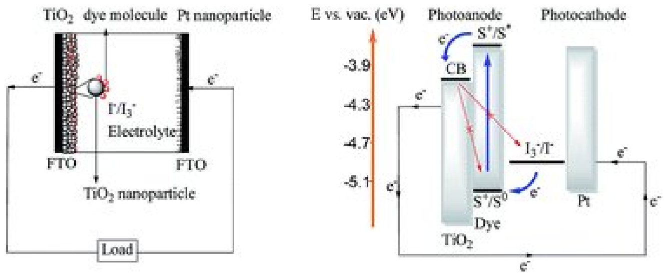
Solar cell discovery opens a new window to powering tomorrow's cities

23 November 2017, by Ron Walli



Credit: Argonne National Laboratory

Buildings of the future may come equipped with windows that can generate their own electricity, thanks to a finding of a team led by Jacqui Cole, a materials scientist from the University of Cambridge, UK, currently based at the U.S. Department of Energy's (DOE) Argonne National Laboratory.

For the first time, Cole and colleagues determined the molecular structure of working solar cell electrodes within a fully assembled device that works like a window. The finding, published in *Nanoscale*, helps advance smart window technology that could enable cities to move closer to the goal of being energy sustainable.

The experiments were performed on dye-sensitized solar cells, which are transparent and thus well-suited for use in glass. Attempts to create smart window technologies have been limited by the many unknown molecular mechanisms between the electrodes and electrolyte that combine to determine how the device operates.

"Most previous studies have modeled the molecular function of these working electrodes without considering the electrolyte ingredients," Cole said. "Our work shows that these chemical ingredients can clearly influence the performance of solar cells, so we can now use this knowledge to tune the ions to increase photovoltaic efficiency."

To make the discovery, Cole—the 1851 Royal Commission 2014 Design Fellow—and her colleagues used neutron reflectometry to probe the function and interplay of the electrolyte ingredients with electrodes of the dye-sensitized solar cells. Neutron reflectometry, similar to X-ray reflectometry techniques, allows scientists to measure the structure of thin films with high resolution. But it was the fact that the tests were performed in a window-like system that made for a significant discovery.

"Prior research considered the working electrodes outside the device, so there has been no path to determine how the different device components interact," Cole said. "Our work signifies a huge leap forward as it's the world's first example of applying in situ neutron reflectometry to dye-sensitized solar cells."

Previous efforts to characterize the dye/titanium dioxide interface in these solar cells have been limited to determining this interfacial structure within an environment exposed to air or in a solvent medium. Because of these constraints, these solar cell environments are essentially artificial with limited relevance for window applications.

With this discovery, however, Cole and colleagues have moved beyond artificial constraints. In doing so, they can better understand how a thin-film electrode containing titanium dioxide, a naturally occurring compound found in paint, sunscreen and food coloring, can have a huge impact on solar cell efficiency.

"Our work has shown that certain chemical ingredients, some of which have so far been overlooked, can clearly influence the photovoltaic performance of these solar cells," Cole said.

More efficient solar cells like these can move smart window technology closer to the marketplace, said Cole, adding that the science is almost there.

"We just need a modest boost in performance to make these solar cells competitive," Cole said, "since price-to-performance governs the economics of the solar cell industry. And manufacturing dye-sensitized solar cells is very cheap relative to other solar cell technologies."

Performance-wise, the cells recently broke a world record with a power conversion efficiency of 14.3 percent using a dye-sensitized electrode featuring two co-sensitized metal-free organic dyes. These dyes "promise cheaper, more environmentally friendly synthetic routes and greater molecular design flexibility than their metal-containing counterparts," according to the paper.

The discovery was made with colleagues from the University of Cambridge, United Kingdom, the Australian Nuclear Science and Technology Organization and the Rutherford Appleton Laboratory, UK. Researchers are continuing to apply this materials characterization technique to dye-sensitized solar cells, which could reveal further molecular secrets and lead the way to future energy applications.

More information: Lei Zhang et al. Dye aggregation in dye-sensitized solar cells, *J. Mater. Chem. A* (2017). DOI: 10.1039/C7TA05632J

Provided by Argonne National Laboratory