22.2: Thermally Stable LC Alignment on Polyimide Films Exposed to UV During Imidization

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Abstract

Polyimide alignment layers have been prepared using "in-situ" exposure to linearly polarized UV (LPUV) light during imidization. Liquid crystal alignment on these layers exhibits higher anchoring strength and thermal stability than the "conventional" UV method that employs LPUV exposure after imidization. The in-situ method requires fewer steps and shorter processing time compared to the conventional method.

Introduction

The most commonly used alignment method in mass production of liquid crystal displays (LCDs) employs rubbed polyimide (PI) films because of their good thermal and chemical stability. However, rubbing causes static charge, dust, or mechanical defects, which reduce production yield, especially of active matrix LCDs. In order to overcome these problems, alignment of LCs by a variety of PI films exposed to linearly polarized UV (LPUV) light has been attempted[1-5]. The photo-alignment method used in these studies allows for an easy control of the alignment direction so those multi-domain devices with improved viewing angle characteristics can be easily produced. However, in all previous studies the LPUV exposure is carried out after imidization of the PAA. The alignment layers prepared with this "conventional" method possess low anchoring energy and poor thermal stability. Evidently, the goal of developing a non-contact method for preparing stable alignment layers has not yet been accomplished.

Here, we report a new non-contact LPUV exposure method for preparing alignment layers with stronger anchoring and higher thermal stability than the layers prepared by the conventional UV method.

In-Situ UV Alignment Method

PI alignment layer are prepared by spin coating the substrate with a solution of polyamic acid (PAA) synthesized by chemical reaction between tetracarboxylic dianhydride and diamines. These films are first soft baked to evaporate the solvent used in spin coating. Then, they are hard backed, i.e., baked at elevated temperatures. During the hard bake, the precursor PAA film undergoes imidization forming PI. In the conventional method, the PI film is exposed to LPUV at room temperature. Thus exposed films align LC along the direction perpendicular to the electric field of LPUV.

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In the in-situ method, the PAA film is exposed to LPUV during thermal imidization (or hard bake). Fig. 1 schematically shows the experimental setup. A collimated beam of UV light from a Xe lamp is polarized using an Oriel UV sheet polarizer. The intensity of the polarized UV light is approximately 6 mW/cm^2 at the film's surface. The PI/PAA coated substrate is placed on hot plate or inside an oven with UV transparent windows for simultaneous thermal imidization. We have tested this method on a number of commercially available PIs such as Nissan SE 610, 7311, and 7511; and found it to work well for all of them.

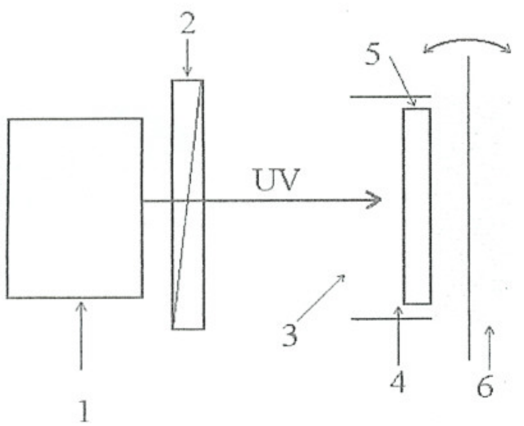

Fig. 1 Schematic experimental setup: 1. UV source, 2: UV polarizer, 3. UV-transparent window, 4. PI/PAA film, 5. Glass substrate, and 6. Hot plate

Results and Discussion

The optical anisotropy of a film prepared with the in-situ method is shown along with that of conventional film for comparison in Fig.2. Both films have the same sign and nearly the same magnitude of the birefringence. This suggests that the polymer chains are aligned perpendicularly to the direction of polarization of LPUV. From FTIR study, we find that, in both methods, the orientation of PI molecules change after LPUV exposure and appears to be primarily due to preferential degradation of PI molecules parallel to the electric field of LPUV. Reorientation of PI chains due to breaking of imide bonds may also be contributing to the optical anisotropy and alignment of LC molecules.

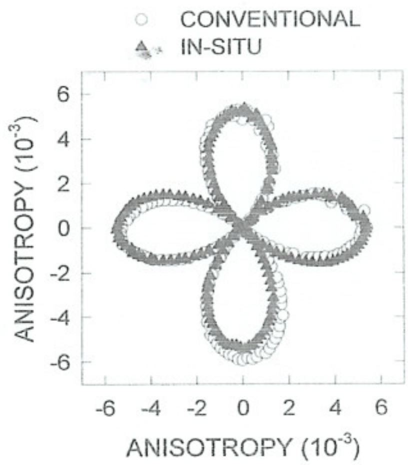

Fig. 2: Optical anisotropy of SE-610 PI films prepared by conventional and in-situ method in polar coordinate

Optical texture of cells filled with a nematic LC and aligned with SE-610 layers prepared using the in-situ and the conventional methods are initially equally uniform. However, thermal stability of the cell prepared with the in-situ method becomes evident upon annealing at 100°C for 12 hours. Textures of the conventional and the in-situ cells are shown in Fig. 3. While the cell prepared with conventional method shows schlieren texture indicating a loss of alignment [Fig. 3(a)], no degradation is observed in the cell prepared with the in-situ method [Fig. 3(b)]. Even when annealed at an elevated temperature of 150°C for 12 hours, only a slight degradation of the alignment is observed in the in-situ sample. These results establish clear superiority of the in-situ method over the conventional method in yielding very stable alignment layers.

