

Peelable Inkjet Protective Film Process Development for MicroLED

Jongduk Roh, Myungkoo Hur and Jongmoo Huh
Samsung Display, Korea

Abstract

The research task of this paper is the development of an inkjet thin film process that protects the front and rear stacking layers during the 80 inch or larger Micro LED TV manufacturing process by the Tiling modulus of the IT size panel (cell). During the LTPS FAB manufacturing process, the inkjet protective film must be transparent for intermediate inspection and must have vacuum resistance (No Outgasing) / chemical resistance required for processes such as dry etching or wet etching to remove the sacrificial layer. In addition, it should be possible to form a patterning film that prints only the necessary area so that there is no interference in the process such as vacuum chuck, logistics roller, and glass cell cutting. In order to satisfy these requirements, we first built a multi-head monomer inkjet and infrastructure as a stage-compatible facility that can respond to original size and UV Insitu. By splitting the separation distance between the temporary curing unit and the inkjet head (temporary curing waiting time/tuning the overlapping part of the head), the adhesion precision and edge thickness distribution were improved. Through component (Binder/monomers/additives) tuning, it was confirmed that peeling force < 20gf/inch (thickness fixed at 100~150um) proceeded without tearing from initial peeling to main peeling. In addition, in order to secure resistance to FAB progress, the process was verified by reducing the amount of He flow during the dry etching process and adding additives to prevent peel off during the wet etching process. there was no the peel force distribution of the inkjet sample, which is currently developed for mass production, is $\pm 10\%$ gf/inch, which is superior to that of general films $\pm 20\%$. However, the current modulus and elongation need to be further improved in order to lower the thickness to reduce inkjet chemical cost.

Author Keywords

Inkjet Protective Film, Coating precision, Peelable film property verification, Coating thickness

1. Introduction

Recently, Samsung Electronics started the premium TV business of 100 inches or larger, and competitors are also competing with each other to launch prototypes. It has excellent technical characteristics to replace LCD and OLED, which are currently technologically complete, but productivity is still insufficient. Samsung Display is also developing a process for mass production by creating a related organization recently. As shown in Figure 1, Tiling technology is applied to make the small IT size into an extra-large size with the goal of supplying panels to Samsung Electronics. Although the wiring handed over to the image quality area was laminated in the Dead Space, the dead sapce was reduced by tiling technology. Back plane layer is laminated not only on the front side but also on the back side, so there must be a film that protects the front side and the back side during the production process or handing over to the customer.



Figure 1. Micro LED Panel manufactured by Samsung Display

As shown in Figure 2, Since the driving circuit layer is stacked on the front and back of the substrate, a protective film is required in the outer region of the panel during the manufacturing process and must be peelable for subsequent processes. This paper is a development of a protective film process for a substrate by applying inkjet patterning for the above purpose.

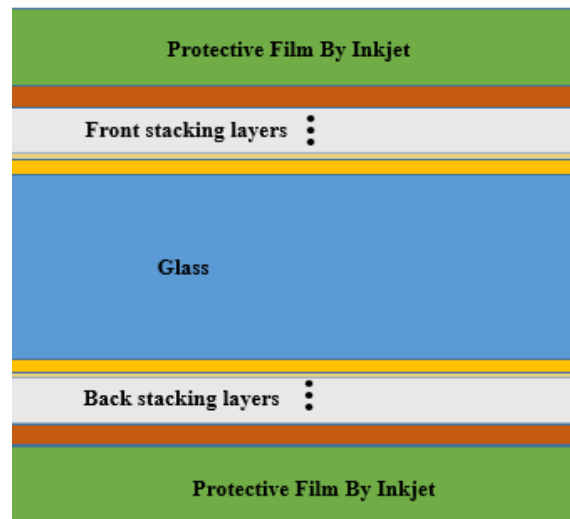


Figure 2. Schematic diagram of Samsung Display Micro LED front/rear stacking

2. Experimental equipment design

In Figure 2, the front stacking layers is performed first during the u-LED substrate FAB manufacturing process. Afterwards, in order to proceed with the rear stacking layers, it is inevitably necessary

to additionally proceed with the sacrificial layer on the front side. This is because, when the substrate is inverted, the entire surface may be scratched or a foreign material defect may occur. However, since the sacrificial layer must be removed again, an additional protective layer is required on the back side. In addition, Films attached in the dry process do not have vacuum resistance (No Outgasing) / Chemical resistance (No Peel Off) that require processes such as Dry Etch or Wet Etch, and pattern lamination is impossible. That is why we decided to develop a method for printing the required area by inkjet (as shown in Figure 3) and securing vacuum resistance/chemical resistance.

