Solution Processing of Small Molecule OLED Materials at DuPont Displays

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Abstract
DuPont Displays has developed a new solution printing fabrication process for OLED displays, using small molecule OLED materials. The new manufacturing process is more cost-effective and scalable than evaporation of materials through physical masks, and addresses issues associated with ink jet printing. A new material (DB) has been developed for use as a hole-injection layer in OLEDs.

1. Introduction
Solution processing of OLED materials to fabricate displays has long been viewed as desirable from a cost and efficiency point of view, but polymer OLED materials (PLED) still require more development to achieve the performance needed for AMOLED. On the other hand, small molecule materials (SMOLED) have adequate performance for commercial AMOLED applications. However, the standard method of fabrication of OLED displays containing SMOLED materials, by vapor deposition of the materials through a series of physical shadow masks has drawbacks that impact cost and yield of the manufacturing process. For instance, the vapor deposition process has not yet been scaled to large size glass. Shadow masks are expensive, require frequent cleaning and have a limited lifetime. Many mask alignment steps must be carried out to build multi-layer OLED structures. There is very low utilization (approximately 5%) of expensive OLED materials, and repeated contact of the shadow masks with the substrate can cause yield loss.

To address these issues, DuPont Displays has developed a solution printing process that allows the solution printing of SMOLED materials, thereby combining the advantages of solution processing with the performance of SMOLED materials. At the same time, we have focused on limiting expensive manufacturing process steps such as patterning, photolithography and vacuum deposition whenever possible.

2. Results
We have developed a process that is substantially lower cost than either LCD or OLEDs made by evaporative methods. The hole injection layer (HIL) in all our devices is DuPont Buffer (DB) and it is blanket coated over the TFT backplane substrate, as is the primer layer. The primer layer serves a dual function: it has hole transporting properties, and can be formed into wetting and non-wetting areas. The HIL and HTL materials are also tailored to prevent cross-talk between pixels. Blanket coating the first two layers in the OLED device allows us to take advantage of standard, high yield coating processes. The tunable wetting characteristics of the primer layer allow precise placement of red, green and blue emitters without any physical containment structures such as photoresist banks.

Elimination of the containment structures [1] traditionally used in solution patterning processes such as ink jet printing results in significant cost savings, and enables flat OLED films.

We have built cost models of the DuPont Solution Process and compared the output to the cost of manufacturing OLEDs by evaporation, as well as the cost of manufacturing TFT LCDs. Figure 1 shows a comparison of costs for a 15.4" diagonal display, built in a Generation 5 facility.

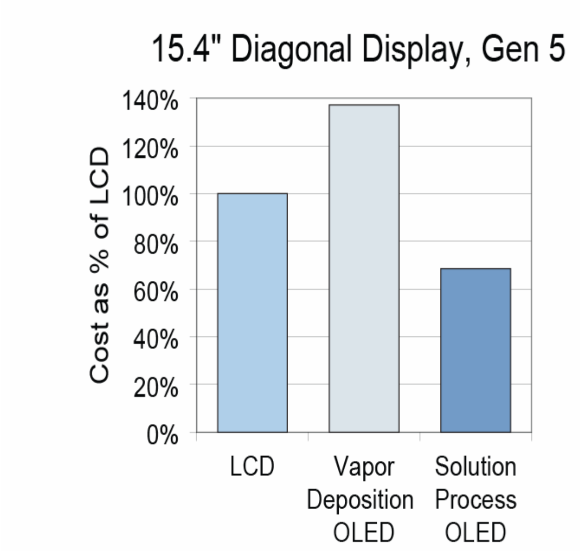

Figure 1. Comparison of costs for a 15.4" diagonal display built in a Generation 5 facility.

The cost model conservatively assumes higher costs for OLEDs relative to LCDs. For example, OLED-TFT substrates and drivers are assumed to be significantly higher cost than their LCD counterparts. Also, 10-20% lower yields are assumed for OLED versus LCD in the beginning. Even with these assumptions, the solution processed OLEDs are about 30% cheaper to produce than the equivalent LCDs. Should the assumptions be overly conservative, there will be even more cost advantage for OLEDs produced by the DuPont Solution Process.

The performance of OLEDs produced by our solution processing method is very good. Figure 2 shows the luminance and power efficiency of a red solution processed small molecule OLED device. The CIE coordinates of the red device are (0.66, 0.33).

