High Contrast Top Emission OLED

R. Wood and WY Kim

Luxell Technologies Inc, 2145 Meadowpine BLVD, Mississauga, Canada, L5N 6R8

rwood@luxell.com, wykim@luxell.com, 905-363-0325

Objective/Background:

Top-emission OLED display manufacture has proven challenging due to issues with both the deposition and the reflective nature of the transparent cathode. The metallic nature of the OLED cathode reduces display contrast and legibility, due to reflection of ambient light. In addition damage occurs in the organic layers when using standard sputter or plasma techniques to deposit ITO onto the organic device, further reducing efficiency. This paper presents a solution to these issues: a top emission OLED structure utilizing anti-reflective layers throughout the device, and a novel semi-transparent cathode, resulting in reduced reflectivity and increased efficiency relative to standard contrast approaches, which dramatically increases display contrast and legibility. In addition the devices structures may be deposited without damage to the underlying organic material.

The structure utilizes a reflective anode behind which may exist a silicon TFT backplane or similar opaque substrate. In this sample set, ITO coated aluminum was used as an anode. Organic layers are then deposited in thicknesses commensurate with a microcavity effect. Here, a green emitter was deposited with emission occurring primarily near the ETL/HTL interface. The organic layers are then topped with a semi-transparent aluminum cathode. Al thickness was varied in this work from 10 to 20 nm. The Al is then capped with an optical interference thin film structure that absorbs and eliminates ambient reflections, causing the device to appear dark. Note that this approach allows the devices to be independently optimized for both light emission using microcavity effects and contrast enhancement using optical interference.

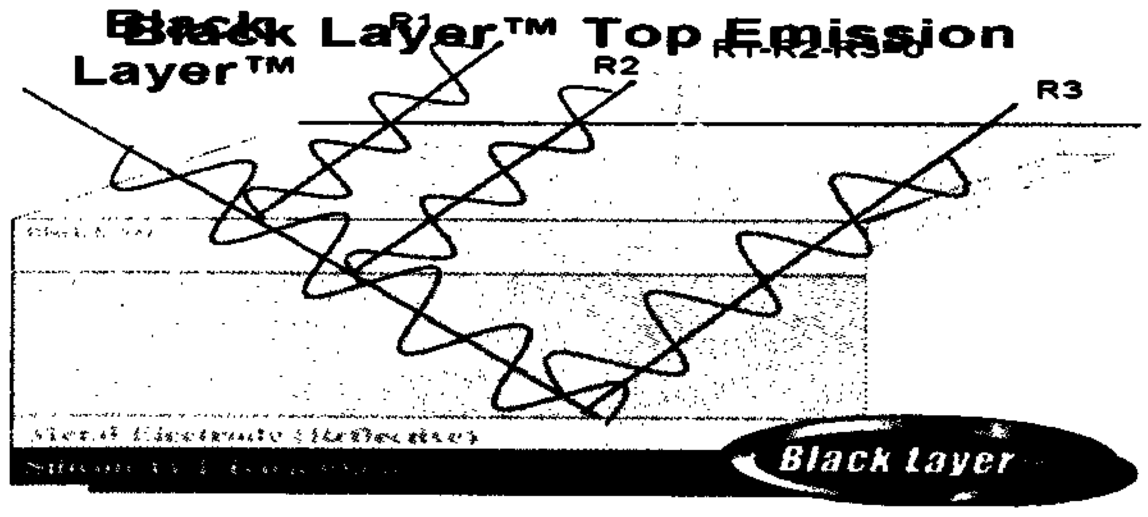

Figure 1. High Contrast OLED showing design of optical interference structure. Note that in some cases further optical interference can be achieved using the OLED structure (R3).

Figure 2. High contrast OLED showing design of the microcavity.

