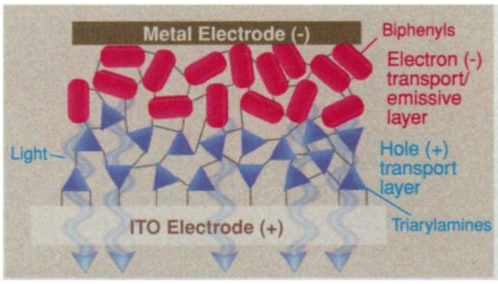
MATERIALS SCIENCE

Self-Assembled LEDs Shine Brightly

SAN JOSE, CALIFORNIA—There's no easy path to illumination, at least when the light in question comes from organic molecules.

Devices that coax light from these materials, instead of from traditional semiconductors, could serve as flexible, large-area displays. The leading materials, small organic molecules, do yield bright, long-lived devices, but they have to be laid down from a vapor to create the uniform, thin layers that emit light efficiently—and doing so requires costly machines. Large, chainlike molecules called polymers can also emit light, but it can be hard to control their arrangement and purity, making polymer-based devices less bright and in many cases shorter lived. Now Tobin Marks and his colleagues at Northwestern University in Evanston, Illinois, along with Nasser Peyghambarian, Bernard Kippelen, and their colleagues at the University of Arizona, Tucson, have found a middle way.

At the Photonics West conference here last month, the researchers offered a hybrid approach that relies on benchtop chemistry instead of elaborate machines to entice small organic molecules to form a stack of precisely controlled layers. The new strategy attaches specially designed chemical linking groups to a series of small molecules. When a substrate is simply dipped into a series of containers holding different building blocks, the molecules link end to end into the desired arrangement, forming polymerlike networks. "From a scientific point of view, it's very exciting work," says Homer Antoniadis, an organic LED (light-emitting diode) expert at Hewlett-Packard. Antoniadis adds, though, that at this early stage the self-assembly process is too slow to be commercialized.



Self-made. Molecular self-assembly created the light-emitting layer of this organic LED.

Like other strategies for turning out organic LEDs, the new technique aims to create a light-emitting layer sandwiched between conducting layers. When a voltage is applied to the device, negatively charged electrons and positively charged "holes" funnel from the conducting layers into the light-emitting layer. There, they annihilate each other and produce photons of light, in a color determined by the electronic properties of the organic layer.

Marks and his colleagues aren't the first to build up these multilayer devices through self-assembly. Researchers have used the strategy to make polymer-based devices, simply allowing each new polymer layer to adsorb to the one below. But Marks hoped to produce brighter, more durable devices by transferring the approach to small, organic light emitters and linking layers together with strong covalent bonds.

The researchers constructed their devices on a base of glass coated with a transparent electrode of indium tin oxide (ITO). For one typical device, they first dipped the glass into a solution containing chlorosiloxanes, which bind to the ITO, forming a layer with unbound hydroxyl groups exposed on the surface. Next came a bath in a solution of chlorosilane-functionalized triarylamines, which were designed to bind to the hydroxyl groups. These first two layers created a route for positively charged holes to travel from the ITO electrode to the light-emitting layer, which was created next, when the team dipped the glass into molecules called chlorosilane-functionalized biphenyls. Finally, they coated the top with another electrode.

At the meeting, Marks presented evidence that the organics assemble themselves into the well-ordered, smooth layers that make the most efficient devices. And when the LEDs were powered up, they emitted blue light about as bright as the glow of a standard television set—on par with the best organic blue LEDs. Marks has shown that the same strategy can produce other colored LEDs as well. Jean-Michel Nunzi, of the French Atomic Energy Commission in Gif-Sur-Yvette just outside Paris, says Marks's technique may also "be the way to go" for creating organic-based solar cells.

–Robert F. Service

Your (Light-Emitting) Logo Here

With a printer no different from one you might hook up to your PC, University of California, Los Angeles (UCLA), physicist Yang Yang is pushing the state of the art in light-emitting displays. At the Photonics West meeting in San Jose, California, last month, Yang reported using an ink-jet printer to create the first polymer-based light-emitting logos.

Other researchers trying to create polymer displays with ink-jet printers have run into obstacles (*Science*, 17 October 1997, p. 383). One is that the organic solvents needed to dissolve the best polymer light emitters tend to melt key components of standard printers. Another is that ink-jet printers spray liquid into tiny dots, rather than a continuous film, creating gaps that can cause printed light emitters to short out.

Yang and his UCLA colleague Jayesh Bharathan hit on the idea of printing not the light-emitting layer itself but a conducting polymer called polythiophene, which is water soluble. The polythiophene pattern, roughly 2 centimeters square, provides an electrical connection from a transparent bottom electrode made from indium tin oxide (ITO) to an overlying layer of a light-emitting polymer called MEH-PPV. The light-emitting material dissolves only in a solvent, but it does not need to be patterned. Moreover, it also seals any gaps in the printed polythiophene, thereby preventing a short. The device is capped with a metal electrode.

When the current is turned on, positive electrical charges, called holes, migrate from the ITO electrode through the polythiophene and into the light-emitting polymer. There, they meet up with negatively charged electrons coming from the top electrode and combine, giving off light. The display lights up only in areas where the polythiophene is patterned.

Fit to print. Ink-jet printer made this pattern.

For now, the UCLA displays shine in just a single color. Cheap, large, full-color display screens, made in one simple ink-jet printing step, will have to wait until water-soluble, light-emitting polymers are available. But display researchers such as Hewlett-Packard's Homer Antoniadis think Yang's strategy of sealing gaps in a printed layer with an adjacent layer will also help. "Yang has shown that you can really make it work," says Antoniadis.

–R.F.S.