Low cost, printed P-OLED displays for entry into the flexible display market

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Abstract

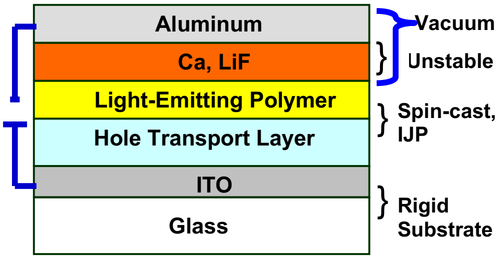
Add-Vision has developed a low-cost print technology for P-OLED displays on flexible substrates that meets several essentials for a new technology including: (1) Functionality including low DC voltage and wide color gamut; (2) Utilization of inexpensive tools; (3) Performance matching entry applications and markets. AVI's process is based on large-area printing of a combination of doped emissive and air-stable cathode inks utilizing truly low-cost tools to create printed P-OLEDs.

1. Introduction

There has been considerable research and development effort invested in demonstrations of the functionality and manufacturing possibilities for organic electronics.[1-2] This has been fueled by the potential for new applications and form-factors, such as flexible emissive displays, which lie outside of what conventional approaches can provide. There is also the enticing assumption that established applications can be served by this new technology at low cost due to new processing routes, such as printing and liquid coating, enabled by organic and nanotechnology-based materials.[3] However, after more than 15 years, large-scale commercialization of this technology is still around the corner. In some cases, commercialization has been hampered by materials and toolset unavailability. However, more fundamental issues have included a mismatch between the performance strengths of organics; the maturity, capability and yields of the manufacturing processes versus the application; and the markets available to proposed organic electronic applications. In this presentation, the author will discuss a promising near-term strategy for commercializing organic electronics with Add-Vision's (AVI) low-cost approach to flexible organic light-emitting displays.

A particularly attractive opportunity for organic electronics commercialization may lie in AVI's technology for low-information content printed polymer organic light-emitting diode (P-OLED) displays. This approach meets several essential requirements for a fundamentally new technologies including: (1) Product functionality that cannot be met by conventional technology such as low-voltage DC operation with a wide color range; (2) The process utilizes existing low capital, high throughput, easily adaptable tools that can be operated at acceptable yield outside of expensive, controlled environments; and (3) The performance of the devices fit requirements for existing, entry-level markets such as point-of-purchase displays, signage, backlighting, identification and military applications.

(a) Conventional P-OLED



(b) Add-Vision Printed P-OLED

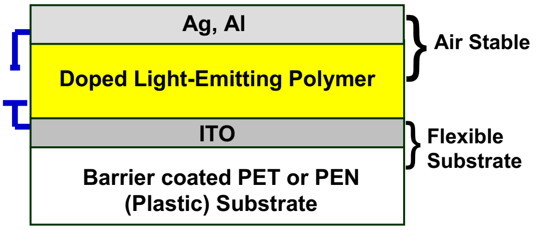


Figure 1. (a) A schematic cross-section of a conventional P-OLED structure with typically ~100 nm thick layers and unstable metal components. (b) AVI's simplified, air-printable doped P-OLED structure.

Add-Vision has developed a low cost fabrication process for P-OLEDs based on screen-printing and patterning of all conductive and emissive materials on low-cost flexible substrates. Printing provides the capability to print over relatively large areas on flexible substrates, at high throughput with low capital and operating costs. In addition to printable emissive layer inks, a core strength of AVI's approach is its utilization of relatively high work-function, air-stable cathode materials matched with the doped LEP layer to achieve air-printable efficient electron-injecting contacts. Most OLED approaches utilize low work-function cathode metals which are inherently unstable, require controlled environment processing, and are often the lifetime-limiter for the devices. The sensitivity of these structures to the ingress of water and oxygen has limited their integration with flexible substrates due to the difficult barrier requirements.

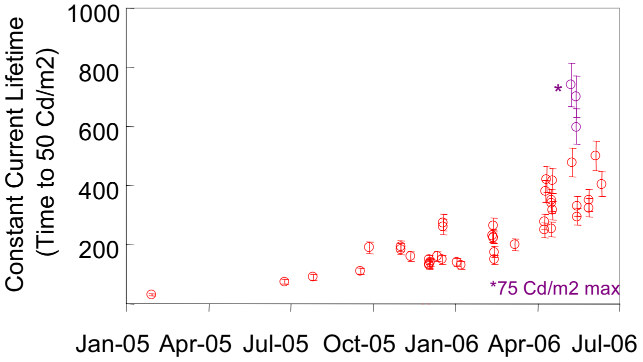


Figure 2: Operating lifetimes (time to 50 Cd/m^2) of air-printed P-OLED devices on flex approaching our 1000 hr constant current goal.

