Reducing AMOLED Manufacturing Costs

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Abstract
Announcements by many companies have shown that market interest and technical potential exist for AMOLEDs. DuPont Displays is developing solution processing technology designed to address the high cost of manufacturing AMOLEDs via vapor deposition methods. By printing OLED displays, we can reduce costs and can subsequently scale OLED manufacturing to a competitive motherglass size.

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1. Introduction
Full color active matrix OLED displays are in the commercial arena now, and continue to delight customers with their image quality, form factor, and power consumption. However, the cost of manufacturing AMOLEDs by the current commercial method of vapor deposition is prohibitively high. In order to fully realize the potential of AMOLEDs, manufacturing methods must be developed for large glass sizes that result in a significant cost advantage compared to the alternate technology of LCD. DuPont Displays has focused on addressing high manufacturing costs of AMOLEDs by developing a solution patterning process that provides tremendous benefits compared to vapor deposition of OLED materials through shadow masks. [1]

DuPont Displays has developed a solution processing method based on small molecule emitter materials which preserves the good lifetimes obtained via vapor deposition while delivering cost and scaling advantages.

2. Results and Discussion
Description of DuPont Displays OLED Process. The cost advantage of the DuPont process results from blanket, or continuous, solution processing of as many OLED layers as possible and patterning the emissive layer by printing with a nozzle printer, made by Screen. We have found the nozzle printing method to be much more robust and high yielding than the more commonly employed ink jet printing method. The DuPont process is depicted schematically in Figure 1.

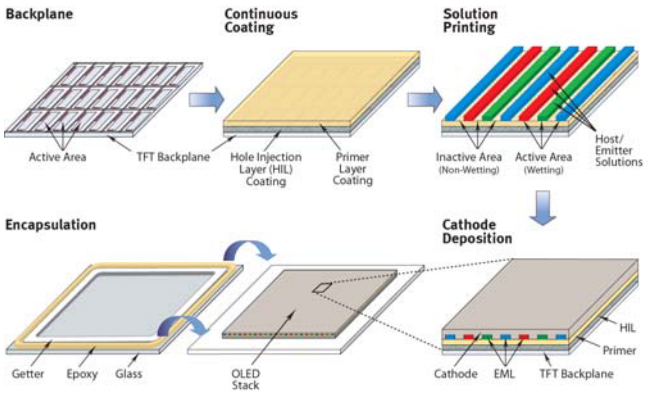

Figure 1. Sequence of steps in DuPont Displays Solution Process method.

HIL and HTL layers are first deposited sequentially via slot die coating onto an active matrix backplane. Slot die coating is used because it produces minimal waste and is scalable up to gen 8 glass size. Adapting slot die coating, which is already used in the manufacture of flat panel displays, shortens the development time by taking advantage of existing expertise and equipment. Our results show that slot die coating technology can produce high quality conformal thin films over a variety of OLED passive and active matrix backplanes. The DuPont™ HTL is formulated to incorporate wetting and non wetting areas on the surface, which serve to contain the emissive layer inks in their respective locations during ink application and subsequent drying. This methodology does not require any physical containment features (banks or wells) on the substrate, although if present they can easily be accommodated.

The RGB pixels are coated with a nozzle coater. DuPont and Screen recently announced a strategic alliance for the development of OLED coating/printing equipment. The two companies have been working together for some time to combine DuPont solution small molecule materials and Screen nozzle printing. The first production scale printer (Gen 4 glass size, 730 x 920mm) has been constructed at DNS, and is now being shipped to Santa Barbara.

In nozzle printing, the pixels are filled by continuously extruding solution from small diameter nozzles moving at high speeds, as illustrated in Figure 2.

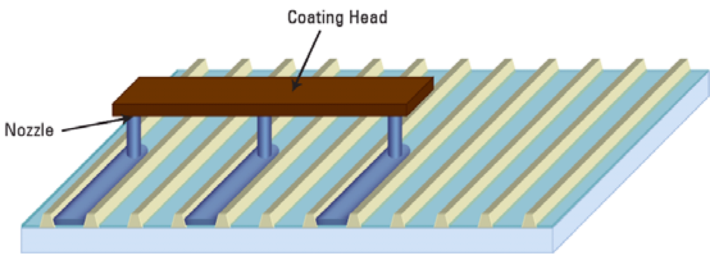

Figure 2. Schematic of Nozzle Printing Process.

Performance of a Nozzle Printed OLED Device. Emissive layer thickness uniformity is critical to OLED device performance. A common issue seen with solution printed displays is a region of thicker EML at the edges of the printed line, due to drying effects known as "coffee ringing". [2] A thicker EML at the edge of a pixel will not emit light. Through our ink containment process and ink formulation we are able to routinely obtain very flat films with high effective aperture ratios. (Figure 3).

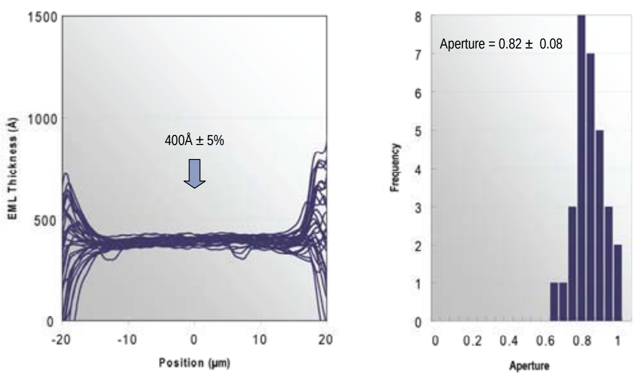

Figure 3. Optical profilometer traces of dried EML film printed using nozzle coating. The traces come from 32 measurements on a single AM panel.