Results

General devices are shown in Figures 1 and 2, showing structures optimized for both the microcavity effect and ambient light elimination through optical interference. The optical interference structure was designed to both maximize light transmission while eliminating ambient reflections. The reflectance curve for a typical device is shown in Figure 3. In general this curve exceeds the performance of a typical circular polarizer

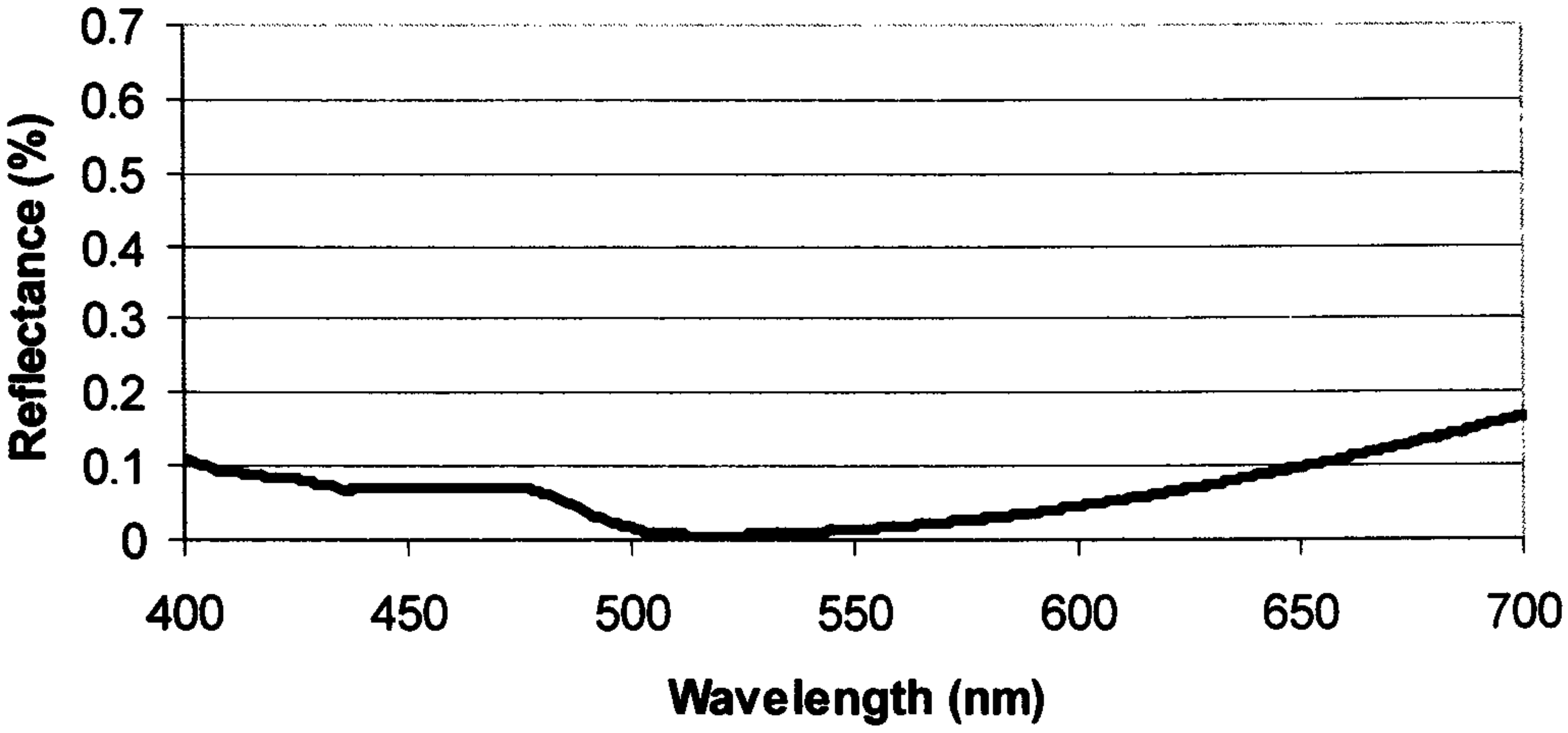

Figure 3. Radiometric Reflectance Profile.

