BAPVC Annual Project Report

Project Title: Properties of TF-VLS InP Solar Cells on Metal Substrates
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Summary:

The work focuses on the successful development and characterization of first generation solar cell devices based on thin-film vapor-liquid-solid (TF-VLS) grown InP absorbers. Promising conversion efficiencies exceeding 12 % are demonstrated. For the employed device architecture, an ex-situ doping process was established to convert the as grown n-InP to p-InP by Zn incorporation. In depth device analysis has been performed to extract the limiting parameters and is complemented by an ongoing collaboration with Oregon University.

Key Accomplishments:

An ex-situ p-type doping process was developed to convert the as-grown n-InP to p-InP by Zn doping via closed space sublimation. Low temperature PL measurements were used to track the different doping stages, Figure 1a. To evaluate the solar cell performance of TF-VLS InP the following device architecture was successfully tested: Mo foil back contact/p-InP/TiO_2/ITO window layer. Cross sectional SEM micrographs of a representative device and a zoom-in image are depicted in Figure 1b.

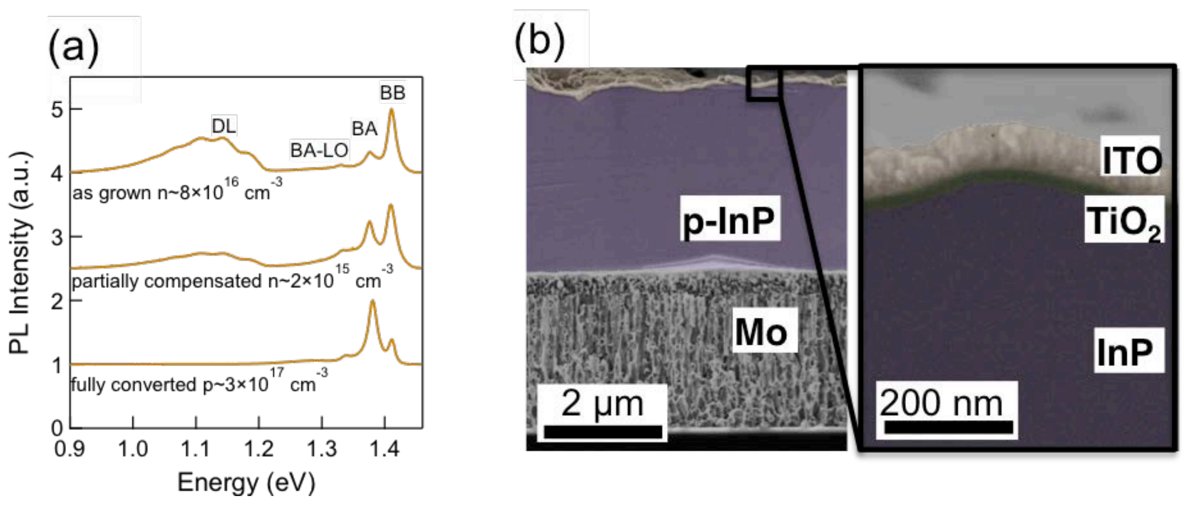

Figure 1. (a) PL spectra of InP taken at 8 K. From top to bottom: as-grown (n~ 8×10^{16} cm^{-3}), partially compensated (n~2×10^{15} cm^{-3}) and fully converted to p-type (p~3×10^{17} cm^{-3}). (b) Cross section SEM image of a completed cell and a higher magnification cross section SEM image of the surface region (SEM images are false colored).

The first generation of TF-VLS devices exhibits efficiencies up to 12.1 % with V_{oc} = 692 mV, J_{sc} = 26.9 mA/cm^2 and FF = 65.0 % (see Figure 2a). The corresponding EQE and 1-R of the cell is shown in Figure 2b.

To investigate the effect of the grain boundaries, electron beam induced current (EBIC) mappings and line measurements were performed on full devices. The dark regions in the EBIC map (Figure 2c) correspond to lower carrier collection. Variations along grains can be seen as well as poor carrier collection at the grain boundaries. EBIC line scans across gain boundaries were used to extract the grain boundary recombination velocity and the minority carrier diffusion length, Figure 2d. The obtained diffusion length is in the range of 1-3 um and is comparable to reported values for CdTe and CIGS based thin film solar cells. However, the extracted grain boundary recombination velocity is about two to three orders of magnitude higher in TF-VLS InP.

