# 'Superstructured' solar cells achieve record efficiency of 10.9%

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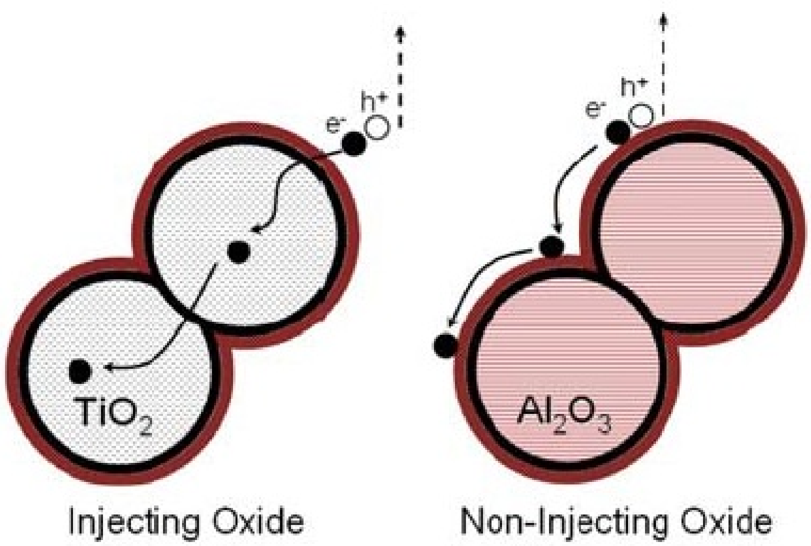


A comparison of the charge transfer and transport in (left) a solar cell with a titanium dioxide electrode (where excitons travel through the titanium dioxide) and (right) a solar cell with an alumina electrode (where excitons travel more quickly through the thin perovskite layer). Credit: Michael M. Lee, et al. ©2012 AAAS

(Phys.org)—It may sound counterintuitive that replacing one of the most photosensitive solar cell materials with a material with less desirable photosensitive properties can improve the solar cell's efficiency, but that's what scientists have shown in a new study. By replacing the highly photosensitive titanium dioxide ($TiO_2$) with alumina ($Al_2O_3$) in a solution-processable solar cell, the researchers have achieved a record power conversion efficiency of 10.9%. They attribute this high efficiency to the $Al_2O_3$ acting as an inert scaffold, forcing the electrons to remain within and be transported through an extremely thin absorber (ETA) layer.

The researchers, led by Henry J. Snaith at the University of Oxford in the UK, with coauthors from the University of Oxford, Toin University of Yokohama in Japan, and the National Institute of Advanced Industrial Science and Technology in Ibaraki, Japan, have published their study on the highly efficient solar cells in a recent issue of *Science*.

"This is a new technology, so in essence a new record," Snaith told *Phys.org*. "All solar cell technologies have different efficiencies, with GaAs being the highest at over 28%. This is not an absolute world record, but probably the highest for a solution-processable solid-state solar cell. And the real excitement is where it may reach over the next few years; it should have a steep improvement curve."

The choice of electrode material in a solar cell is one of the most important factors contributing to solar cell efficiency, and $TiO_2$ is often used as an electrode material in solution-processable solar cells due to its good ability for photoexcitation, or converting photons into electrons, as well as its strong electron-accepting properties when photosensitized with a dye or absorber.

But in order to improve solar cell efficiency, the scientists here addressed the fundamental energy losses that arise throughout the photovoltaic process of absorbing photons and generating electrons. As they explain, energy is lost during the photogeneration of electron-hole pairs (excitons), the separation of tightly bound excitons, and the extraction of free electrons from highly disordered networks.

In attempts to overcome these losses, previous research has investigated the use of coating an ETA layer, 2 to 10 nm in thickness, on the internal surface of the $TiO_2$ electrode in order to increase the current density and voltage. So far, solar cells with ETA layers have achieved power conversion efficiencies of up to 6.3%.

Here, the researchers have investigated the possibility that $TiO_2$ may be hindering the effectiveness of the ETA layer due to its electronic disorder and low mobility. Because $Al_2O_3$ is a wide band gap insulator, the researchers found that, when it's used as the electrode, the photoexcited electrons remain in the ETA layer and do not drop to lower energy levels in the oxide as they do in the $TiO_2$ electrode.

This difference offers several advantages. For instance, the researchers found that using $Al_2O_3$ significantly speeds up the electron transport process, forcing electrons to quickly travel through a perovskite ETA layer, and also increases the voltage. These improvements increased the power conversion efficiency from 8% with the $TiO_2$ electrode to 10.9% with the $Al_2O_3$ electrode. Because the $Al_2O_3$ is mainly acting as a meso-scale scaffold, and does not play a role in photoexcitation, the researchers call this device a "meso-superstructured solar cell" (MSSC).

"The alumina is acting as a scaffold for the perovskite layer, and subsequently the hole-conductor which is coated on top of the perovskite layer," Snaith said. "It is not electronically active, but purely acting as a physical support.

"It is very surprising and would not have been predicted," he added. "However, in hindsight we can see where the efficiency gains come from. The real surprise is that the perovskite layer is so effective at transporting charge and generating high photovoltage in the solar cell."

The scientists expect that the efficiency can be further improved in the future by various means, such as experimenting with new perovskites, using other semiconductors, and extending the absorption range.

"This work moves low-cost solution-processable solar cells significantly closer to the performance of perfectly crystalline semiconductors, while at the same time opening extensive possibilities for future research and development," Snaith said.

**More information:** Michael M. Lee, et al. "Efficient Hybrid Solar Cells Based on Meso-Superstructured Organometal Halide Perovskites." *Science Express*. DOI: 10.1126/science.1228604