The efficiency of the device was further optimized by varying the aluminum cathode thickness as shown in figures 4 and 5. While this results in enhancing microcavity effects, a thicker Al layer also reduces transmission and the two effects must be balanced. Initial results produced a device with an efficiency greater than 3.5 cd/A. However, with further improvements to hole injection at the anode, increased anode reflectivity, and increased materials efficiency an overall efficiency of 10 cd/A can be achieved

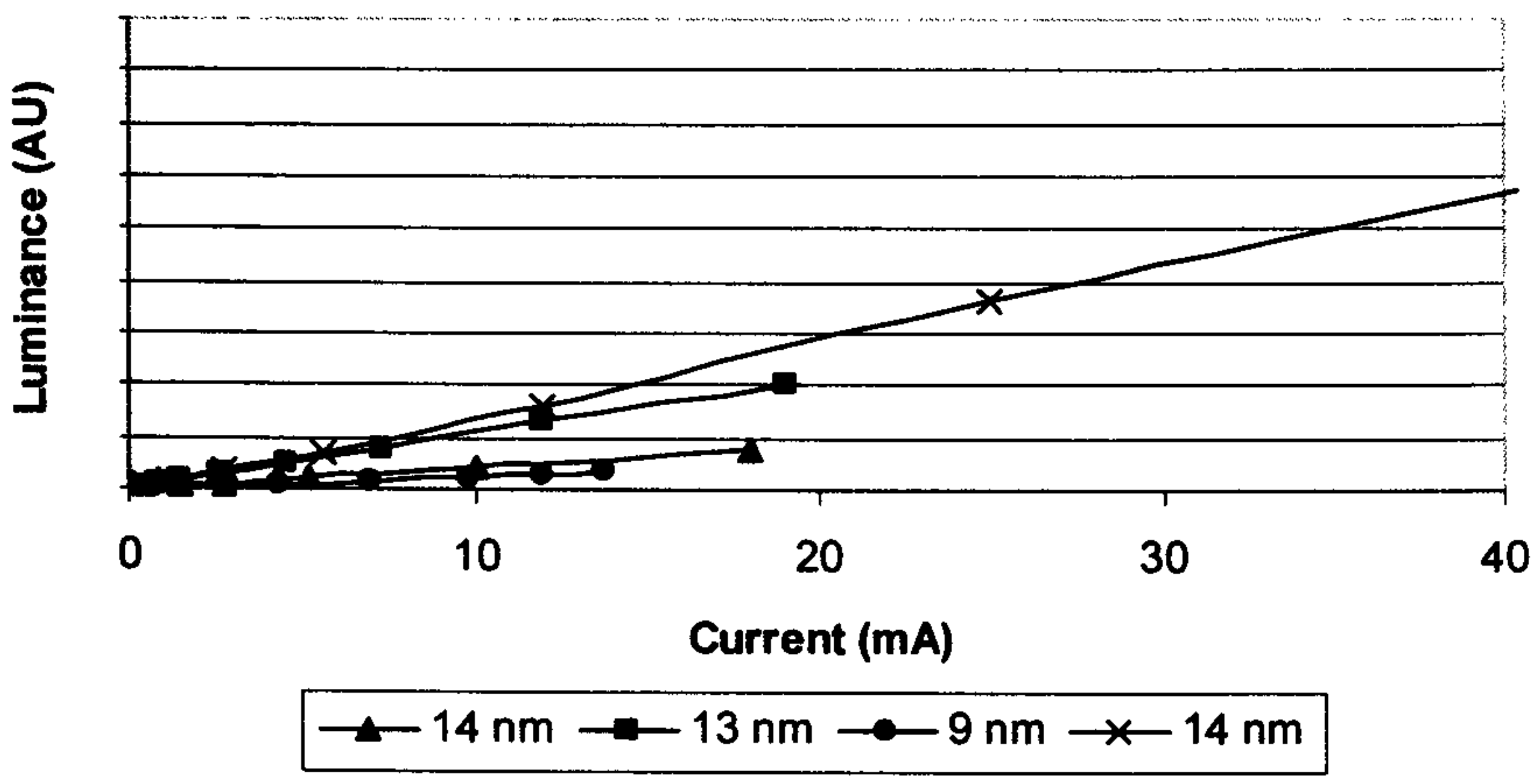

Figure 4. Varying LI Performance

Figure 5, shows peak efficiency at a cathode reflectance of 0.5, which in this case translates to an Al cathode thickness of approximately 14 nm. When comparing this result with models showing the effect of reflectivity on device efficiency due to both decreased cathode transmission and optical microcavity enhancement (labeled amplification), the experimental results are seen to follow a simple two process model.