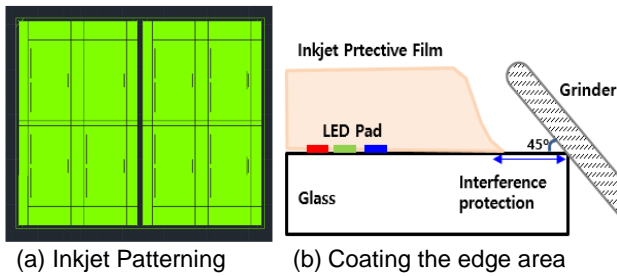


Figure 3. Protective film pattern shape of FAB mother substrate(a), Vertical schematic diagram of panel edge (b)

As a stage-compatible facility that can handle large area mother glass size, three liquid chemical-based inkjet heads are sequentially configured as Multi-Heads as shown in Figure 4 to secure an effective scan width of the panel.

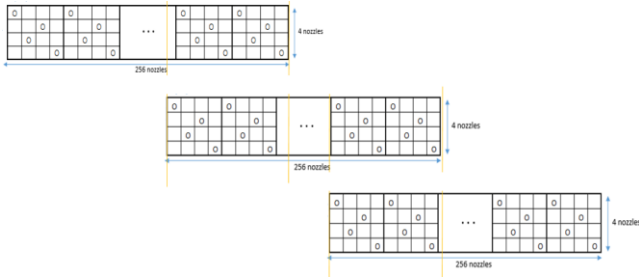
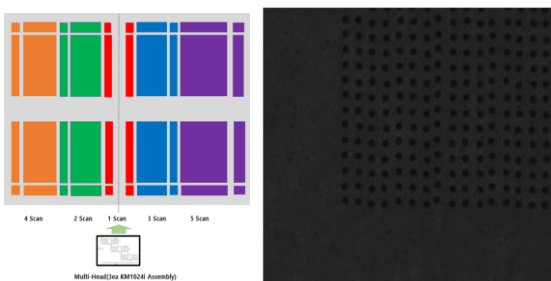


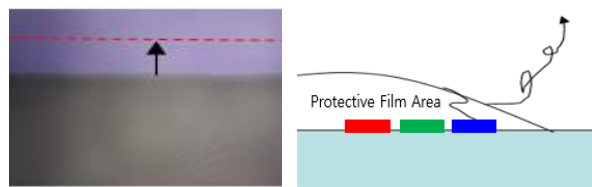
Figure 4. Multi Inkjet Head Configuration

It is a margin that can print the short length of the Micro LED panel (Cell) at once, and the total number of scans of the original plate requires 5 Jig-Zag processing as shown in Figure 5. (a), and 50~100um thickness can be printed. As shown in Figure 5. (b), the uniformity of the Jetting Dot Map can be checked with the precise setting of the device.



(a) Printing sequence (b) Inkjet dotting uniformity
Figure 5. Inkjet dotting map verification

In addition to the inkjet head configuration, there are a UV pre-curing unit, a UV main curing unit, and a plasma processing device that operate in conjunction. In particular, in the setup of the experimental equipment, UV pre-curing is performed before the main curing in order to increase the panel attachment precision of the protective film. The curing rate is less than 10%, and the reason is to prevent the spread due to the time delay until the main curing. In other words, it is to form a temporary wall by temporary curing immediately after the inkjet process to improve the panel attachment precision. However, when the UV curing power was raised to specified amount of energy or more to control the adhesion precision to the extreme, the inkjet edge cracked and overflowed as shown in Figure 6. So UV Insitu. Power must be managed within a specified range.



