

Study of Polyimide on Improvement of Crushed Bright Spot Mura on FFS Display

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Abstract

In fringe field switching (FFS) displays, the used polyimides possess no side-trains to guarantee the low pre-tilt (typically 0.2°), and the photolysis type at 254nm linear polarized ultraviolet is in dominant. The photolysis product was removed during follow-up oven process with temperature over 200°C. If the photolysis product remains, it will influence the liquid crystal alignment, the liquid will be disordered around the residue, and caused light leakage in dark state of the panel (L0), which is called crushed bright spot mura.

In this work, we tried to solve the crushed bright spot mura via three efforts. We developed a new polyimide with low molecular weight diamine, optimized the exposure dose of the ultraviolet intensity, and enhanced the baking time and temperature after ultraviolet treatment, which greatly improves the crushed bright spot mura issue in FFS displays. Our work can be a guidance for LCD display industry in polyimide structure design and high reliability panel fabrication.

Author Keywords

Polyimides; LCD displays; diamine; photolysis.

1. Introduction

The polyimide was widely used as alignment film in liquid crystal displays (LCDs) industry^[1,2]. Polyimides possess outstanding features, including the electrical insulation, the high temperature tolerance, and the excellent mechanical properties and easy-processing features. However, in practical LCD industry, much issues were attributed to the invalidation of polyimide films^[3-5]. For example, in the PI pre-oven process, mixed polyimides will phase separates into two layers, and serious image sticking (IS) issue will cause if the phase separation failed. During the pre-oven process, solvents will be pumped out. However, the trace of gas will cause faster evaporation rate of solvents and cause polyimide thickness uneven and further brightness uneven, which is called airflow mura. Much mura including folk mura, foggy mura, rustling mura, et al, were found to strongly linked to the uneven polyimide film fabrication.

In FFS displays, for the purpose of low pre-tilt, the polyimide alignment films possess no side-trains, and two kinds of polyimides were used: contact type rubbing polyimides and non-contact type photo alignment polyimides, mainly photolysis type at 254nm linear polarized ultraviolet^[6]. The non-contact alignment possesses lower pre-tilt (0.2°), high contrast ratio and low L0 brightness. But the removal of photolysis product relies on high temperature evaporation, typically over 200°C, and in some situation, a solvent cleaning and follow-up baking to remove residual solvents was performed. The solvents include de-ion water, lactic acid and methanol, et al. If the photolysis product remains, the liquid crystal alignment was disordered around the residual, which can cause the light leakage, especially obvious in dark state L0. In L0, normal area was darker, and area around photolysis product were brighter, so it was call crushed bright spot mura. Because the product was randomly distributed on polyimide film, the crushed bright spot mura usually was full of the panel.

Herein, we tried to solve the crushed bright spot mura via three efforts. We developed a new polyimide with low molecular weight diamine, optimized the exposure dose of the ultraviolet intensity, and enhanced the baking time and temperature after ultraviolet treatment, which greatly improves the crushed bright spot mura issue in FFS displays.

2. Experiment

2.1 Polyimide structure design

The structures of different polyimides were listed in table 1. Compared to polyimide A, two new structures of diamines were introduced into polyimide B: diamine-C with small molecule weight (<math>< 120 \text{ g/mol}</math>) and diamine-D with biphenyl structure alike to liquid crystal. The DMCBDA was the dianhydride used for polyimide synthesis. Reagents were bought from sigma-aldrich company.

Table 1. Composition of polyimides

Item	Structure	Polyimide A	Polyimide B
		Ratio	
Diamine	Diamine-A	20	30
	Diamine-B	80	30
	Diamine-C	0	20
	Diamine-D	0	20
Dianhydride	DMCBDA	100	100

2.2 Product properties

Appearance of synthesized PAA solutions were shown in Fig. 1. The photolysis PAA was light yellow viscous liquid.



Figure 1. Appearance of synthesized PAA solutions.

Table 2. Properties of PAAs.