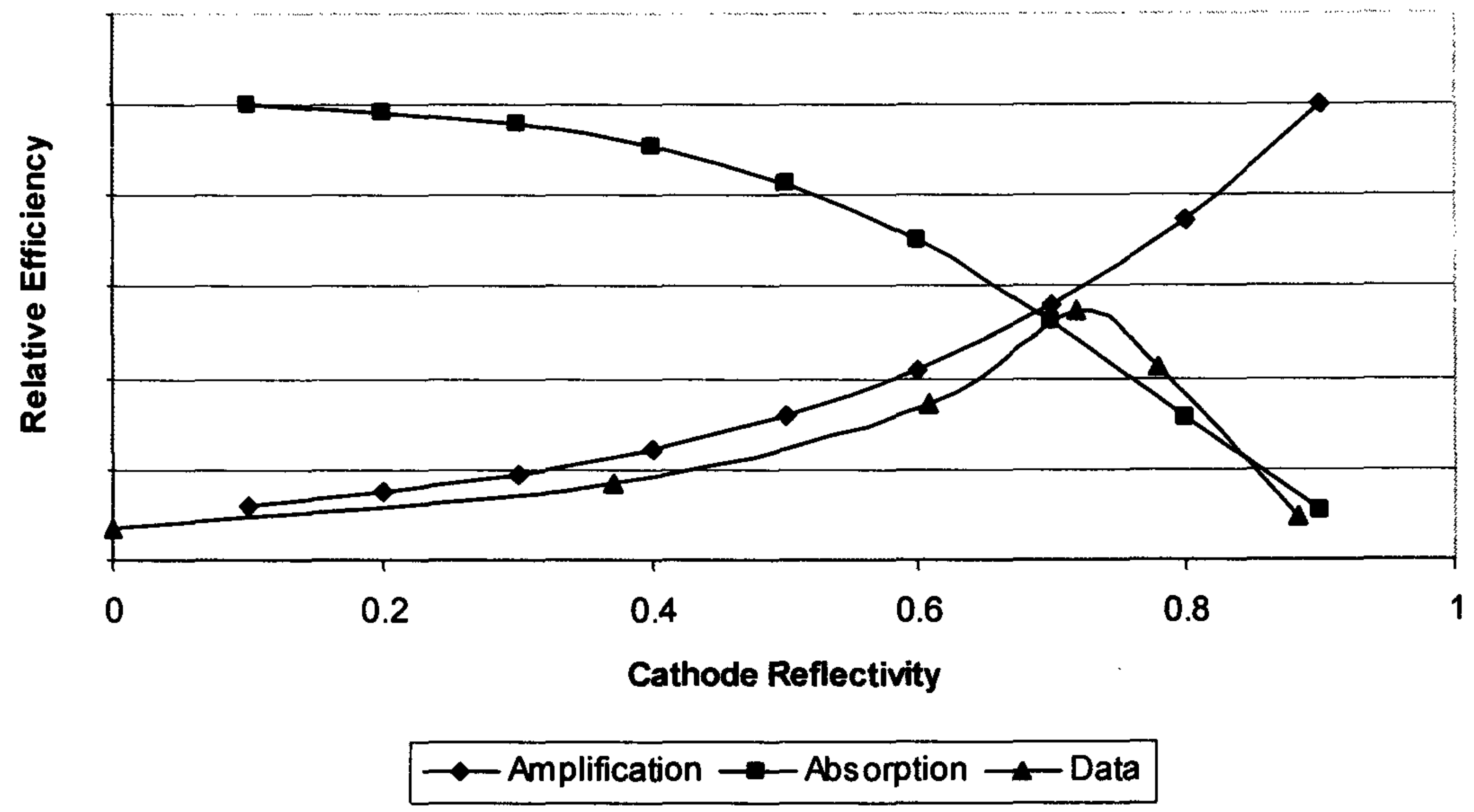

Figure 5. Device Efficiency Variance.

