Sunny Future for Nanocrystal Solar Cells

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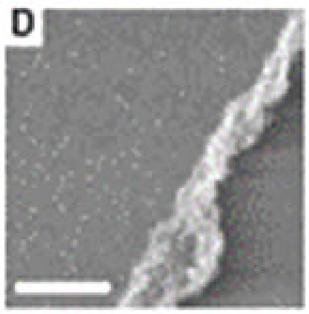

Imagine a future in which the rooftops of residential homes and commercial buildings can be laminated with inexpensive, ultra-thin films of nano-sized semiconductors that will efficiently convert sunlight into electrical power and provide virtually all of our electricity needs. This future is a step closer to being realized, thanks to a scientific milestone achieved at the U.S. Department of Energy's Lawrence Berkeley National Laboratory.

Image above: This image, which was produced through scanning electron microscopy, shows a typical spin-cast film of nanocrystal solar cells that is homogeneous and defect free. The film edge of this 100 nanometer film is shown for contrast with the silicon substrate.

Researchers with Berkeley Lab and the University of California, Berkeley, have developed the first ultra-thin solar cells comprised entirely of inorganic nanocrystals and spin-cast from solution. These dual nanocrystal solar cells are as cheap and easy to make as solar cells made from organic polymers and offer the added advantage of being stable in air because they contain no organic materials.

“Our colloidal inorganic nanocrystals share all of the primary advantages of organics — scalable and controlled synthesis, an ability to be processed in solution, and a decreased sensitivity to substitutional doping – while retaining the broadband absorption and superior transport properties of traditional photovoltaic semiconductors,” said Ilan Gur, a researcher in Berkeley Lab’s Materials Sciences Division and fourth-year graduate student in UC Berkeley’s Department of Materials Science and Engineering.

Gur is the principal author of a paper appearing in the October 21 issue of the journal Science that announces this new development. He is a doctoral candidate in the research group of Paul Alivisatos, director of Berkeley Lab’s Materials Sciences Division, and the Chancellor's Professor of Chemistry and Materials Science at UC Berkeley . Alivisatos is a leading authority on nanocrystals and a co-author of the Science paper. Other co-authors are Berkeley Lab’s Neil A. Fromer and UC Berkeley’s Michael Geier.

In this paper, the researchers describe a technique whereby rod-shaped nanometer-sized crystals of two semiconductors, cadmium-selenide (CdSe) and cadmium-telluride (CdTe), were synthesized separately and then dissolved in solution and spin-cast onto a conductive glass substrate. The resulting films, which were about 1,000 times thinner than a human hair, displayed efficiencies for converting sunlight to electricity of about 3 percent. This is comparable to the conversion efficiencies of the best organic solar cells, but still substantially lower than conventional silicon solar cell thin films.

“We obviously still have a long way to go in terms of energy conversion efficiency,” said Gur, “but our dual nanocrystal solar cells are ultra-thin and solution-processed, which means they retain the cost-reduction potential that has made organic cells so attractive vis-a-vis their conventional semiconductor counterparts.”

As every consumer in this country is painfully aware, the costs of fossil fuels are rising. From escalating prices at gas pumps, to melting polar ice caps, the message is loud and clear: Alternative energy sources must be found. Solar energy is in many ways an ideal choice. As a source it is plentiful – the sun shines approximately 1,000 watts of energy per square meter of the planet's surface every day – and would last the lifetime of our planet. It would add no pollutants to the atmosphere, contribute nothing to global climate change, and is free. The cost comes in when solar energy is converted to electrical power.

Most commercial solar cells today are made from silicon. Like many conventional semiconductors, silicon offers excellent, well-established electronic properties. However, the use of silicon or other conventional semiconductors in photovoltaic devices has to date been limited by the high cost of production — even the fabrication of the simplest semiconductor cell is a complex process that has to take place under exactly controlled conditions, such as high vacuum and temperatures between 400 and 1,400 degrees Celsius.

When it was discovered, back in 1977, that a certain group of “conjugated” organic polymers could be made to conduct electricity, there was immediate interest in using these materials in photovoltaic devices. While it was shown that plastic solar cells could be made in bulk quantities for a few cents each, the efficiency by which these devices converted light into electricity has always been poor compared to the power conversion efficiencies of cells made from semiconductors. In 2002, Alivisatos and members of his research group announced a breakthrough in which they were able to fashion hybrid solar cells out of organic polymers and CdSe. While these hybrids offer some of the best features of semiconductor and plastic solar cells, they remain sensitive to air because they contain organics.

“A solar cell that relies exclusively on colloidal nanocrystals has been anticipated theoretically in recent years,” said Alivisatos. “We’ve now demonstrated such a device and have presented a mechanism for its operation.”

Unlike conventional semiconductor solar cells, in which an electrical current flows between layers of n-type and p-type semiconductor films, with these new inorganic nanocrystal solar cells, current flows due to a pair of molecules that serve as donors and receptors of electrical charges, also known as a donor-acceptor heterojunction. This is the same mechanism by which current flows in plastic solar cells.

“Because our inorganic nanocrystal solar cells appear to work primarily based on the donor-acceptor heterojunction model that is typical of organic systems, they help us to better understand the specific material properties needed to make such devices,” said Gur. “This work also elucidates some key similarities between polymer and nanocrystal films.”

The CdSe and CdTe films are electrical insulators in the dark but when exposed to sunlight undergo a dramatic rise in electrical conductivity, as much as three orders of magnitude. Sintering the nanocrystals was found to significantly enhance the performance of these films. Unlike plastic solar cells, whose performance deteriorates over time, aging seems to improve the performance of these inorganic nanocrystal solar cells.

“The next step is for us to better characterize and further develop our prototypical system, as there is still a great deal we don't fully understand," said Gur. "After that, we have a lot of directions that we'd like to pursue, such as introducing variations in the system architecture and our choice of semiconductor materials."

According to the Energy Foundation, if the available residential and commercial rooftops in this country were to be coated with solar cell thin films, they could furnish an estimated 710,000 megawatts of electricity across the United States, which is more than three-quarters of all the electricity that this country is currently able to generate. Because of its favorable sunlight levels, California is considered a prime candidate for this technology.

Soruce: Berkeley Lab