Item	Spec.	Result
viscosity	7-8cP	7.3cP
Solvent content	/	NMP 49.5%, BCS 20%, GBL 25%

Solid content 2.5% 2.5%

The properties of PAA were listed in table 2. The CSOT G4.5 inkjet printing machine was brought from Shibaura Lt. Co., and the viscosity limit of is 7-8cP. The viscosity of the PI liquid synthesized by rotational viscosity measurement is 7.3 cP, which meets the viscosity requirements for normal inkjet printing on the machine. The solid content of the solution measured by TGA method is 2.5%. The solvent composition has already been proportioned according to NMP/BCS/GBL=49.5/20/25 during the synthesis of PI, and was double checked by GC-MS.

The UV-vis absorption spectrum was performed on polyimide A and polyimide B. as shown in Fig. 2. The curves were normalized, and the main peak of polyimides was 254nm, implying the strong absorption at 254nm, which was correlated to the decomposition of cyclobutene ring, and it's noticeable that the PAAs possesses nearly no absorption at wavelength over 450nm, indicating the high transmittance in visible light region, which is advantageous to high brightness, high contrast ratio and low color deviation.

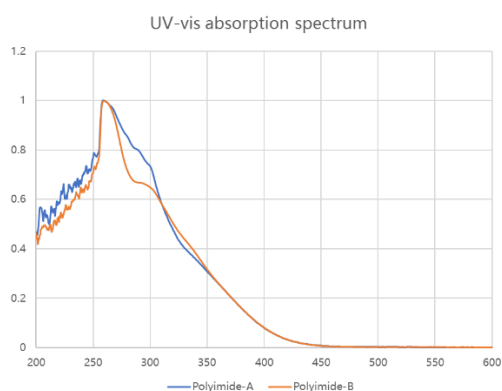


Figure 2. UV-vis absorption spectrum of polyimide A and polyimide B.

3. Results and discussion

3.1 The cell fabrication

The cell fabrication was performed on G4.5 generation production line. As shown in Fig. 2, the glass was first cleaned (BPC), and then the inkjet printing of PAA solution (PIP), followed by pre-oven of PAA (PPO) with 80°C to remove over 80% of the solvents. Then the main cure (PMO) of PAA under 230°C for 20 mins was performed to remove the residual solvents and promote the circularization of PAA to form PI film, with typical thickness dozens of nanometers. After that, a linear polarized ultraviolet light with wavelength of 254nm was used to illuminate the film (PUV), and the exposure dose was typically 200 ~ 1000 mJ. The photolysis product was first removed by de-ion water scour (BOC), and further by a high temperature sublimation under 230°C for 20 mins (PAO). Then the films flow to the one drop filling (ODF) process and finally the cell was fabricated. The test cell size was 5x5 cm and the panel size was 14 inches.

3.2 Improvement via changing polyimide structure

The alignment of liquid can greatly influence the optical performance of cell. The optical performance of cells with polyimide A and polyimide B was listed in table 5. The PUV light were both 500 mJ. It's obvious that the polyimide A possessed high L0 brightness and lower contrast ratio, while the L255 brightness was nearly the same as polyimide B. The OM images revealed that the loss of L0 was mainly attributed to the crushed bright spot,

which was much improved in polyimide B. The result implied that the polyimide structure strongly influenced the optical performance of cell, and by changing the polyimide structure, the crushed bright spot issue and L0 loss phenomenon can be improved.

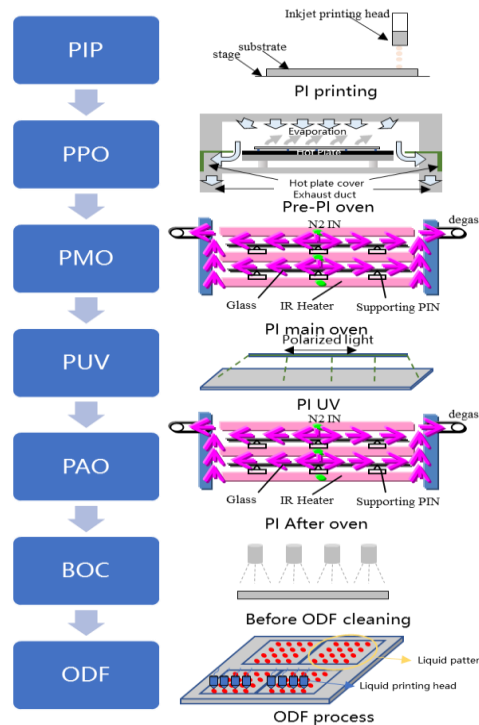
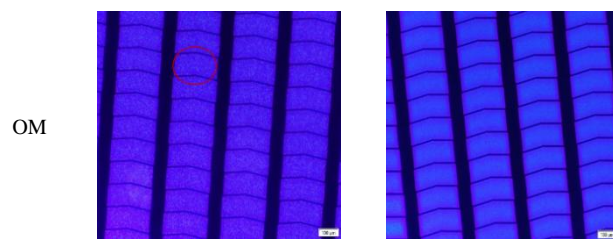


