High-performance transparent thin-film transistors

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A hybrid approach integrates a transparent inorganic semiconductor with a large carrier mobility and a nanoscopic, organic gate dielectric.

Thin-film transistors (TFTs), already embedded and indispensable in a myriad of portable electronics, would benefit from optical transparency and compatibility with flexible, lightweight plastics. TFTs with these qualities would represent a major advance if they could be fabricated by a scalable, large-area process. To this end, we have adopted a hybrid approach in developing ‘invisible’ TFTs that heterogeneously integrate a transparent, inorganic semiconductor with a large carrier mobility and a nanoscopic, organic gate dielectric.1

The high-performance transparent circuitry of this novel TFT combines a high-mobility n-type metal oxide thin-film semiconductor,1,2 In2O3, with a low-leakage, robust ‘high-k’ self-assembled organic gate dielectric.3 Growth takes place at room temperature by scalable two-beam sputtering while a simple solution-coating process implements self-assembly. Transistor performance—based on combined scalability, ease of deposition, and optical transparency—far exceeds anything achieved to date. These wholly transparent hybrid TFTs (see Figure 1) exhibit excellent operating characteristics near 1.0V with field-effect mobilities of > 120cm²/Vs, high modulated on/off current ratios of 10⁵, near-zero threshold voltages, and sub-threshold gate voltage swings of ~90mV/decade. These parameters outpace those of amorphous Si TFTs, and rival or improve upon those of poly-crystalline Si TFTs. In addition, they offer optical transparency not possible with Si materials.

These high-performance TFTs can be used in large-scale, transparent displays and have a range of applications, from television to automotive and aerospace windscreen displays. Other prospects include visors for bicyclists, motorcyclists, soldiers, and assembly-line workers. Our next step will be to further enhance performance, durability, and scalability, and to diversify the range of acceptable substrates.

Figure 1. Photo of a 70-device array of fully transparent inorganic-organic hybrid thin film transistors on a 1” × 1” glass substrate. The edges of the glass substrate are marked in green for clarity.

In principle, this hybrid transparent-TFT strategy is also applicable to a host of wideband-gap metal-oxide semiconductors4,5 and to other transparent ultra-thin organic gate dielectrics.6 The compatibility of these devices with large-scale/large-area deposition techniques and simple dielectric growth processes, together with their very low operating bias, delineates a promising approach to high-performance portable optoelectronics.

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References