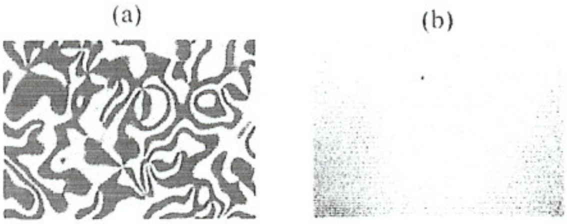

Fig. 3: Optical textures of a nematic LC in cells prepared with SE-610 using the (a) conventional and (b) in-situ method and after annealing at 100°C for 12 hours.

Table I provides a comparison of thermal stability of alignment layers prepared by the rubbing method and the two LPUV methods. The stability was studied by annealing the substrates with alignment layers at 100°C for different duration's. Two Pis, namely SE 7311 and 7511 were used in this study. Clearly and expected, rubbing produces the most stable alignment layers. However, for both PIs, thermal stability of the film prepared with the in-situ method is higher than by the conventional method.

Higher stability of the alignment layers prepared with the in-situ method is due to several factors. In the conventional method, LPUV exposure breaks chemical bonds at room temperature, which caused changes in the length of polymer chains. Normally, these chains would prefer to change their conformation and orientation. However, in the crystalline state they are not free to reorient. Consequently, there is significant strain energy stored in such films. But, in the in-situ method, these chemical changes take place at elevated temperature and before imidization is complete. Various chemical units including the polymer chains are relatively

Table I. Thermal stability for different alignment layers

PI	Method	Annealing Time (Hrs) at 100°C				
		0	24	48	72	96
7311	Rubbing	O	O	O	O	O
	Conventional	O	O	O	×	×
	In-Situ	O	O	O	O	×
7511	Rubbing	O	O	O	O	×
	Conventional	O	O	×	×	×
	In-Situ	O	O	O	×	×

O : Uniform alignment texture
× : Appearance of disclination line or micro-domain

mobile and free to reorient, and consequently are devoid of any stored strain energy when they are cooled to room temperature. Hence, the resulting alignment films are highly stable.

To prepare the most stable in-situ alignment layer, we studied the effect of LPUV exposure time on their thermal stability for SE-7311. LPUV exposure was done at 400W of UV lamp power. The sample cell was annealed at 100°C. Results are summarized in Table II.

Table II. Thermal stability of in-situ alignment layers with different exposure times for SE-7311.

UV Exposure Time (min)	Annealing Time (Hrs) at 100°C						
	0	24	48	72	96	108	132
60	O	O	O	O	×	×	×
50	O	O	O	O	×	×	×
40	O	O	O	O	O	O	×
30	O	O	O	O	O	O	×

Clearly, the in-situ is method holds the promise of producing even more stable alignment layers, when other parameters, such as temperatures of soft- and hard-bake, intensity of UV, and the exposure time have been optimized.

Since, in the in-situ method, LPUV exposure occurs during imidization, the processing time are significantly reduced. Moreover, multi-domain cells can be easily fabricated with this method. Figure 4 shows a cell prepared using two step UV exposure between cross polars. Entire substrate was first exposed to normally incident LPUV for 20 minutes during hard bake. During the second normal exposure of 20 minutes with polarization rotated by 45° with respect to the first, half of the substrate (marked I) was covered by a photo-mask. For region I, the polarization direction of LPUV coincides with the axis of one of the cross polars and minimum transmittance is obtained while region II, with two LPUV exposures appears bright.

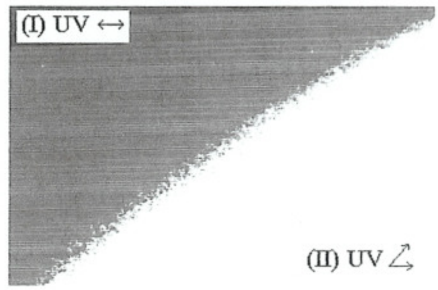

Fig. 4: Nematic (E7) LC textures in a multi-domain cell prepared by the in-situ method. The arrows indicate the direction of polarization.

Conclusions

We have demonstrated a novel method for LC alignment using LPUV exposure during imidization of polyimide. Alignment layers prepared by this method have higher thermal. We note that this method may also be applicable to films of solutions of a cross-linkable resin and a curing agent.

Acknowledgements

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References

1. M. Hasegawa and Y. Taira, Proceedings Int'l Display Reasearch Conference, 213 (1994).
2. J. L. West, X. Wang, Y. Li, and J. R. Kelly, SID Digest **XXVI**, 703 (1995).
3. J.-H. Kim, Y. Shi, S. Kumar, and S.-D. Lee, Appl. Phys. Lett. **71**, 3162 (1997).
4. M. Nishikawa, B. Taheri, and J. L. West, SID Digest **XXIX**, 131 (1998).
5. J. –H. Kim, B. R. Acharya, K. Ha, and S. Kumar, Appl. Phys. Lett. **73**, 3372 (1998).