Challenges for Add-Vision's technology include materials availability and preparation, EL uniformity, lifetime and efficiency. However, rapid improvements for light-emitting devices created by AVI's low cost, printed process have been observed over the last year with continuous operating brightness lifetimes approaching our 1000 hr goal for 2006, as shown in Figure 2, and a >3 fold decrease in operating voltage

2. Results

As can be seen in Figure 2, there has been consistent progress in operating lifetime of our devices. This has followed two paths. The first path has involved consistent improvement in quality, processing, ink preparation and formulations based on trials, device data and analysis. The second route has been to explore substantially new cathode, LEP materials, and printing approaches to achieve larger steps in lifetime improvement, operating voltage, EL uniformity and emission color. Both these routes have led to the technology progress in the last year and there are ample and expanding opportunities for the future. An example of the impact of new cathode materials can be seen in Figure 3 which shows the dramatic effect of optimizing cathode ink formulation and solvent system on operating voltage aging. The <24V DC operating voltage performance demonstrated for these devices is very attractive compared to the incumbent, competing technology (printed inorganic thick film phosphor) which typically operates at >80 V AC drive.

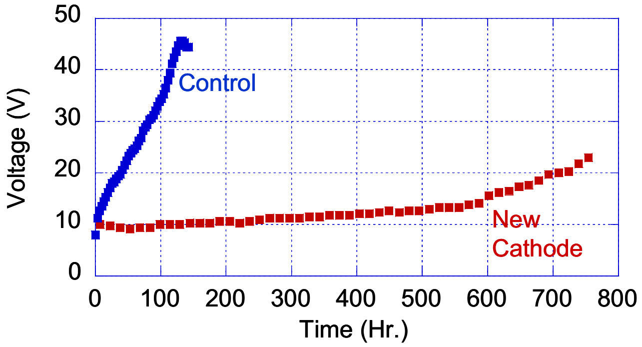


Figure 3. Voltage vs. time curve showing the difference in operating voltage rise during constant current (2ma/cm^2) lifetime testing of control devices vs. a new cathode material with improved formulation. This voltage reduction has direct impact on power efficiency and correlates with brightness lifetime improvements.

Recent performance improvements towards our 1000 hour operating lifetime goal, along with increases in processing throughput, are key to AVI's commercialization plan. Figure 4. charts the serviceable market opportunity for AVI's technology in various entry level markets as a function of operating lifetime. The inflection point occurs between 500 and 1000 hours. This is also the performance range of AVI's current devices. Figure 5. shows operating examples of AVI printed devices as examples of some of the applications and markets shown in Figure 4.

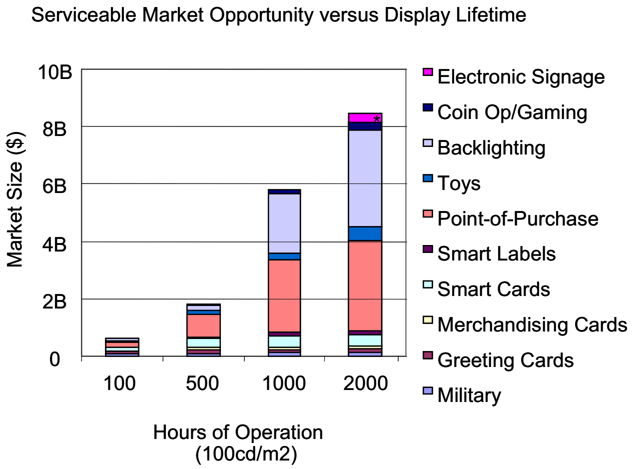


*Figure 4. This graph shows the serviceable market opportunity for AVI's technology as a function of operating lifetime. The inflection point towards 1000 hrs. has defined AVI's lifetime improvement goals. *Note that many Electronic Signage applications require high brightness(>200 Cd/m^2).*

3. Conclusion

Add-Vision's low-cost approach to printed organic electronics commercialization seeks to leverage low-cost printing infrastructure with novel materials technology. By minimizing the barrier to entry usually presented by large capital expenditure in new display technologies, AVI can achieve early market entry in low-cost applications not being addressed by much of the RGB-based OLED industry. AVI has shown consistent technical progress and is reaching lifetime performance targets matched to $B markets along with continuous improvements in manufacturability.

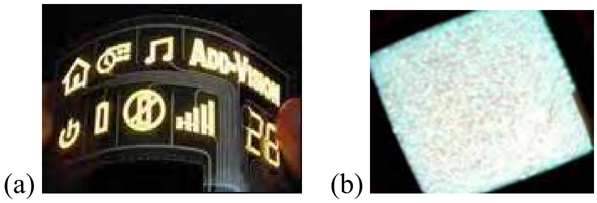


Figure 5. (a) A printed AVI display with mixed graphic content (b) An example of a 1cm^2 white-emitting printed P-OLED on flex for backlighting applications..

5. References

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