directly at a parallel plane). Use a model RM50 rubbing machine. When this step was finished, we using atmospheric pressure plasma beam to bombard PI film for test conditions as shown in Figure 2. Important points for the splay to bend transition are how to generate the bend nuclei efficiently and how to reduce the splay to bend transition time. So we try to increase bend nucleus for shortening the overall transition time.

![Structure Chart](image)

**Fig.2 Structure chart of sample.**

With atmospheric pressure treatment, the surface modification and activation is effected by chemical and physical interaction of plasma with the substrate. Plasma treatment is an effective method of treating surfaces to increase surface energy. Plasma produces uniform surface treatment without any backside treatment of a substrate. A novel atmospheric plasma treatment (APT) process offers unique advantages over existing technologies of surface treatment. The APT apparatus does not require any vacuum systems, produces a high density plasma, and provides treatment of various substrates at low temperatures while operating open to the atmosphere. In this paper, we propose and demonstrate new way of polyimide with atmospheric pressure plasma (NEMST-Jet2008I) treatments to improve nucleus transition and obtain a shorter transition time as shown in Figure 3. Important points for the splay to bend transition are how to generate the bend nuclei efficiently and how to reduce the splay to bend transition time. So we try to increase bend nuclei for shortening the overall transition time.
In this experiment, the different conditions of atmospheric pressure plasma treatments will be selected for the technique. We used power 700W and different treatment speed (mm/s) and interval (mm) of atmospheric plasma beam to induced the partial liquid crystal arrangement irregularity and increase in the number of transition nucleus sites for shortening the warm-up time. And investigate the reduction in warm-up time than the control sample. Finally, we took the electro-optical properties measurement. The experimental flow chart is as shown in Fig.4.

![Flow chart of experiment](image)

**Fig.4. Flow chart of experiment**

### 4. Results and discussion

We provide a voltage output to 5.5v supply and instantaneous output to the Basic OCB cell. The molecular alignments between the splay and bend states are shown in Fig. 5 During the electric field on period, the splay area 5(a) transforms to a transition nucleus is created in the liquid crystal cell 5(b). Bend state is generated and spreads full screen 5(c). In this experiment, we analyzed the different treatment speeds 700, 650, 600 and 550 (mm/s), i.e. same (d) interval (mm) from atmospheric pressure plasma source. Table 1 shows the control transforms from splay to bend configuration measuring the actual time in 92 seconds and the experimental group transition time. It shows significantly reduction in warm-up time 45%~74% be compared with the control sample by atmospheric pressure plasma beam to bombard PI film.

![Figure 5. Transforms from splay to bend](image)

**Table 1: Transforms from splay to bend configuration measuring the transition time and the percentage of reduction.**

<table>
<thead>
<tr>
<th>Sample</th>
<th>control</th>
<th>550mm/s</th>
<th>600mm/s</th>
<th>650mm/s</th>
<th>700mm/s</th>
</tr>
</thead>
<tbody>
<tr>
<td>Transition time (sec)</td>
<td>92 sec</td>
<td>37 sec</td>
<td>51 sec</td>
<td>24 sec</td>
<td>49 sec</td>
</tr>
<tr>
<td>Reduction (%)</td>
<td>0%</td>
<td>60%</td>
<td>45%</td>
<td>74%</td>
<td>47%</td>
</tr>
</tbody>
</table>

The number of transition nucleus accelerated the efficiency of bend transition and to reduce the splay to bend transition time in OCB. For this reason we to generate the bend nuclei efficiently by atmospheric pressure plasma beam to bombard PI film. The data is summarized in Table 2 the average number of bend nucleus of liquid crystal cell has increased more than 6 times from 0 to 6 sec.

![Figure 6. The first 6 seconds bend nucleus situation](image)

**Table 2: The average number of bend nucleus from 0 sec to 6 sec**

<table>
<thead>
<tr>
<th>Sample</th>
<th>control</th>
<th>700mm/s</th>
<th>650mm/s</th>
<th>600mm/s</th>
<th>550mm/s</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bend nucleus unit</td>
<td>6</td>
<td>50</td>
<td>30</td>
<td>127</td>
<td>41</td>
</tr>
</tbody>
</table>

The relationships between the transmittance and the applied voltage, V–T curves, were measured for each sample cell. A square wave voltage with a frequency of 1 kHz was applied. The change rate of applied voltage was 0.1 V/sec. The electro-optical properties of the cells were
measured with a 632.8nm He-Ne laser. The transmission axis was set at an angle of 45° with respect to the rubbing direction of the sample cell. Fig. 7 show experimental results of the voltage-dependent transmittance of a pi-cell before and after atmospheric pressure plasma treatments (the power intensity is 700 watt, the interval from atmospheric pressure plasma source is 25 mm). The V-T curve with an increase in applied voltage. It can be seen that at the initial state of splay alignment and the initial state is transformed to the bend state in that critical voltage at 2.0 V. As can be seen in the figure 7, the transition from the bright state (the maximum transmittance) to the dark state (the minimum transmittance) appears in the pi-cell with an increase in applied voltage.

The different initial transmittance when low voltage is applied, we considered causes of phase retardation as shown in Table 3. The light transmittance (T) of the crossed polarizer can be written as

\[ T = \frac{1}{2} \cdot \sin^2(2\phi) \cdot \sin^2(\delta/2) \]  

(1)

Where \( \phi \) are the angle between the long axis of liquid crystal molecules and the transmission axis of polarizer. \( \delta \) is exact indicated as the phase retardation. When the transmission axis was set at an angle of 45°, can be achieved the brightest state. For the above reasons, transmittance (T) is proportional to phase retardation. In the calculation with eq. (1), The transmittance of OCB cell before and after atmospheric pressure plasma treatments decrease as follows: Td > Te > Tc > Tb > Ta. The results are the same with the different initial transmittance of V–T curves. Furthermore, the data of pretilt angle are nearly the same before and after atmospheric pressure plasma treatments. Therefore, we infer that it would be partial high pre-tilt angle after atmospheric pressure plasma treatments.

### Table 3: Values of datum used in analysis for the relationship between transmittance and phase retardation of V–T curves

<table>
<thead>
<tr>
<th>Sample</th>
<th>Control (a)</th>
<th>700mm/s (b)</th>
<th>650mm/s (c)</th>
<th>600mm/s (d)</th>
<th>550mm/s (e)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cell gap</td>
<td>8.4 ( \mu )</td>
<td>8.4 ( \mu )</td>
<td>8.4 ( \mu )</td>
<td>8.5 ( \mu )</td>
<td>8.5 ( \mu )</td>
</tr>
<tr>
<td>Pre-tilt Angle</td>
<td>6.5°</td>
<td>6.5°</td>
<td>6.5°</td>
<td>6.5°</td>
<td>6.5°</td>
</tr>
<tr>
<td>Retardation (( \delta ))</td>
<td>365°</td>
<td>365°</td>
<td>365°</td>
<td>410°</td>
<td>410°</td>
</tr>
<tr>
<td>Response Time</td>
<td>4.7ms</td>
<td>4.6ms</td>
<td>4.9ms</td>
<td>5ms</td>
<td>5.1ms</td>
</tr>
</tbody>
</table>

5. Conclusions

In this experiment, we successful induced the partial liquid crystal arrangement irregularity and increase in the number of transition nucleus sites for shortening the warm-up time by atmospheric pressure plasma beam to bombard PI film. We proved that the number of the bend nucleus of liquid crystal cell has increased more than 6 times and 45%~74% reduction in warm-up time than the control sample. We maintained the original optical properties and response time about 5mS for the OCB mode LCD.

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### References