The IV characteristics of an optimized device are shown in Figure 6. As the device was not optimized for hole injection at the anode, a operating voltage were slightly higher than expected. The angular emission characteristics of this d

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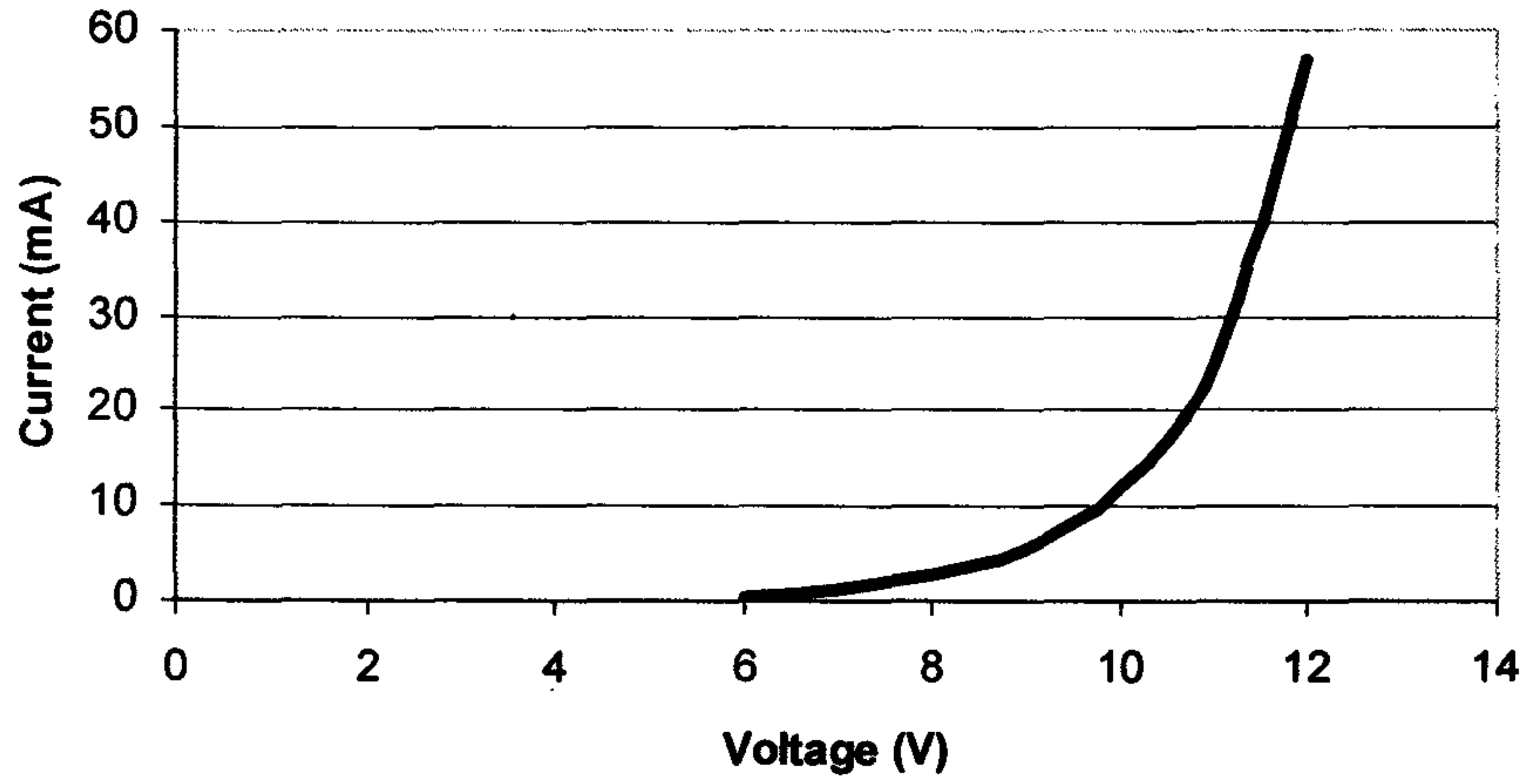

Figure 6. IV Characteristics.

