NATIONAL RENEWABLE ENERGY LABORATORY

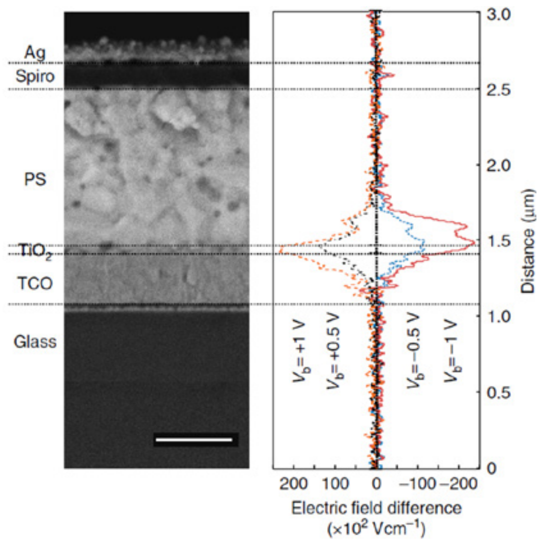
NREL Studies Carrier Separation and Transport in Perovskite Solar Cells

Highlights in Research & Development

The discovery of a *p-n* junction in these solar devices may help to advance R&D toward better cell performance.

Studies by scientists at the National Renewable Energy Laboratory (NREL) are exploring the detailed physics involved in the operations of perovskite solar cells. These cells have shown increasingly high power conversion efficiencies over the last few years; however, the continued improvement in cell performance requires a deeper understanding of the basic physics and chemistry around perovskites and perovskite solar cells.

NREL is focusing research on the electrical field distribution in two perovskite solar cell structures—a planar structure and a porous titanium dioxide (TiO_2)-based structure. The Kelvin probe force microscopy (KPFM) characterization technique is being used to detail the intricacies of the electrical field distribution. Key outcomes of the KPFM studies reveal that the field distribution is dominated by a *p-n* junction, with free charge carriers being collected by diffusion toward the *p-n* junction at the TiO_2/perovskite interface.



Potential profiling and layer structure of a thick planar TiO_2/perovskite device. (Left) Scanning electron microscopy image of cross-section of 1-micrometer-thick planar device. (Right) Changes in the electric field by voltage biases. Scale bar is 500 nm. Illustration by NREL

Until now, the nature of photocarriers in perovskite cells has been unclear—whether the photocarriers are excitons or free carriers. The research community has typically thought the electrical field in perovskite solar cells to be *p-i-n*-like because of the organic-inorganic hybrid light-absorber materials. Such knowledge undergirds the understanding of the photovoltaic effect in perovskites, yet, it has not been completely understood. NREL's discovery of a *p-n* junction significantly contributes to the critical need for understanding this new material/device and opens the door to a new research and development path by recognizing similarities to inorganic thin-film solar cells.

The KPFM technique profiles the electrical field across the perovskite devices with both optimized and increased thicknesses of the absorber layer, and it reveals surface potential changes resulting from the position of the junction in the device. The surface potential relates directly to changes in the electrical field within the device. One conclusion is that improving mobility is a rational route for enhancing conversion efficiency. Future research can compare the mobility-improved devices with the electrical field distribution and then compare it with inorganic thin-film devices.

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Reference: C.-S.Jiang; M. Yang; Y. Zhou; B. To; S.U. Nanayakkara; J.M. Luther; W. Zhou; J.J. Berry; J. van de Lagemaat; N.P. Padture; K. Zhu; M.M Al-Jassim. "Carrier separation and transport in perovskite solar cells studied by nanometer-scale profiling of electrical potential," *Nature Communications* 6, 8397 (2015). DOI: 10.1038/ncomms9397

Key Research Results

Achievement

NREL scientists studied charge separation and transport in perovskite solar cells by determining the junction structure across the solar device using the nanoelectrical characterization technique of Kelvin probe force microscopy.

Key Result

The distribution of electrical potential across both planar and porous devices demonstrates a *p-n* junction structure at the interface between titanium dioxide and perovskite. In addition, minority-carrier transport within the devices operates under diffusion/drift.

Potential Impact

Clarifying the fundamental junction structure provides significant guidance for future research and development. This NREL study points to the fact that improving carrier mobility is a critical factor for continued efficiency gains in perovskite solar cells.

NREL is a national laboratory of the U.S. Department of Energy, Office of Energy Efficiency and Renewable Energy, operated by the Alliance for Sustainable Energy, LLC.

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NREL/FS-5K00-65783 | January 2016

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