(The aperture in Figure 3 is defined as the number of scan points at +/-10% of local scan minimum.) Another indication of the flatness of the EML in the active area may be seen by looking at Figure 4. PL and EL pictures of the same display were obtained, and overlaid to show that the printed lane is emitting light uniformly across the line, to the edge of the line, as evidenced by equal width EL and PL lane images.

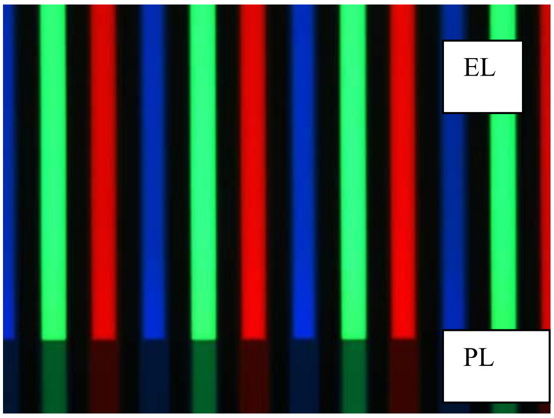

Figure 4. PL+EL Close-up of full color printing

A key technical challenge with solution printed displays is the appearance of periodic brighter or dimmer lines in the display, known as "stitching" or "swath" effects. The stitching effect can be attributed to the fact that lines deposited by interior nozzles on the multinozzle head will experience a different rate of drying than the outermost lines. Through control of formulation and the printing process, we have demonstrated stitch-free displays on the Gen 4 multinozzle coater (Figure 5)

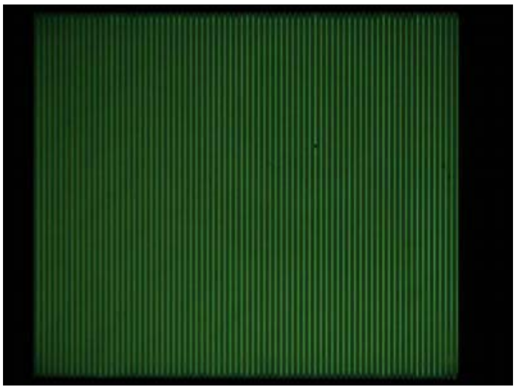

Figure 5. Stitch-free monochrome display printed with Gen 4 multinozzle printer.

DuPont OLED Materials Performance. A solution processed OLED device requires multiple, distinct layers with well-defined interfaces. The engineering of materials so that the solution being coated does not dissolve underlying layers is a complex task. Our technology has largely overcome the challenges inherent in this task, so that the best printed efficiencies and lifetimes we have achieved are suitable for most portable display applications. Data are shown in Figure 6 for printed test coupons made using the DuPont solution process. Lifetimes are defined as 50% of the initial R, G, and B luminance required to achieve 200 nit front of screen at 30% duty cycle with polarizer and 40% aperture ratio from the active matrix backplane.

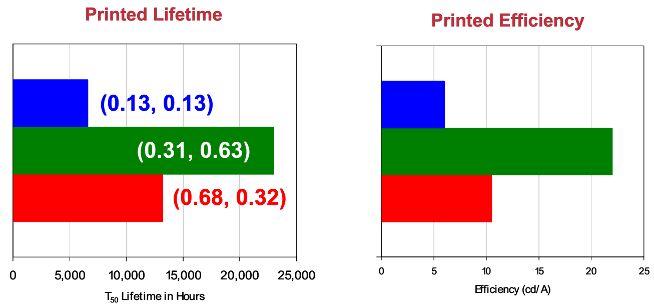

Figure 6. Printed Test Coupon Performance

We continue to work on lifetimes improvements to enable stationary applications such as OLED TV.

Reducing Manufacturing Cost. An analysis of manufacturing costs shows that solution OLEDs are significantly cost advantaged over OLEDs made using standard vapor deposition patterning. The advantages come from the more efficient material usage in solution OLED processes (Figure 7) as well as the higher capital productivity. Use of a patterned evaporated layer adds about 2.5-3x over the cost of a printed or coated layer. A ½ cut Gen 4 solution line will have approximately 3x the volume of an equivalent vapor deposition line. There is also a significant cost advantage over LCD, particularly as the motherglass and display sizes increase.

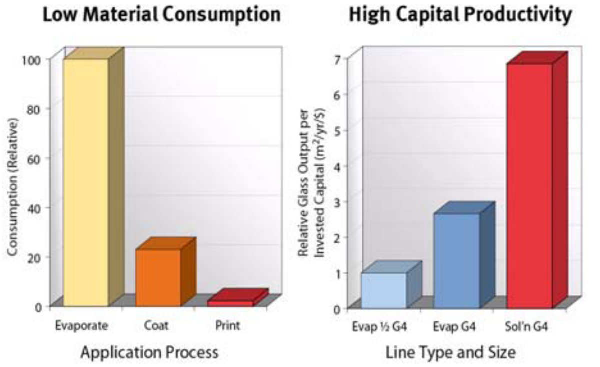

Figure 7. Solution OLED uses less material and more efficient equipment than Vapor Deposition OLED

3. Summary

DuPont Displays has developed solution processing technology to address the high cost of manufacturing AMOLEDs via vapor-deposition methods. We have developed a set of full color solution processible OLED materials with good printed performance. By printing OLED displays, we can reduce costs and can subsequently scale OLED manufacturing to a competitive motherglass size.

4. Acknowledgments

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5. References

1. W. F. Feehery, SID '07 Technical Digest, Vol **38**, p1834 (2007).
2. R.D. Deegan, Phys. Rev. E, 2000, 61, 475.