New approach to OLEDs

ELECTRONIC MATERIALS

A new approach to building organic light emitting diodes (OLEDs) produces devices with better performance [Lee *et al.*, *Proc. Natl. Acad. Sci. USA* (2004) **101** (2), 429].

The new type of OLED consists of two parts: a transparent elastomeric element coated with a thin metal film and a transparent substrate supporting an electrode and electroluminescent organic. When the two parts are brought together, van der Waals interactions create a tight and robust bond at room temperature without having to use applied pressure. "It is very different from the standard procedure for fabrication of OLEDs, which involves the sequential deposition of electrode and electroluminescent layers on top of one another," explains Tae-Woo Lee of Samsung Advanced Institute of Technology, who developed the method with colleagues at Bell Laboratories and the University of Illinois at Urbana-Champaign. This 'soft' contact lamination technique yields devices with quantum efficiencies more than a factor of ten higher than those produced in the usual way. This could be because the technique avoids the various forms of disruption that standard methods produce.

Since the technique is compatible with soft lithography tools, it is possible to create nanoscale OLEDs. By patterning the top electrode prior to device integration, the researchers successfully fabricated OLEDs with active dimensions smaller than the wavelength of the emitted light. "This ability to manipulate the top electrode creates not only opportunities for OLED technology, but also enables the fundamental study of the organic-electrode interface in ways that would be impossible with conventional approaches," says Lee.

Display of unbreakable behavior

ELECTRONIC MATERIALS

Flexible, active-matrix display produced by Polymer Vision, a venture in the Philips Technology Incubator, using Philips' ultrathin backplane and organic TFTs with E Ink's electronic ink frontplane. (Courtesy of Polymer Vision, Philips Technology Incubator.)

Philips Research has moved a step toward lightweight, large-area, unbreakable displays. Gerwin H. Gelinck and colleagues have developed a flexible, active-matrix monochrome electrophoretic display comprising organic transistors on an ultrathin (25 µm) polyimide foil [*Nat. Mater.* (2004) 3, 75]. The researchers use thin-film transistor (TFT) technology based on a bottom-gate device architecture. Gate electrodes and interconnects are formed by patterning Au using standard photolithography techniques. Both the gate dielectric (350 nm layer of photo-imageable polymer polyvinylphenol) and the organic semiconductor (pentacene) can be processed from solution via spin-coating. A second Au layer provides source-drain electrodes and second-level interconnects. To complete the display, a layer of electronic ink (from E Ink Corp.) is laminated onto the TFT backplane. The electronic ink consists of electrophoretic microcapsules containing black and white pigments suspended in a transparent liquid. The microcapsules are coated onto a polyester/ITO (indium tin oxide) sheet, which forms the electrode plane of the display. Depending on the charge, the viewer will see either the black or white pigment in the capsule. The display shows high contrast and appears very similar to printed paper. Philips' prototype 5 cm display is only 300 µm thick and weighs a mere 1.2 g, but it can be rolled up without degrading the image.

To realize large-area displays, however, the number of interconnect lines needs to be reduced by integrating the driving circuitry with the active-matrix backplane. The researchers take an important step along this path by creating, in the same way, organic shift register circuits, which shift the line selection pulse from one row to the next on every clock cycle. The devices are some of the largest organic integrated circuits to date and are sufficient for a video speed display (operating frequency of 5 kHz).

Integrating nanotubes into electronics

NANOTECHNOLOGY

Hybrid technology combining carbon nanotubes and Si technology is emerging as a possible way forward for electronics. Two recent papers represent important steps in this direction.

Researchers from the University of California, Berkeley (UCB) and Stanford University have created an integrated circuit combining single-walled nanotube (SWNT) devices with n-channel metal oxide semiconductor field effect transistors [Tseng *et al.*, *Nano Lett.* (2004) **4** (1), 123]. The random access nanotube test (RANT) chip allows the rapid characterization of multiple nanotube devices. "The circuit is interconnected in such a way that only 22 control signals are needed in testing more than 2000 nanotubes," explains Yu-Chih Tseng of UCB. "We succeeded in making a tool for nanotechnology researchers and, in the process, we demonstrated the broader proof of principle that nanotubes can be successfully integrated in a complex circuit."

More recently, Ane Jensen and colleagues at the Niels Bohr Institute, Denmark have fabricated hybrid devices combining SWNTs and epitaxially grown III-V semiconductors [Jensen *et al.*, *Nano Lett.* (2004), doi: 10.1021/nl0350027]. SWNTs are encapsulated in a GaAs-based heterostructure grown by molecular beam epitaxy with ferromagnetic (Ga,Mn)As contacts forming the source and drain. The nanotubes are capacitively coupled to the *n*-doped base GaAs to form a three-terminal device. "It opens possibilities for designing hybrid SWNT/semiconductor devices, where SWNTs act as interconnects in traditional semiconductor integrated circuits or as active devices," says Jensen.