NREL
NATIONAL RENEWABLE ENERGY LABORATORY

High-Efficiency CdTe Ink-Based Solar Cells Using Nanocrystals

Highlights in Science

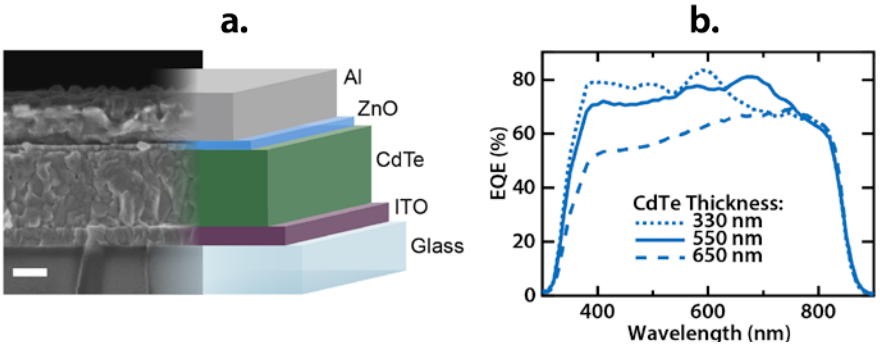
NREL researchers create a solution-processable "ink" to produce high-efficiency solar cells using low temperature and simple processing.

Colloidal nanocrystals (NCs) provide a route toward simplified manufacturing of electronic devices compared to vacuum-based technology. Scientists from the National Renewable Energy Laboratory (NREL) collaborated with researchers at the University of Chicago on the colloidal synthesis of 5–10-nm crystals by using the solution as an ink to form large grains of CdTe when cast into a film and heated. Colloidal synthesis prior to film deposition enables tunable stoichiometry, control of crystal phases, and nearly 100% conversion of material precursors into the final product.

The researchers studied the role of the NC ink properties on grain growth, and how device architecture and film processing further affect device performance. They explored the use of optimized ink in five different device architectures. The highest external quantum efficiency across the largest spectral width was obtained using a superstrate configuration, with a sol-gel ZnO:In heterojunction (see figure). Based on the spectral response, larger open-circuit voltage, and best fill factor of all studied devices, this structure shows the most promise for efficiently extracting charges from smooth, thin CdTe films made of sintered NCs.

The processing of CdTe NCs from conventional colloidal NC synthesis was optimized in a preceding publication in *Nano Letters*. The CdTe material was deposited via spin-coating as eight to twelve sequential layers. Annealing these layers yields uniform CdTe with large columnar grains that span between the indium tin oxide (ITO) and ZnO layers (see figure).

The resulting efficiency of the finished device was greatly increased to more than 12% by optimizing the energetic alignment at the CdTe/ITO interface and the ink shows great potential for large-scale, inexpensive devices manufactured from NCs.



(a): Scanning electron microscope cross-section and schematic of superstrate device architecture showing best performance in NREL study. White scale bar is 250 nm. (b): External quantum efficiency for three thicknesses of CdTe used in the structure; all three have power conversion efficiency ≥10%. An efficiency ≥10% has not been previously published for such thin CdTe films. Left image by Bobby To and Al Hicks, NREL; right image by Ryan Crisp and Joey Luther, NREL.

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References: Crisp, R.W., et al. (2014). "Nanocrystal Grain Growth and Device Architectures for High-Efficiency CdTe Ink-Based Photovoltaics." *ACS Nano*. Vol. 8(9), 23 Sept 2014; pp. 9063–9072. *http://dx.doi.org/10.1021/nn502442g*

Panthani, M.G., et al. (2014). "High Efficiency Solution Processed Sintered CdTe Nanocrystal Solar Cells: The Role of Interfaces." *Nano Letters*. Vol. 14(2), 12 Feb. 2014; pp 670–675. *http://dx.doi.org/10.1021/nl403912w*

Key Research Results

Achievement

NREL explored grain growth of sintered CdTe NC-based absorber layers, studied device performance in various device architectures, and discovered interfacial conditioning that boosts efficiency.

Key Results

- CdTe deposited from NC inks behaves differently in various structures. An ITO contact with a CdTe/ZnO heterojunction resulted in the highest-efficiency devices using solution processing.
- These devices using ZnO enable broader-band spectral response compared to those with CdS, which is traditionally used in CdTe PV.
- Solar cells made from CdTe NC films and held under illumination at forward bias showed an efficiency increase to 12.3% and a stable, certified 8.5% efficiency.

Potential Impact

NREL's studies are a first step in fully understanding the grain growth required for using NC-based inks in commercial photovoltaic modules. Also, attention to the CdTe/ITO interface proves that CdTe NC inks have potential for producing solar cells with respectable efficiency while using low temperature and simple processing.

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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