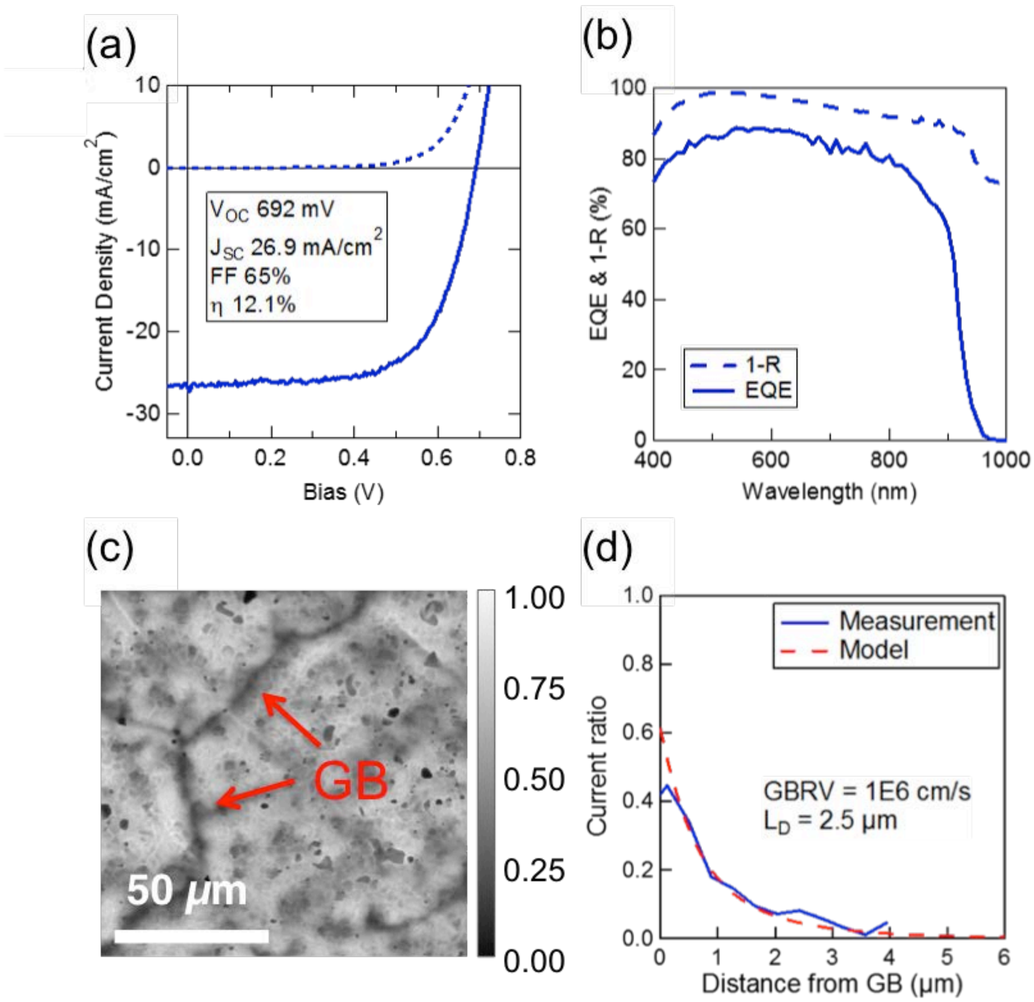

Figure 2. (a) JV measurement under 1 sun illumination and in the dark. (b) Corresponding EQE and 1-R curve. (c) EBIC map on a TF-VLS solar cell device where dark areas represent reduced charge carrier collection. (d) EBIC line scan over a grain boundary.

Future Work:

Future work will focus on the improvement of device efficiency as well as the development of in-situ doping processes and the role of impurities in TF-VLS InP.