(a) Overflow area (b) Bad peeling quality
Figure 6. Edge part overflow due to UV strong Pre-curing

3. Experiments

3.1. Coating precision

The dispersion of adhesion precision by inkjet is more than 100um due to equipment alignment precision, spread after inkjet dotting, which is a low-viscosity device, and curvature of the panel surface. However, the distance from the wheel cut mark to the electrode of the LED panel must be less than 100um because tiling technology must be applied in the design of the Micro LED panel. Therefore, coating precision management is most important. So, as shown in Figure 7, the four corners of the panel and the center of each side (L, T, R, B) linearity quality defense line measurement standards were established.

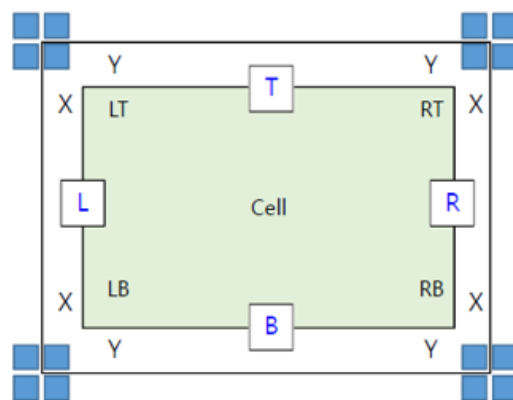


Figure 7. coating precision measure points

In particular, the central linearity management of each side as shown in Figure 7 should not exceed 100um in the (Max-Min) value in the sampling section (3mm, within the camera FOV). In Table 1., it is proved that the error is managed with $500 \pm 100\text{um}$ as the result value. In the future, we will establish an abnormal system through intelligent numerical management (AI).

Table 1. Four corner measure result
(Target: X 500um, Y 500um)

	Rep. (times)	Position	Max X (um)	Max Y (um)	Min X (um)	Min Y (um)
Front	4	LT	550	563	465	422
		RT	507	516	490	422
		LB	548	562	476	477
		RB	579	522	447	480
Back	4	LT	569	528	494	467
		RT	550	531	500	463
		LB	543	508	477	455
		RB	535	528	498	490

However, as shown in Figure 8, the current process capability has a defect that does not protect the LED of the outer portion of the substrate. To improve this, the contact angle of the inkjet chemical solution was raised by designing the outer structure of the substrate in an intaglio shape. Through this, it is possible to protect the vulnerable outer LED from external exposure.

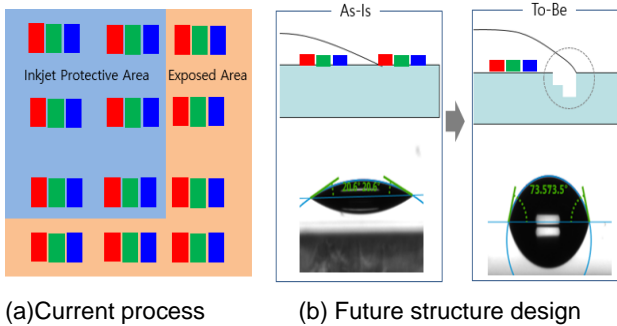


Figure 8. coating precision control of the outer part

3.2. Peelable film property verification

The inkjet protective film developed by us must be peeled off when handing over to the customer, and the peeling residue must not remain on the panel. Adhesion, modulus, elongation, etc. are key factors for tuning such inkjet materials. As a result, success/failure can be known through the peel test, so test the peel force first as shown in Figure 9. As a result of the experiment, the peeling force < 20gf/inch (thickness fixed at 100~150um) proceeded without tearing from the initial peeling to the main

peeling. The peel force distribution of the inkjet sample, which is currently developed and applied for mass production, is $\pm 10\%$ gf/inch, which is superior to that of general films $\pm 20\%$. However, the current modulus and elongation need to be further improved to lower the thickness to reduce inkjet chemical costs.