Figure 3. Process flow of cell fabrication on G4.5 generation production line.

Table 3. L0, CR and OM pictures of polyimide A and B (14 inches notebook)

Item	Polyimide A	Polyimide B
CR	1239	1766
L0	0.2547	0.1794
L255	315.57	316.82



3.3 Improvement via PUV exposure dose

Another strategy to solve the crushed bright spot issue was to adjust the PUV exposure dose, considering the issue is originated from the photolysis product. We verified the relation between PUV and optical performance, and the results are shown in Fig. 3. The L0 result was strongly correlated to PUV exposure dose, the higher dose, the heavier light leakage (higher L0), which can be explained by the more photolysis product produced through the photodecomposition process. Therefore, it's useful to reduced the PUV exposure dose to improve the crushed bright spot issue.

However, this will cause a worse image sticking (IS), which should also be taken into consideration.

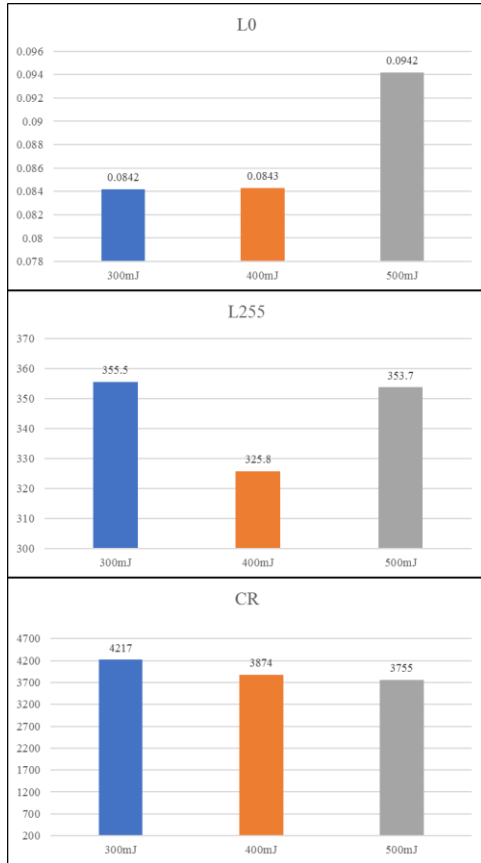


Figure 4. Influence of PUV exposure dose on (a) L0, (b) L255 and (c) contrast ratio.

3.4 Process improvement

The PAO and BOC process in Fig. 3 was thought to useful in removing the photolysis product in PUV. We focused on the time and temperature process changed on PAO process, considering the sublimation of photolysis product was in dominate. The results were listed in Table 4 and Table 5, with different PAO time at 230°C and different PAO temperature for 30 mins, respectively. The results shown that the L0 will improve whether by expending the PAO time or by raising the PAO temperature.

