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Researchers prepare cheap quantum dot solar paint

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Titanium dioxide nanoparticles are coated with CdS or CdSe. The composite nanoparticles, when mixed with a solvent, form a paste that can be applied as one-step paint. Image credit: Mathew P. Genovese, et al. ©2011 American Chemical Society

(PhysOrg.com) -- It typically takes a day or two to prepare quantum dot solar cells in the conventional multifilm architecture. Now a team of researchers is reducing the preparation time of quantum dot solar cells to less than an hour by changing the form to a one-coat quantum dot solar paint. Although the paint form is currently about five times less efficient than the highest recorded efficiency for the multifilm form, the researchers predict that the efficiency can be improved, which could lead to a simple and economically viable way to prepare solar cells.

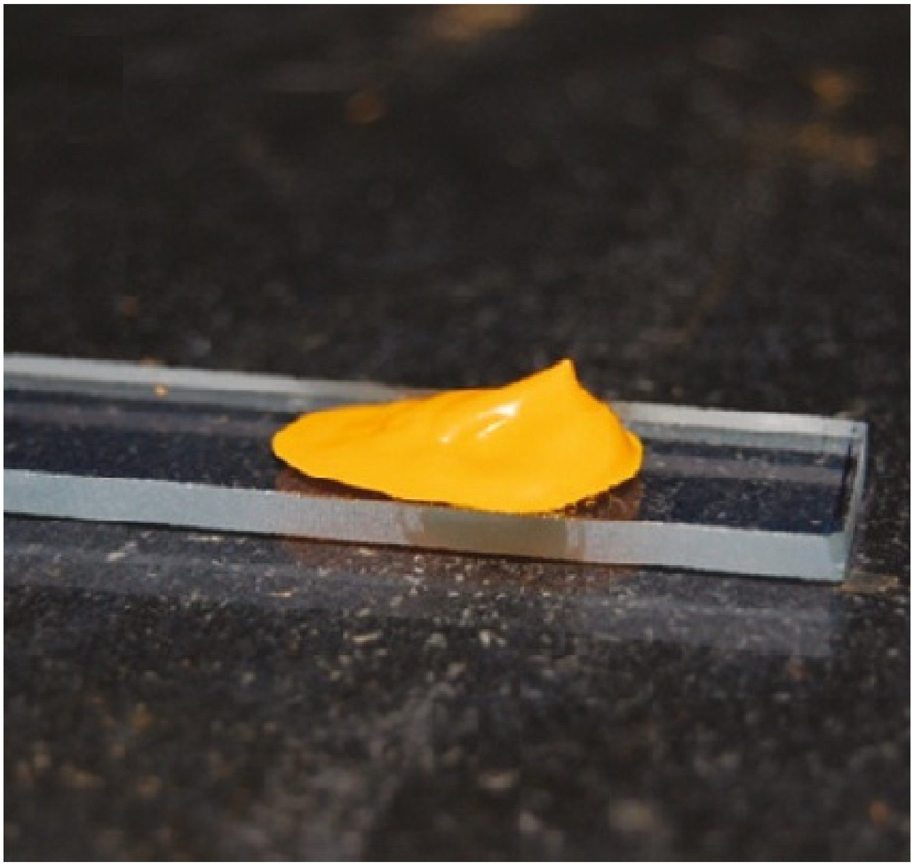
The researchers, Mathew P. Genovese of the University of Waterloo in Canada, with Ian V. Lightcap and Prashant V. Kamat of the Radiation Laboratory and Department of Chemistry and Biochemistry at the

University of Notre Dame in Indiana, will be publishing their study in an upcoming issue of *ACS* Nano.

The new solar paint, which the researchers humorously call “Sun Believable solar paint,” consists of a yellow or brown paste made of quantum dots. The small size of these tiny semiconductor nanocrystals makes it possible to capture nearly all incident visible sunlight with an extremely thin layer of dots. The researchers experimented with three types of quantum dots: CdS, CdSe, and TiO_2, all of which are powder-like, with water and tert butanol as the solvent. As Kamat explained, all commercial paints are TiO_2 nanoparticle-based suspensions. But instead of adding dye to give the paint a desired color, here the researchers added colored semiconductor nanocrystals to the solar paint to achieve the desired optical and electronic properties.

“Quantum dots are semiconductor nanocrystals which exhibit size-dependent optical and electronic properties,” Kamat told *PhysOrg.com*. “In a quantum dot sensitized solar cell, the excitation of semiconductor quantum dot or semiconductor nanocrystal is followed by electron injection into TiO_2 nanoparticles. These electrons are then transferred to the collecting electrode surface to generate photocurrent. The holes that remain in the semiconductor quantum dot are removed by a hole conductor or redox couple and are transported to a counter electrode.”

As Kamat explains, solar paint has advantages in simplicity, economics, and stability compared to multifilm solar cell architectures. While preparing a quantum dot film as a solar cell usually requires multiple time-intensive steps, solar cells in paint form can simply be brushed on to a surface in one step.



Application of solar paint to an optically transparent electrode. Image credit: Mathew P. Genovese, et al. ©2011 American Chemical Society

“If we can optimize the paint preparation, it should be possible for anyone to open a bottle (or a can in the long run) and apply it to a conducting surface,” he said. “This will decrease the variability between lab to lab or person to person as one encounters in a multi-step process. Having fewer fabrication steps and ambient preparative conditions should provide an economically viable transformative technology.”

The researchers experimented with several different combinations and ratios of the quantum dots to make different paint mixtures. They found that a composite of mixed CdS/TiO_2 and CdSe/TiO_2 nanoparticles achieve the best performance, particularly when the CdS and CdSe are deposited directly on the TiO_2 nanoparticles as a coating. When coated on a glass electrode, the paint has an overall power conversion efficiency exceeding 1%. Although some multifilm quantum dot solar cells have efficiencies greater than 5%, the researchers think that using different quantum dots and further optimization could significantly increase the efficiency of the paint.

“Careful control of particle size and better electron transport through TiO_2 network should enable us to maximize the efficiency,” Kamat said. “We will also extend the absorption range to near IR by using semiconductors such as PbS and PbSe. Our short term goal is to attain efficiencies greater than 5%, comparable with other semiconductor nanocrystal-based solar cells.”

The new solar paint is the first step toward developing a solar technology that could potentially have wide-ranging applications. Some uses could include painting electronic devices such as cell phones and computers, in addition to rooftops, windows, and cars. Large-scale applications could be used to build solar farms in deserts.

“The goal is to prepare a solar paint that has long shelf life,” Kamat said. “In our laboratories we have tested the performance for a few days to a week, and we find it stable as long as it is stored in the dark. Additional tests are underway to investigate long-term stability of paints with different compositions.”

In order to develop a commercial product, the researchers still have to work on two other components of the solar cell paint.

“The solar paint developed in this study is only one component of the solar cell,” Kamat said. “The other two components that need further development are a hole conducting layer and a counter electrode network. We will continue the theme of simplicity and versatility to develop these other two remaining steps. The present study is the first step in developing a transformative technology for solar cells."

More information: Mathew P. Genovese, et al. "Sun-Believable Solar Paint. A Transformative One-Step
Approach for Designing Nanocrystalline Solar Cells." *ACS Nano*. To be published. DOI: 10.1021/nn204381g

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