BAPVC Annual Project Report

Project Title: Applying Cation-Exchange Chemistry to Nanowire Arrays for Efficient Solution-Processed Solar Cells

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Summary:

This group has developed solution-processed sulfide-based nanowire array solar cells that take advantage of improved charge collection and light-trapping effects in nanowire arrays. Within the past year, this group has achieved power conversion efficiencies approaching 4%. This group is also developing low temperature processing techniques for $CH_3NH_3PbX_3$ nanorod array absorber layers that can be applied for photovoltaic devices.

Key Accomplishments:

In the past year, this group has demonstrated CdS- Cu_2S core-shell nanorod array photovoltaics with efficiencies approaching 4%, and a full description of this project has been recently published.[1] In brief, the fabrication of these solar cells is shown in figure 1a. These photovoltaics are based on CdS nanorod arrays grown by a hydrothermal method on an FTO substrate. After protection layers are added to prevent shorting of the p-type Cu_xS to the n-type contact, the CdS nanorod array can be dipped into an aqueous Cu^+ solution to perform cation exchange to yield an array of CdS-Cu_xS core-shell nanorods. The phase and thickness of the Cu_xS can be controlled by varying the cation exchange temperature and time. A plot of the *I-V* curve of a champion device is shown in figure 1b. Contrary to reports on planar devices, the performance of the device is stable after a period of about one month of storage in an inert atmosphere.

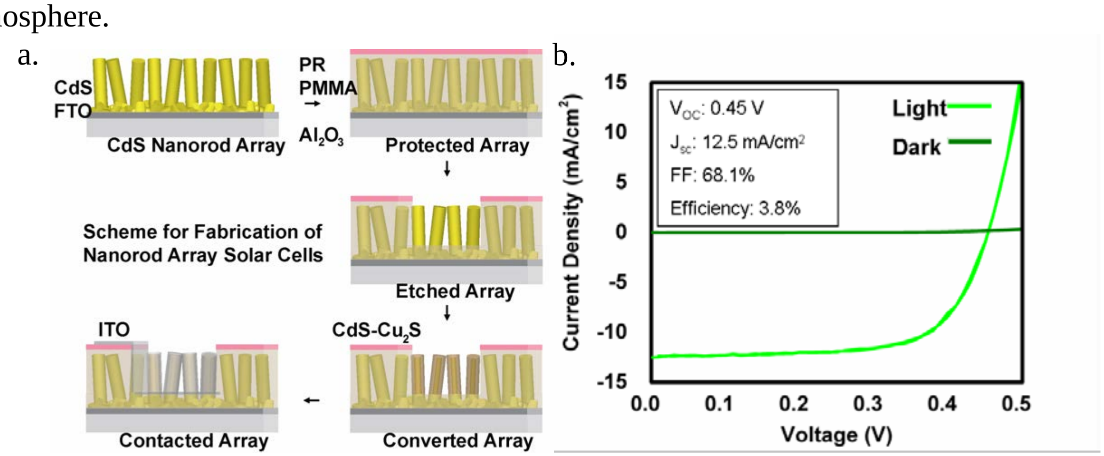

Figure 1. CdS-Cu_2S core-shell nanorod array photovoltaic. a) Schematic for device fabrication. b) *IV* characteristic of a champion device.

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[1] Wong, A.B.; Brittman, S.; Yu. Y.; Dasgupta, N.; Yang, P. *Nano Lett.*, **2015**, 15, 4096-4101.

This group is also developing other new methods for the low temperature processing of nanostructured absorber layers for photovoltaics. This group has recently synthesized hybrid perovskite nanorod arrays with a composition of $CH_3NH_3PbBr_3$, and this group has shown that is it possible to use a vapor phase anion exchange technique to transform this material into $CH_3NH_3PbI_3$ nanorod arrays as shown in Figure 2.

a. b.

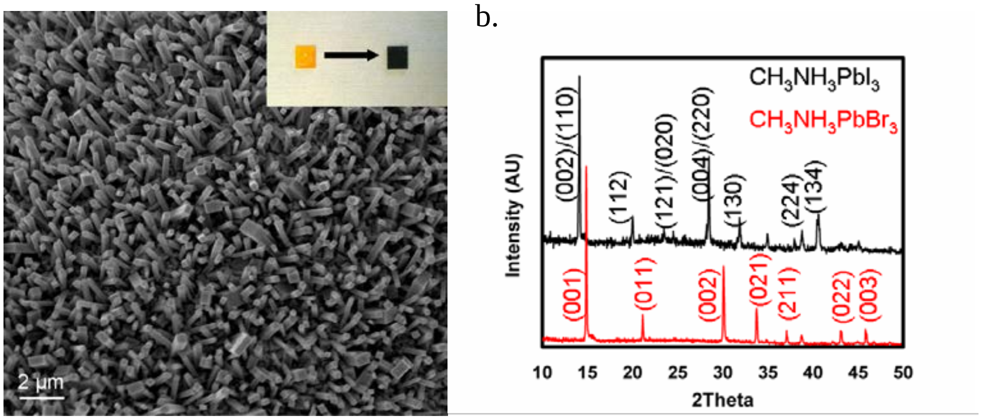

Figure 2. Characterization of $CH_3NH_3PbX_3$ nanorod arrays. a) Scanning electron microscopy image of a $CH_3NH_3PbI_3$ nanorod array after conversion from the as-grown $CH_3NH_3PbBr_3$ nanorod array. b) Powder X-ray diffraction of $CH_3NH_3PbBr_3$ nanorod array and $CH_3NH_3PbI_3$ nanorod array after anion exchange.

Future Work:

Future work will build on the successful fabrication of nanowire photovoltaic devices. This group will optimize performance by tuning the geometry and morphology of the nanowire absorber layer, by controlling the chemistry of the hole and electron transport layers, and by optimizing the design of the electrical contacts to increase device performance beyond current levels.