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## **A Cheap Route to Robust LEDs**

### **Chemical bonds put a new spin on quantum-dot hybrid light-emitting devices.**

By Anne-Marie Corley

Organic light-emitting diodes (OLEDs) are steadily making their way into commercial devices like cell phones and flat-screen displays. They're fabricated with layers of organic polymers, which make them flexible, and they use less power and less expensive materials than liquid crystal displays.

The downside is that because the polymers react easily with oxygen and water, OLEDs are expensive to produce--they have to be created in high-vacuum chambers--and they need extra protective packaging layers to make sure that once they're integrated into display devices, they don't degrade when exposed to air or moisture.

MIT chemical-engineering professor Karen Gleason and MIT postdoc Sreeram Vaddiraju have developed a process that aims to solve the problems of high fabrication costs and instability for OLEDs while still maintaining their flexibility. Gleason's solution is a hybrid light-emitting diode, or HLED. The device would incorporate both organic and inorganic layers, combining the flexibility of an OLED with the stability of an inorganic light-emitting material. "The idea is to have a mixed bag and capture the qualities that allow inexpensive fabrication and stability," Gleason says.

Gleason starts with a substrate of electrically conducting organic polymer, which she creates through a chemical vapor deposition process in a low-vacuum chamber. It's the only step in the process that requires a vacuum, which should make the approach cheaper than conventional methods. For the light-emitting layer, Gleason uses quantum dots, nanocrystals of inorganic semiconductors; each quantum dot can be "tuned" to emit certain frequencies of light. Although quantum dots are inflexible themselves, they're so small--two to six nanometers across--that even arranging them side by side in a continuous film still allows for flex in the material.

While using quantum dots in light-emitting devices isn't new, Gleason's technique is. The problem is how to get the dots to stick onto a substrate in a uniform, even layer, without moving. Vaddiraju says that they use "molecular wiring." Instead of just laying down the quantum dots on top of the polymer substrate, the scientists use linker molecules between the layers to chemically bond the quantum-dot layer and the polymer together.

This "cross-linking" molecule between the layers is "a beautiful evolution of the present structures," says Vladimir Bulovic, an associate professor of electrical engineering at MIT and the first to demonstrate practical use of quantum dots in optoelectronic devices. Bulovic's research has depended on other methods of depositing quantum dots: dropping the dots onto a fast-spinning substrate, called spin casting, and, more recently, stamping them onto a surface.

The advantage of Gleason's technique, Bulovic says, is that "you end up with a very robust structure" mechanically, chemically, and electrically. "It validates an idea of stabilizing quantum dots inside organic structures by providing covalent bonds around them." Bulovic adds that there are still hurdles to overcome, but he thinks that the research "represents another one of those advancements we were hoping for in the field."

Covalent bonding solves the degradation problem, says Vaddiraju, because the linker molecules grab hold of "free bonds" in the organic material, leaving none to react in air. That effectively seals off the organic polymer layer from outside influence.

The cross-link should also take care of scaling up. Rather than dealing with the mechanical problem of depositing millions of nanocrystals onto a substrate through spin casting or stamping, the chemical reaction itself wires the dots to the substrate in a smooth, even layer. And unlike a process like spin casting, the researchers' technique uses all the dots and all the polymer. "So from a material cost point of view, we're not losing material," says Vaddiraju.

So far, the team has succeeded in creating a red HLED, which lasted 2,200 hours at 100 °C. The researchers think that's about equivalent to their goal at room temperature: 10,000 hours, or about three years at a little under 10 hours a day, which they estimate is how long a cell phone should last.

The next step is to complete testing with green and blue dots; the researchers will need all three colors working for a complete prototype. Then they'll move on to see how the device works with rapid patterning--using the dots just like ink from an ink-jet printer. Eventually, the goal is to do bulk printing. Because the layers are so thin and flexible, roll-to-roll processing will be simple and make the process even more economical. "Roll-to-roll is the same process used to put a metallization barrier layer on potato-chip bags," says Gleason. "And if it's cheap enough for potato chips, it should be cheap enough for displays."

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