The UCLA engineers address this challenge by replacing the rigid ITO anode with a stretchy material — an elastic polymer embedded with single-walled carbon nanotubes (SWCNTs). The elastic polymer on its own lacks the necessary conductivity, while the SWCNTs are conductive but rigid.

"This is not the first time carbon nanotubes have been used as an electrode," says Qibing Pei, a professor of materials science and engineering at UCLA. Typically, CNT electrodes are made by coating these tiny tubes onto a polymer substrate. The problem with this approach is that the CNTs can poke through the light-emitting polymer and create a short. In addition, when the substrate is stretched, the CNTs do not stretch and instead slide past one another.

By embedding the CNTs in a polymer composite, the engineers were able to create a stretchy electrode with a smooth surface.

The rigid metal cathode used in existing OLED devices was also replaced with this polymer-SWNT composite. Using the same material for both the anode and the cathode was made possible by the formation of a p-i-n junction, which is a semiconductor with three distinct regions: p-type (positive), i-type (intrinsic), and n-type (negative).

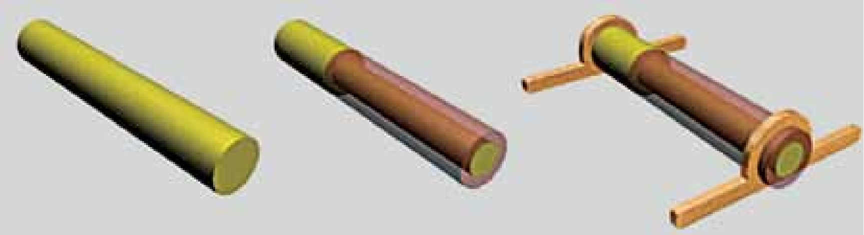
"Normally without the p-i-n junction, the typical OLED device would need different materials for the two electrodes — a high work function anode and a low work function cathode," Pei explains. "We are able to create a p-i-n junction, not because of the CNT electrodes, but because of what we put in the emissive polymer layer."

The light-emitting layer between the electrodes consists of an emissive copolymer, an ionic conductor, and a salt. The junction is formed by applying a voltage to the structure.

The resulting proof-of-concept OLED device still needs work before it can be used in rollable displays and other novel electronics. Pei says that his team is pursuing several paths to improve the device's performance.

Nanowires Hold Promise for Future Solar Cells

Nanowires could be the key to low-cost, efficient solar cells. They require small amounts of active material (which keeps costs down), can be made



▲ The solar nanowires are made by first dipping a CdS nanowire (green) into a solution of CuCl, where cation exchange creates a Cu_2S shell coating (brown). Metal contacts are then deposited on the CdS core and Cu_2S shell. Image courtesy of Yang, *et al.*

with relatively simple manufacturing processes, and exhibit superior light-trapping ability. So far, however, their ability to convert the trapped sunlight into electricity (*i.e.,* efficiency) has been elusive.

Now, researchers at the Lawrence Berkeley National Laboratory have come up with a way to make these nanowires more efficient.

The team, led by Peidong Yang, a professor of chemistry at the Univ. of California at Berkeley, used solution chemistry to produce nanowires of cadmium sulfide (CdS) and copper sulfide (Cu_2S) with a core-shell structure. The resulting solar cells had an efficiency of 5.4% — comparable to that of planar cells made of the same materials.

"This is an important step forward in showing that it is possible to have good efficiency from materials that are made by relatively straightforward scalable solution-based processing," says Nate Lewis, a professor of chemistry at the California Institute of Technology, who is considered an expert on nanowires but was not involved in this research.

This is not the first time that core-shell nanowires have been used in photovoltaics. Yang and his team previously demonstrated this technology with silicon-based photovoltaics. They found that replacing the planar p-n junction with a radial one, which was formed with p-type silicon as the core and n-type silicon as the shell of the nanowires, improved the light-trapping ability of solar cells by a factor of 73. The efficiency of these solar cells was only 5–6%, however, which is much lower than the 20% achieved with planar silicon photovoltaics.

The researchers applied the same core-shell nanowire strategy to CdS and Cu_2S. The solar cells were fabricated by making nanowires of CdS via physical vapor transport using a vapor-liquid-solid mechanism. The CdS nanowires were then dipped into a solution of copper chloride (CuCl) at 50°C, which through cation exchange converted the surface of the CdS into Cu_2S.

"The solution-based cation exchange reaction provides us with an easy, low-cost method to prepare high-quality heteroepitaxial nanomaterials," says Yang. "Furthermore, it circumvents the difficulties of high-temperature doping and deposition for typical vapor-phase production methods, which suggests much lower fabrication costs and better reproducibility. All we really need are beakers and flasks for this solution-based process," Yang adds.

The research team has taken one more step toward realizing the potential of nanowires in solar cells. They have applied the core-shell nanowire concept to abundant, nontoxic semiconductor materials using low-cost processes. The next step will be to eliminate the cadmium component, Yang says.

The team's goal is to create core-shell nanowire solar cells prepared with low-energy-intensity processes, made entirely of all abundant, nontoxic elements, with energy conversion efficiencies of 10% to 15%.

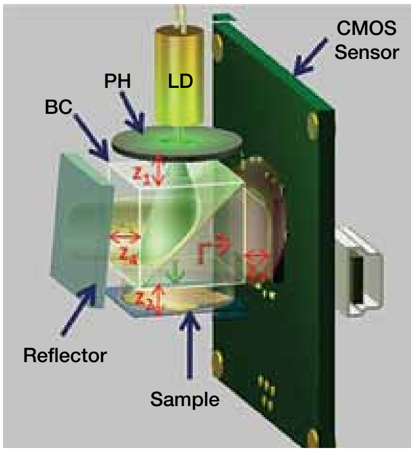
INSTRUMENTATION

Handheld Microscope Uses Holograms Instead of Lenses

Scientists from the Univ. of California at Los Angeles (UCLA) have made a dual-mode microscope that fits into the palm of a hand. Potential applications for the handheld device include water quality monitoring, blood testing for the presence of bacteria, and screening for common diseases in the field.

"This is the first demonstration of essentially a handheld version of a microscope that can do dual-mode imaging within a very compact and cost-effective form," says Aydogan Ozcan, an associate professor of electrical engineering and bioengineering at UCLA.

The portable microscope weighs about 200 g (about the same as a medium-sized banana), and has dimensions of 15 cm × 5.5 cm × 5 cm. To achieve this slight profile, the research team nixed the bulky lenses that typical microscopes rely on and



▲ When operating in reflection mode, laser light from a laser diode (LD) is projected through a pinhole (PH) and then split into two beams by a beam cube (BC). One beam of light hits the sample; the other does not. The beams are then reunited to form an interference pattern, which is recorded on a CMOS image sensor. Image courtesy of Ozcan BioPhotonics Group at UCLA and *Biomedical Optics Express.*