NEW OPTICALLY TRANSPARENT MATERIALS FOR TRANSPARENT ELECTRONICS AND DISPLAYS

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Abstract. Optically transparent and flexible electronic circuits and displays are attractive for next-generation visual technologies, including windshield displays, head-mounted displays, and transparent screen monitors. Here we report on the fabrication of transparent transistors and circuits based on the combination of nanoscopic dielectrics and organic, inorganic, or hybrid semiconductors. Furthermore, the first demonstration of a transparent and flexible AMOLED display driven solely by In_2O_3 nanowire transistors (NWTs) is reported. The display region exhibits an optical transmittance of ~35% and a green peak luminance of ~300 cd/m^2. These results indicate that NWT-based drive circuits are attractive for fully transparent display technologies.

This AMOLED display contains 54 x 176 μm OLED pixels, in which the switching and driving circuits are comprised exclusively of nanowire transistor (NWT) electronics fabricated at room temperature.[1,2] Proof of concept green-emitting polymer LEDs with interfacial charge-blocking materials are integrated with a transparent bottom contact electrode. The circuit for a unit pixel consists of one switching NWT, two parallel driving NWTs and one storage capacitor. The device is composed of many layers making up the transistor and the OLED (Figure 24). Briefly, the fabrication begins with 200 nm thick SiO_2 layer deposited by e-beam evaporation on a glass substrate. 100 nm of ITO is then deposited by ion-assisted deposition (IAD) at room temperature, and patterned by photolithography. Next, a 22 nm Self-assembled nanodielectric (SAND) multilayer is deposited on the patterned ITO gate electrodes via solution self-assembly.[2] Contact holes are patterned as anode openings for OLED units and as bottom gate electrode contacts for the pixel. Next, a suspension of single crystal In_2O_3 nanowires are dispersed on the substrate. ITO source/drain electrodes are deposited by IAD and patterned by lift-off. Next, 200 nm of SiO_2 is deposited for PLED fabrication and characterization. The mobilities of the present SAND-based In_2O_3 (μ ~ 258 cm2/Vs) are similar to In_2O_3 NWs on oxide dielectrics ($\mu \sim$ 6.9-279.1 cm2/Vs) and bulk single crystals ($\mu \sim$ 160 cm2/Vs). Modest hysteresis, large I_{on} currents (6 x 10^{-6} A at V_G = 2.0 V), and low subthreshold slope (0.35 V/decade) indicate negligible charge trapping and detrapping in/on the SAND and at the NW-SAND interface. Fully transparent, proof-of-concept 2 x 2 mm NW-AMOLED arrays (300 pixels = 900 NWTs) where fabricated using a very thin Al cathode on glass substrates. The optical transmission values are ~72% (before OLED deposition) and ~35% (after OLED deposition) in the 350-1350 nm wavelength range, which corresponds to a green peak luminescence of >300 cd/m^2. Note that transmission coefficients up to 70% have been reported for OLED structures on plastic substrates, although values in the 50% range are more common. These results are very promising for future AMOLED displays.

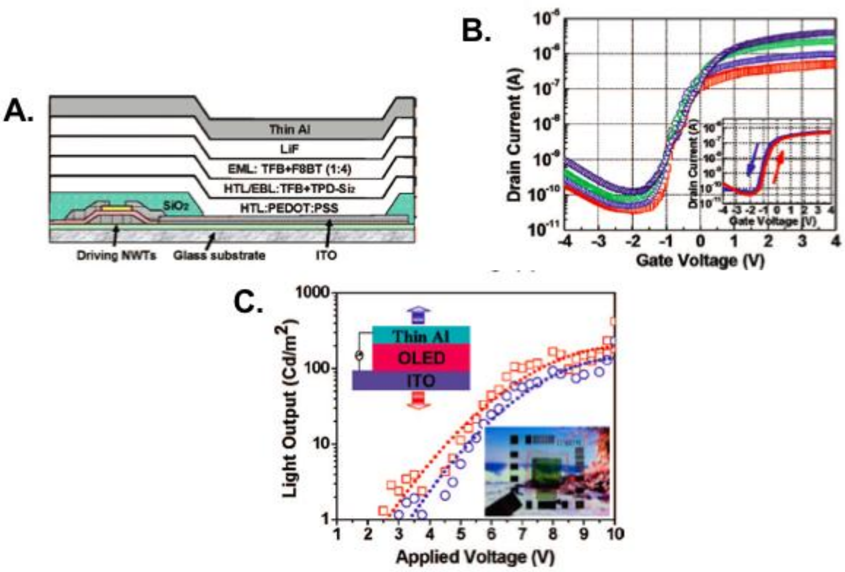

Figure 1. A. Illustration of SAND AMOLED with SAND based In_2O_3-NW TFTs. B. Typical transfer characteristics at different V_{SD} (red, blue, green, and dark = 0.1, 0.2, 0.5, and 1.0 V, respectively), and the inset shows the device hysteresis at V_{SD} = 0.1 V. C. Measured luminance versus supply voltage curves for a 2 × 2 mm AMOLED array with all scan and data lines enabled, demonstrating light emission through the Al cathode (circles) and through the glass substrate (squares). The bottom inset is an optical image of NW-AMOLED consisting of three 2 × 2 mm AMOLED pixel arrays, 340 unit pixels, 80 transistor/circuit test devices, 6 alignment marks, 20 test patterns, and contact pads.

References.

1. Ju, S.; Li, J.; Liu, J.; Chen, P.-C.; Ha, Y.-G.; Ishikawa, F.; Chang, H.; Zhou, C.; Facchetti, A.; Janes, D. B.; Marks, T. J. "Transparent Active Matrix Organic Light-Emitting Diode Displays Driven by Nanowire Transistor Circuitry" *Nano Letters* **2008**, *8*(4), 997-1004.

2. Ju, S.; Ishikawa, F.; Chen, P.; Chang, H.-K.; Zhou, C.; Ha, Y.-g.; Liu, J.; Facchetti, A.; Marks, T. J.; Janes, D. B. "High performance In2O3 nanowire transistors using organic gate nanodielectrics" *Appl. Phys. Lett.* **2008**, *92*, 222105/1-222105/3.

3. Yoon, M.-H.; Facchetti, A.; Marks, T. J. "Nanometer-Scale Insulator Layers Based on σ-π Hydrocarbon Chain-Aromatic Push-Pull Components for Low-Voltage Organic Thin Film Transistors" *Proc. Nat. Acad. Sci. USA* **2005**, *102*, 4678-4682.