Table 4. L0, CR and OM pictures of polyimide B processed at PAO 230°C with different time

Item	20min	30min	40min
CR	3775	3874	4104
L255	310.1	325.5	302.9
L0	0.0825	0.0841	0.0728

Table 5. L0, CR and OM pictures of polyimide B processed at different PAO temperature with 30mins

Item	230°C	240°C
CR	3874	4422

L255	325.5	366.35
L0	0.0841	0.0829

4. Mechanism discussion

The improvement of crushed bright spot mura was linked to the mechanism of its origin. As shown in Fig. 5(a), the 254nm LPUV light will introduce anisotropic polyimide film in plane, and the photolysis product will be sublimation and removed in the PAO process. The mechanism of improvement of polyimide structure and PAO was illustrated in Fig. 5(b), the polyimide segment of photolysis was composed of DMCBDA and diamine. One strategy is to reduce the molecular weight of diamine (polyimide A → polyimide B), which will reduce the sublimation temperature of photolysis product, and make it easier to remove. Another strategy was to increase the PAO temperature and expand the PAO time to remove it out. The results in section 3.2 and section 3.4 proved the strategy to be useful.

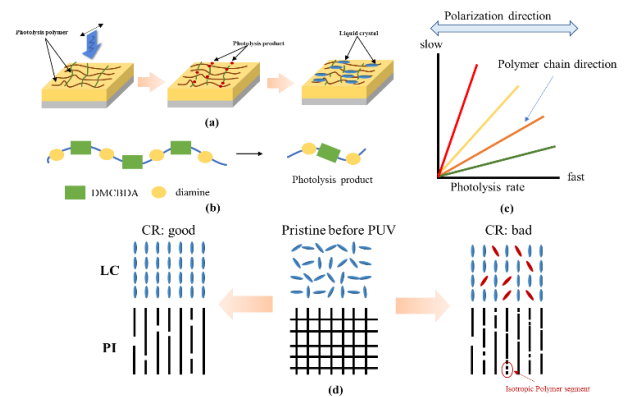


Figure 5. (a) diagram illustration of polyimide chain photolysis reaction and liquid alignment after the radiation of linear polarized ultraviolet light; (b) The photolysis rate of polyimide chain in different polarization direction and (c) good contrast ratio and bad contrast ratio originated from different exposure dose

The illustration of exposure dose on polyimide contrast ratio was shown in Fig. 5(c) and Fig. 5(d). The extinction ratio was defined to be the ratio of polarization degree in two orthogonal directions, and a ideal LPUV light has infinite extinction ratio, which was limited by the equipment fabrication and usually 50:1 ~ 100:1. This implied that along the direction perpendicular to polarization direction also have photolysis of DMCBDA, and the photolysis rate in different direction was shown in Fig. 5(c). And for the same reason, the exposure dose will greatly influence the contrast ratio. In Fig. 5(d), the pristine polyimide film before PUV was isotropic, with no liquid alignment ability, and with appropriate exposure dose, the polyimide chains along the polarization direction were photodecomposed, and the chains perpendicular to polarization direction were slightly photocomposed. That realized a good alignment of liquid crystal, and can achieve good contrast ratio. If the exposure dose further increases, the chains in perpendicular direction will further photocomposed, and some isotropic polyimide segments will appear. The isotropic segments possess weak liquid crystal alignment ability, and the liquid will be disordered in this area, causing the light leakage and crushed bright spot mura. This can explain the L0 results change with different exposure dose in Fig. 4(b).

5. Panel fabrication

Using the polyimide B in table 1, we also fabricated 14 inches notebook in G4.5 generation production line, the picture and performance was shown in Fig. 6 and table 6.



Figure 6. 14 inches notebook fabricated in G4.5 using polyimide B.

Table 6. Optical performance of 14 inches notebook

Item	Unit	Polyimide B
L255	cd/m ²	316.8
L0	cd/m ²	0.1794
CR	/	1766
Tr	%	6.52
RT (Ton+Toff)	ms	26.086
Gamma	/	2.18

6. Conclusion

In this work, we focused on crushed bright spot mura caused by the photolysis polyimide used in FFS panel. We improved the issue via three strategies, from the polyimide structure design perspective, we introduced diamine with lower molecular weight, which will produce photolysis product easier to sublimate. And from the process perspective, we changed the PAO temperature and time to sublimate the photolysis product out. From the liquid alignment perspective, we optimized the exposure dose to avoid overexposure, which can cause polyimide segments without alignment ability and resulted to liquid crystal disordered. Our work can be an effective solution to solve the bright spot mura caused by photolysis product in FFS panel.

7. Reference

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