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Integration of Organic LED's and Amorphous Si TFT's onto Unbreakable Metal Foil Substrates

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A long sought goal has been a flat panel display that is unbreakable, lightweight, flexible, and low-cost. Organic LED's (OLED's) have the potential for such a technology because of their demonstrated performance (>15 lumens/Watt, $>50,000$ hr lifetime), their lack of a need for a crystalline substrate, and potential low cost (e.g. deposition by spin-coating). Amorphous Si (a-Si) TFT's are in widespread production for the switching and storage elements in active matrix liquid crystal displays (AMLCD's). Both of these technologies, however, are conventionally fabricated on breakable glass substrates.

In this paper, we report the integration of amorphous Si TFT's and OLED's onto thin (200 μm) stainless steel foils, and the demonstration of a simple circuit in which the TFT drives the OLED (Fig. 1). The finished substrate (40 x 40 mm^2) has been dropped down 30 feet onto a concrete floor with no degradation in device performance. The work shows that a-Si TFT's can provide adequate current levels to drive OLED's.

Because conventional OLED's emit light out through the glass substrate through an ITO back contact, a top-emitting LED structure was developed for this work (Fig. 2). a-Si TFT's were first fabricated on a Si_3N_4 barrier layer on a 200 μm stainless steel foil, using a maximum process temperature of 310 $^\circ\text{C}$ [1]. After the TFT fabrication, OLED's were made using the sequential deposition of Pt (as a hole injecting electrode), the spin coating of a single layer of a PVK/coumarin 6/PBD polymer/small molecule organic blend, followed by a thin partially transparent top contact for electron injection, all processed at room temperature (Fig. 3). Such blends in isolated devices on glass substrates can be tuned from blue to red with quantum efficiencies in excess of 1%, with turn-on voltages $< 5\text{V}$ [2,3]. Because of roughness resulting from the steel surface, a thick organic layer (170 nm, vs. a usual 50 nm) was used for electrostatic integrity, resulting in a high LED turn-on voltage in this experiment.

Fig. 4. shows TFT characteristics, which were unaffected by LED fabrication. Fig. 5 shows the OLED current (and OLED voltage) as a function of gate voltage, demonstrating that the TFT can switch the current through the OLED. Fig. 6 shows the light emission as a function of gate voltage. Smaller devices are brighter because of a higher current density. Dropping the finished substrates 30 feet onto concrete had no effect on the characteristics. The absolute level of light emission was low in these devices because of a non-optimized top emission structure, resulting in low quantum efficiencies (0.01% vs $>1\%$ in bottom emitters). Assuming a top efficiency of 1%, a typical display brightness of 100 cd/m^2 requires a current density of 3 mA/cm^2 , which can be achieved by a gate voltage swing of 15 V in our example. Matching of the TFT W/L to LED area in an optimized pixel is modelled to reduce this swing to under 5 V. Such results with an optimized top emitter using transparent ITO will be shown at the conference.

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1. S. Theiss and S. Wagner, IEEE Electron Dev. Lett. vol. 17, Dec. 1996, to be published.
2. J. Kido, H. Shionoya, and K. Nagai, Appl. Phys. Lett. vol. 67, 2283 (1995).
3. C.C. Wu, J.C. Sturm, R.A. Register, and M.E. Thompson, Appl. Phys. Lett, accepted for publication, 1996.

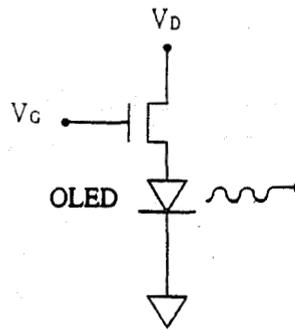


Fig. 1. Circuit diagram of the a-Si TFT driving an integrated OLED

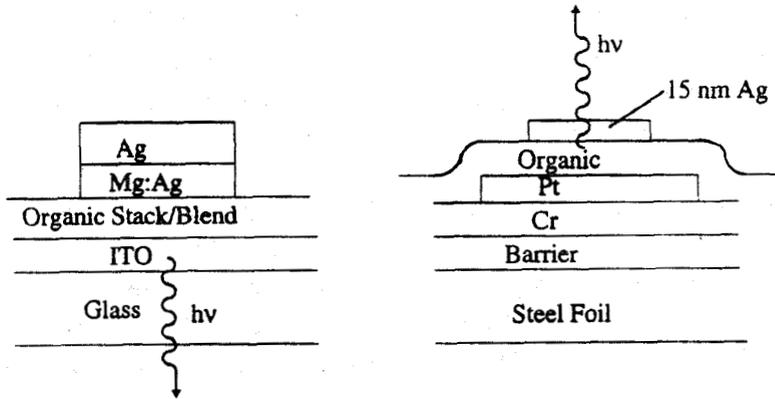


Fig. 2. Cross section contrasting conventional bottom emitter OLED (glass substrate) vs. the top emitter on steel foils used in this