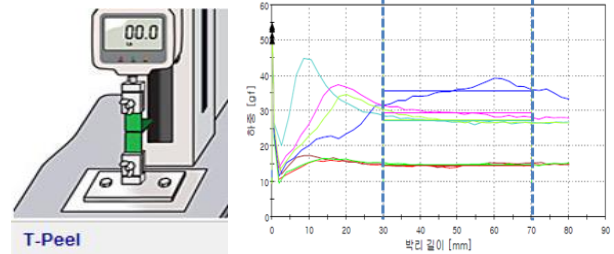
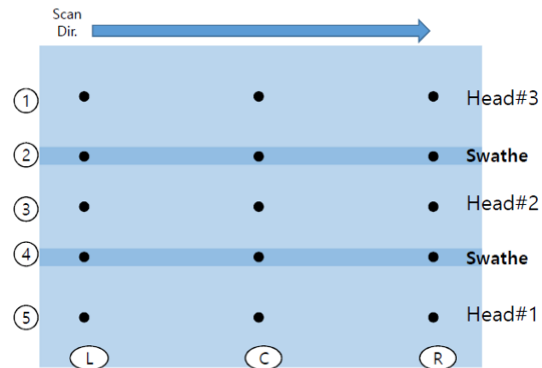


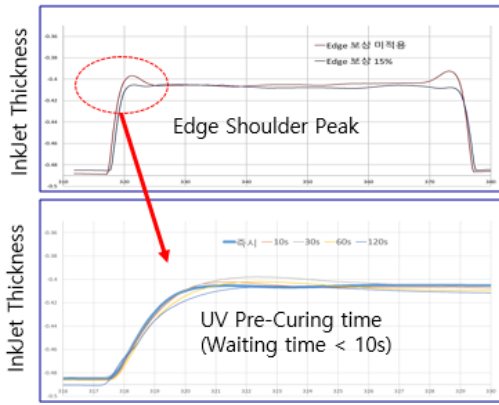
Figure 9. Peel force measurement experiment

3.3. Coating thickness

Inkjet protective film thickness distribution is $\pm 10\%$ compared to $\pm 5\%$ of general films, and the quality is inferior. The main causes are the thickness difference in the head overlap and the shoulder peak in the edge part. First, the thickness step (SWATH Mura) of overlapping heads was solved through fine adjustment of overlap ratio between heads. Second, as shown in Figure 10, for the thickness step of the shoulder peak at the edge, split evaluation was performed such as 0~5s, 5~10s, 10~20s, 20~30s for UV curing waiting time (UV curing waiting time after inkjet jetting). As a result, ①0~5s condition is $150\text{um} \pm 10\%$ of thickness, ②5~10s condition is $150\text{um} \pm 7\%$ of thickness, ③10~20s condition overflows the adhesion accuracy $\pm 100\text{um}$, ④20~30s condition also exceeds the adhesion accuracy $\pm 100\text{um}$ overflow is observed. Therefore, the distance between the inkjet head and UV curing was set so that the optimum UV curing waiting time was 5 to 10s.



(a) Measure points



(b) Measure results

Figure 10. Edge part thickness improvement experiment

3.4. FAB process tolerance

Fab process resistance Micro LED inkjet protective film must be strong against FAB resistance and water washing pressure to supplement the impossible areas of general films. In this respect, as a result of each company's inkjet material tuning, company D was selected in Table 2.

Table 2. FAB process resistance evaluation result of inkjet protective film

FAB Process	Water Jet	Dry Etch	Wet Etch	Problem
Company A	OK	OK	NG	Etchant Peel Off
	OK	OK	NG	Etchant Peel Off
Company B	NG	OK	OK	WaterJet Pressure↓
	OK	OK	OK	OK

4. CONCLUSION

The research task of this paper is the development of an inkjet thin film process that protects the front and rear stacking layers during the 80 inch or larger Micro LED TV manufacturing process by the Tiling modulus of the IT size panel (cell). During the LTPS FAB manufacturing process, the inkjet protective film must be transparent for intermediate inspection and must have vacuum resistance (No Outgasing) / chemical resistance required for processes such as dry etching or wet etching to remove the sacrificial layer. In addition, it should be possible to form a patterning film that prints only the necessary area so that there is no interference in the process such as vacuum chuck, logistics roller, and glass cell cutting. In order to satisfy these requirements, we first built a multi-head monomer inkjet and infrastructure as a stage-compatible facility that can respond to original size and UV Insitu. By splitting the separation distance between the temporary curing unit and the inkjet head (temporary curing waiting time/tuning the overlapping part of the head), the adhesion

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