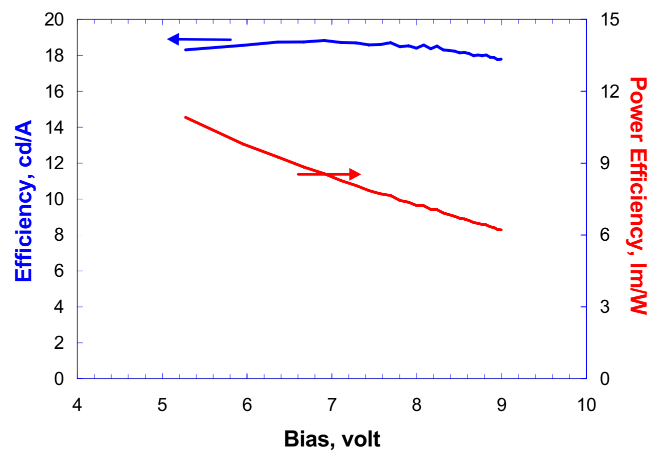

Figure 2. Efficiency (cd/A) and power efficiency (lm/W) for a red solution processed small molecule OLED test coupon device.

Figure 3 shows the lifetime curve for the same red device, tested at 2,000 nits. T50 is projected to be more than 8,000 hours at 2,000 nits.

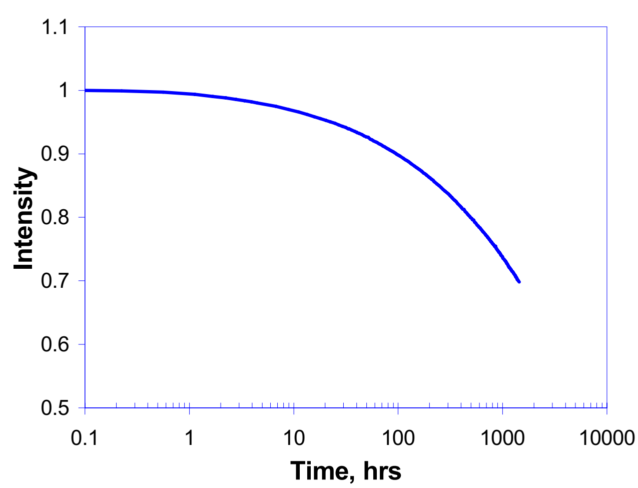

Figure 3. Lifetime curve for a red solution processed small molecule OLED test coupon device, tested at 2,000 nits.

Figure 4 shows the progress achieved in solution processed device lifetime over the last three years.

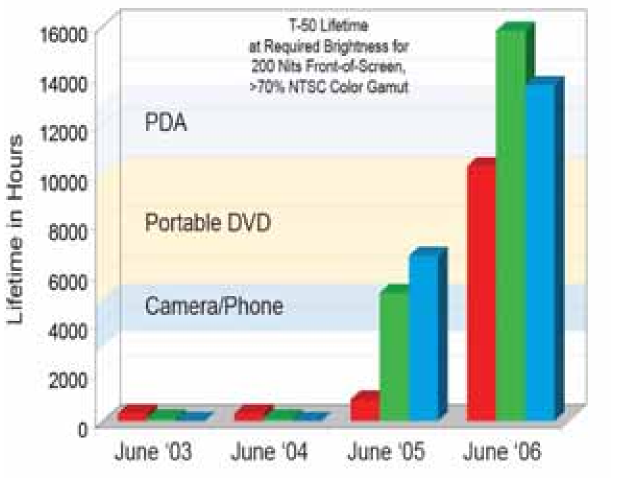

Figure 4. DuPont solution materials lifetime progress.

The data in Figure 4 are taken with test coupons, and assume 40% aperture ratio, active matrix driving conditions and a 55% loss due to the use of a circular polarizer. The time to T50 is shown for red, green and blue running at the subpixel luminances required to achieve 200 nits front of screen brightness. The commercial specifications for some applications are also shown in Figure 4.

3. Conclusion

DuPont has developed unique and inexpensive technology to manufacture an AM-OLED display by solution processing small molecule materials. Solution processing will enable OLEDs to compete broadly with LCDs on a manufacturing cost basis, since our process is more cost effective than LCDs and more cost effective than vapor deposition OLEDs.

4. Acknowledgements

The contributions of all members of the technical teams at DuPont Displays, both in Santa Barbara, CA and Wilmington, DE are gratefully acknowledged.

5. References

[1] S. Miyashita, H. Kiguchi, T. Shimoda, S. Kanbe “Method of Producing organic Eelements, organic EL elements and organic EL display device, EP0880303B1