Cheap, plastic solar cells may be on the horizon, thanks to new technology developed by UC Berkeley, LBNL chemists

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By Bob Sanders, Media Relations

Berkeley - University of California, Berkeley, chemists have found a way to make cheap plastic solar cells flexible enough to paint onto any surface and potentially able to provide electricity for wearable electronics or other low-power devices.

The group's first crude solar cells have achieved efficiencies of 1.7 percent, far less than the 10 percent efficiencies of today's standard commercial photovoltaics. The best solar cells, which are very expensive semiconductor laminates, convert, at most, 35 percent of the sun's energy into electricity.

"Our efficiency is not good enough yet by about a factor of 10, but this technology has the potential to do a lot better," said A. Paul Alivisatos, professor of chemistry at UC Berkeley and a member of the Materials Science Division of Lawrence Berkeley National Laboratory. "There is a pretty clear path for us to take to make this perform much better."

Alivisatos and his co-authors, graduate student Wendy U. Huynh and post-doctoral fellow Janke J. Dittmer, report their development in the March 29 issue of *Science*.

"The beauty of this is that you could put solar cells directly on plastic, which has unlimited flexibility," Dittmer said. "This opens up all sorts of new applications, like putting solar cells on clothing to power LEDs, radios or small computer processors."

A panel of eight plastic solar cells based on inorganic nanorods and semiconducting polymers. The shiny ovals are the aluminum back electrodes of the individual solar cells.

The solar cell they have created is actually a hybrid, comprised of tiny nanorods dispersed in an organic polymer or plastic. A layer only 200 nanometers thick is sandwiched between electrodes, and can produce, at present, about 0.7 volts. The electrode layers and nanorod/polymer layers could be applied in separate coats, making production fairly easy. And unlike today's semiconductor-based photovoltaic devices, plastic solar cells can be manufactured in solution in a beaker without the need for clean rooms or vacuum chambers.

"Today's high-efficiency solar cells require very sophisticated processing inside a clean room and complex engineering to make the semiconductor sandwiches," Alivisatos said. "And because they are baked inside a vacuum chamber, they have to be made relatively small."

The team's process for making hybrid plastic solar cells involves none of this.

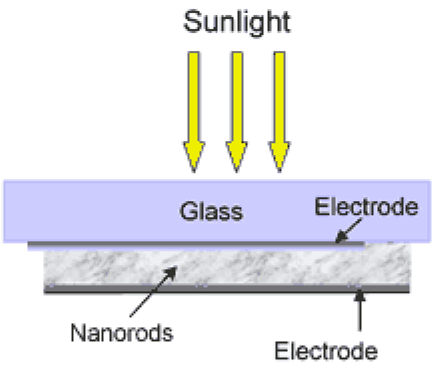
"We use a much dirtier process that makes it cheap," Huynh said.

The technology takes advantage of recent advances in nanotechnology, specifically the production of nanocrystals and nanorods pioneered by Alivisatos and his laboratory colleagues. These are chemically pure clusters of from 100 to 100,000 atoms with dimensions on the order of a nanometer, or a billionth of a meter. Because of their small size, they exhibit unusual and interesting properties governed by quantum mechanics, such as the absorption of different colors of light depending upon their size.

It was only two years ago that a UC Berkeley team led by

Alivisatos found a way to make nanorods of a reliable size out of cadmium selenide, a semiconducting material. Conventional semiconductor solar cells are made of polycrystalline silicon or, in the case of the highest efficiency ones, crystalline gallium arsenide.

Huynh and Dittmer manufactured nanorods in a beaker containing cadmium selenide, aiming for rods of a diameter - 7 nanometers - to absorb as much sunlight as possible. They also aimed for nanorods as long as possible - in this case, 60 nanometers. They then mixed the nanorods with a plastic semiconductor, called P3HT - poly-(3-hexylthiophene) - and coated a transparent electrode with the mixture. The thickness, 200 nanometers - a thousandth the thickness of a human hair - is a factor of 10 less than the micron-thickness of semiconductor solar cells. An aluminum coating acting as the back electrode completed the device.



Schematic diagram of a hybrid "plastic" solar cell with a nanorod/polymer layer sandwiched between two electrodes. The middle layer, a mere 200 nanometers thick, is a jumble of nanorods embedded in the semiconducting polymer.

The nanorods act like wires. When they absorb light of a specific wavelength, they generate an electron plus an electron hole - a vacancy in the crystal that moves around just like an electron. The electron travels the length of the rod until it is collected by the aluminum electrode. The hole is transferred to the plastic, which is known as a hole-carrier, and conveyed to the electrode, creating a current.

P3HT and similar plastic semiconductors currently are a hot area of research in solar cell technology, but by themselves these plastics are lucky to achieve light-conversion efficiencies of several percent.

"All solar cells using plastic semiconductors have been stuck at two percent efficiency, but we have that much at the beginning of our research," Huynh said. "I think we can do so much better than plastic electronics."

"The advantage of hybrid materials consisting of inorganic semiconductors and organic polymers is that potentially you get the best of both worlds," Dittmer added. "Inorganic semiconductors offer excellent, well-established electronic properties and they are very well suited as solar cell materials. Polymers offer the advantage of solution processing at room temperature, which is cheaper and allows for using fully flexible substrates, such as plastics."

Visiting scientist Keith Barnham, professor of physics at Imperial College, London, and an expert on high-efficiency solar cells, agreed.

"This is exciting, cheap technology if they can get the efficiency up to 10 percent, which I think they will, in time," Barnham said. "Paul's approach is a very promising way to get around the problem of the efficiency of plastic solar cells."

Some of the obvious improvements include better light collection and concentration, which already are employed in commercial solar cells. But Alivisatos and his colleagues hope to make significant improvements in the plastic/nanorod mix, too, ideally packing the nanorods closer together, perpendicular to the electrodes, using minimal polymer, or even none - the nanorods would transfer their electrons more directly to the electrode. In their first-generation solar cells, the nanorods are jumbled up in the polymer, leading to losses of current via electron-hole recombination and thus lower efficiency.

They also hope to tune the nanorods to absorb different colors to span the spectrum of sunlight. An eventual solar cell might have three layers, each made of nanorods that absorb at different wavelengths.

"For this to really find widespread use, we will have to get up to around 10 percent efficiency," Alivisatos said. "But we think it's very doable."

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