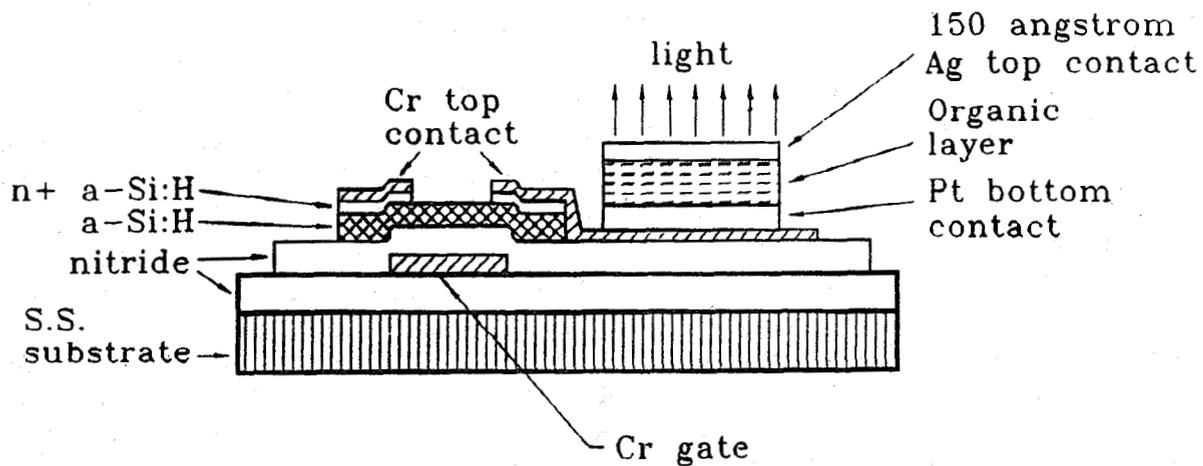


Fig. 3. Cross section of the TFT/OLED integrated structure.

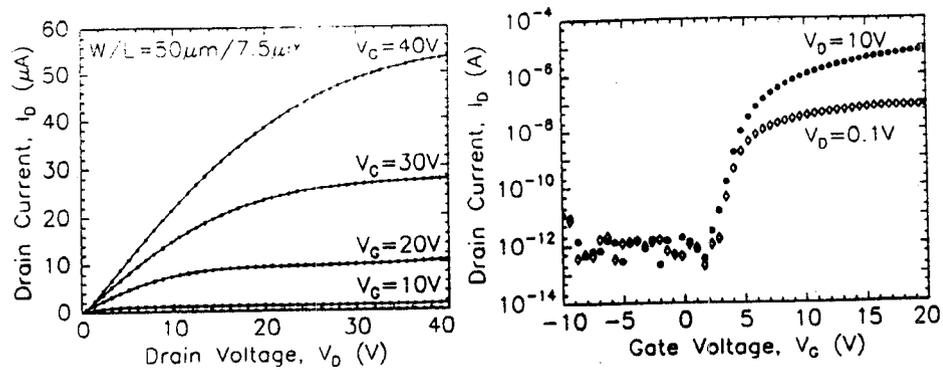


Fig. 4. Typical characteristics of a-Si TFT's. The extracted mobility was $0.7 \text{ cm}^2/\text{Vs}$, the subthreshold slope was 500 mV/decade , and the threshold was 7 V .

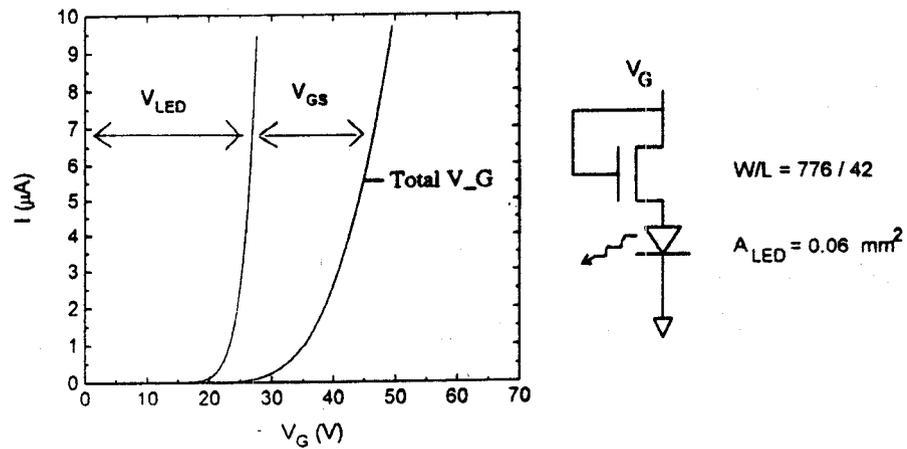


Fig. 5. LED current (and LED voltage) as a function of gate voltage. The drain was tied to gate so the TFT was always in saturation when on.

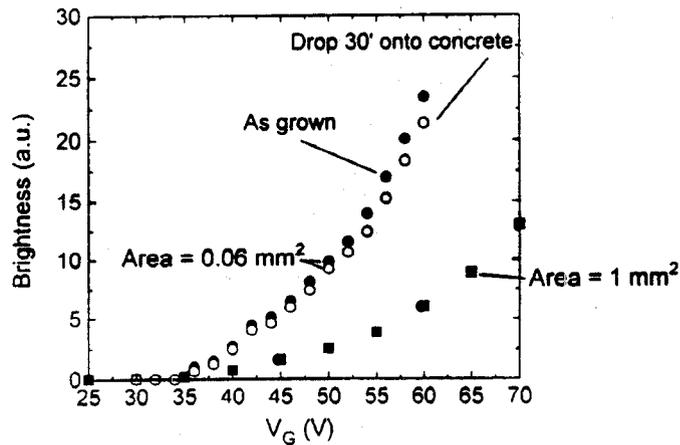


Fig. 6. Light emission (brightness, arbitrary units) as a function of gate voltage.