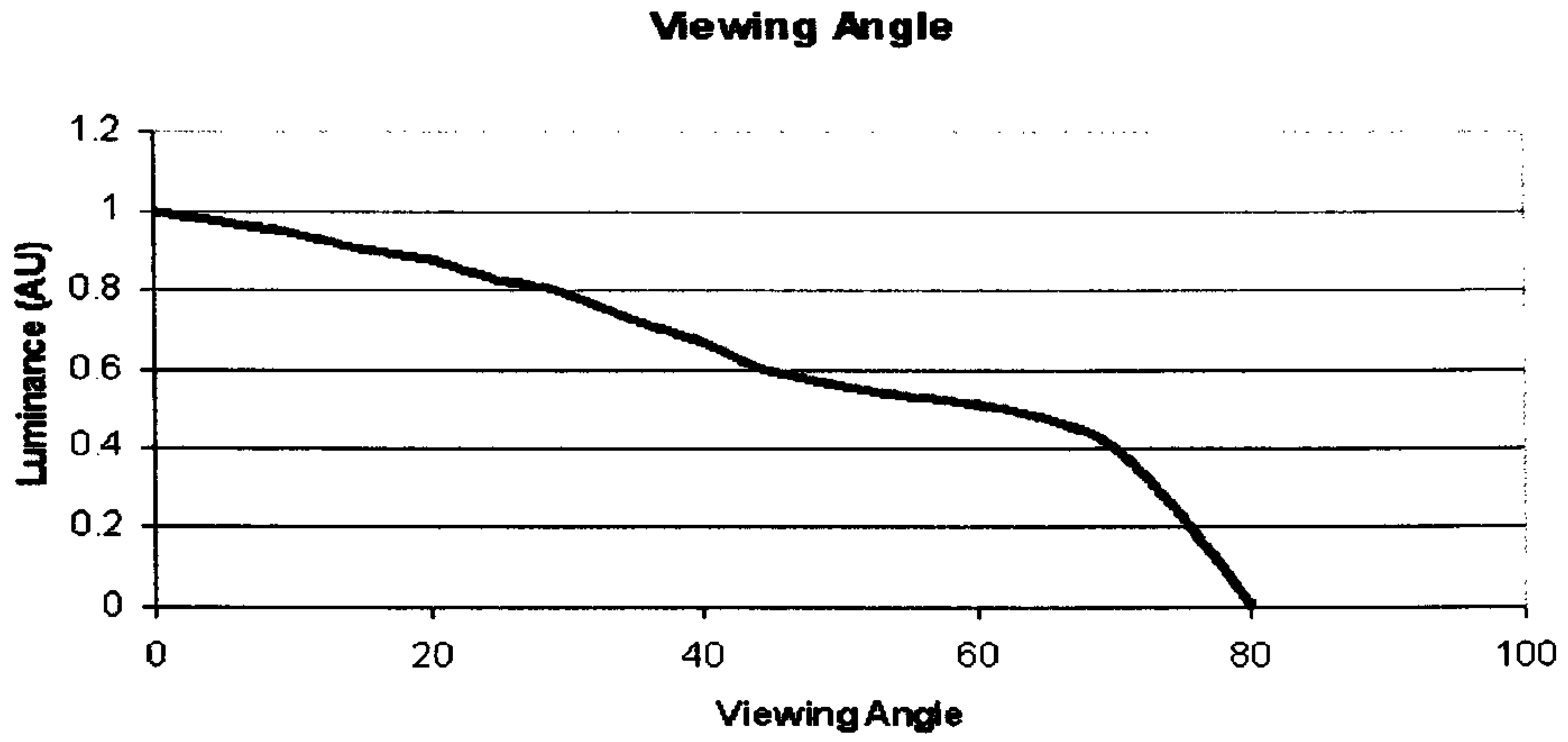

Figure 7. Emission Intensity with Viewing angle.

Impact

Novel top-emission OLED structures utilize standard deposition methods. They can be produced in various configurations and optimized for full colour displays.

A green emission structure studied has been shown to outperform ITO coated top-emission displays using a circular polarizer. Modeled results predict similar performance for blue and red devices/pixels.

References

1. Erratum: "Transparent-cathode for top-emission organic light-emitting diodes". Han, S ; Feng, X ; Lu, Z H ; Johnson, D ; Wood, R. Physics Letters. 2003 , v. 83 , n. 13 , p. 2719

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3. Transparent-cathode for top-emission organic light-emitting diodes. Han, S ; Feng, X ; Lu, Z H ; Johnson, D ; Wood. R. Applied Physics Letters. 2003 , v. 82 , n. 16 , p. 2715 , 3 p.

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