MATERIALS SCIENCE

Organic LEDs Begin Producing Bright White Light

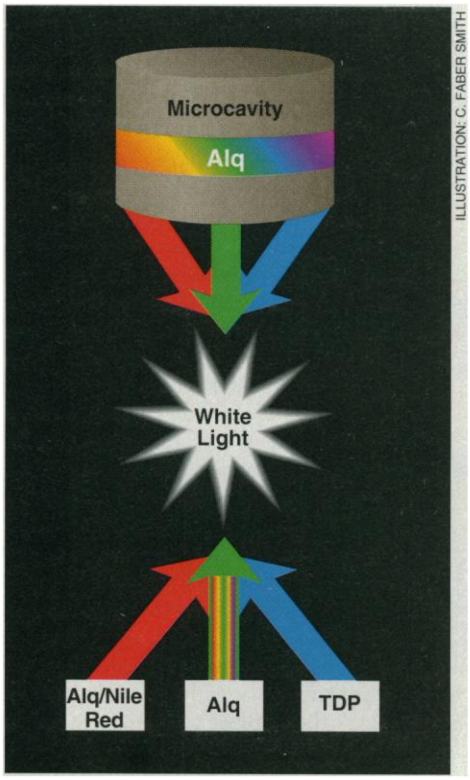
Need white light? Just flip the switch on the wall. Researchers trying to make devices called light-emitting diodes (LEDs) emit white light wish it were that easy. Such devices would have a wealth of applications. They could be used, for example, as backlights for thin, flat television screens, computer displays, and wristwatch faces. But while researchers have built both inorganic and organic LEDs that emit light across the visible spectrum from blue to red, until recently, LEDs emitting a true bright white have been as elusive as Captain Ahab's white whale. Now, it seems, several groups making organic LEDs are getting sightings of the white whale.

One example appears on page 1332, where a group led by Junji Kido of Yamagata University in Japan describes the brightest white LED to date. Another organic LED, developed by researchers at AT&T Bell Labs in Murray Hill, New Jersey, last fall, also shows early promise. "This whole area is moving forward very quickly," says Alan Heeger, a physicist at the University of California, Santa Barbara, who formed a company called UNIAX Corp. to help commercialize organic LEDs. He cautions, however, that all the bugs haven't been worked out yet. Before the new white LEDs start lighting displays, their lifetimes will have to be improved from the current days or weeks to years.

The techniques used by the different groups to produce white LEDs differ widely, but all organic LEDs work on the same general principle. One or more layers of semiconducting organic material is sandwiched between two electrodes. Application of an electric current causes negatively charged electrons to move into the organic materials from the cathode while positive charges, called holes, move in from the anode. When these positive and negative charges meet in the center layers, they combine, producing photons of light; the wavelength—and therefore the color—of the photons depends on the electronic properties of the material in which the photons are generated.

To produce white light, it is necessary to generate blue, red, and green light simultaneously. The Yamagata researchers set out to achieve this by taking what seemed like a straightforward path: They stacked three different light-emitting organic layers between the two electrodes. The first, made of a chemical called triphenyldiamine (TPD), produces blue photons; the middle layer, consisting of tris(8-quinolinolato)aluminum(III) (Alq), emits primarily green light; and this is then topped with a red-emitter, made of Alq doped with an organic dye called Nile Red.

But the route turned out to require some detours, says team leader Kido. The researchers originally found that the holes, which enter the device from the electrode below the blue layer, passed through TPD so rapidly they failed to recombine with electrons there. As a result, little blue light was produced. So to slow down the hole migration, the researchers added another layer of a material abbreviated p-EtTAZ between the blue and green layers to partially block the movement of the holes to the overriding layers. The result: a white LED that turns out light at a record 2000 candela per meter^2, roughly one-half the brightness of a standard fluorescent tube.



Add or subtract. White light can be produced by a microcavity structure that sends only red, green, and blue photons from a single layer of light-emitting material out the bottom of the device *(top)*, or it can be generated by mixing photons from separate red, green, and blue light-emitting materials *(bottom)*.

This, says UNIAX physicist Ian Parker, is "certainly bright enough to use with a laptop computer or a cellular phone." But now, he adds, "it's a question of lifetime." And Kido concedes this could be a problem. Although he has yet to measure the lifetime of his white-light–emitting LED, he suspects that it's far below the commercial requirements for devices such as laptop computers.

Indeed, this problem of short LED lifetimes was one factor that caused researchers at AT&T Bell Labs to choose a totally different route to their white LED. Organic light-emitters fail, says Anath Dodabalapur, one of the team's leaders, in part because the strong electric current moving through the device can cause the organic materials to crystallize, degrading their light emission. But much of the electrical current that goes into conventional organic LEDs is wasted, he adds, because such devices typically kick out their photons in all directions. Yet only those that come out in the direction of the viewer are actually seen.

In the 31 October issue of *Applied Physics Letters* the AT&T researchers describe a technique whereby they steer more of these photons in the viewer's direction. They started with a single light-emitting layer composed of Alq, which emits most strongly in the green but also sends out photons of light across the visible spectrum. They then embedded this Alq layer in a device structure called a microcavity. This acts like a selective lens that steers red, green, and blue photons out the bottom of the device—the face seen by a viewer—while sending other colors such as yellow and orange out the side.

Because the device channels more white light toward an observer, "to get the same [brightness], you need less current," says Dodabalapur. That, he adds, should help extend the lifetime of the device, although the researchers have yet to measure this directly. Dodabalapur acknowledges that even the reduced electrical currents may eventually degrade the organic materials. But, he adds, because the devices can be used with other broad spectrum–emitting organics besides Alq, advances in any of these materials will translate to longer device lifetimes. "It's great stuff," says Richard Friend, a polymer LED specialist at Cambridge University in the United Kingdom.

At present, it's too early to tell whether the microcavity or multilayer white-light LEDs will achieve commercial success. And they are not the only contenders on the horizon. Other approaches include engineering a single polymer layer to emit just red, green, and blue, thereby doing away with the need for a microcavity, and using a mix of materials that change their color emissions as the input voltage changes. All of these techniques have produced sightings of the researchers' elusive white whale. But until researchers can improve the lifetimes of their devices, their prey will likely elude capture.

–Robert F. Service