BAPVC Annual Project Report

Project Title: Laser Processing to Improve CdTe Thin Film Photovoltaics Efficiency and Manufacturing

PI: **Chris Ferekides; University of South Florida**
E-mail: ferekide@usf.edu

Summary:

This is a collaborative project between the University of South Florida (USF) and the University of Utah. The aim is to develop high throughput laser-based solar cell processing techniques to improve manufacturability and lower the manufacturing costs of thin film PV. Work during year 1 focused on investigating the effects of UV laser annealing on the surface of CdTe and the development of a NIR laser system for the investigation of high throughput post-deposition heat-treatments in year 2.

Key Accomplishments:

To first order the activities at USF are device-oriented while the work at Utah is materials based. Laser processing takes place primarily at Utah; however, the team at USF has access to an excimer laser; a NIR laser donated by Coherent (as their cost-share for this project) has been received and is being installed. The two key objectives are to develop laser-based processes for (a) the formation of an effective back contact, and (b) the post-deposition heat-treatment of CdTe films and cells. During year one most activities focused on laser surface annealing and understanding its effects on material properties. USF supplied CdTe samples to Utah for their annealing experiments, while USF focused on cell fabrication (with limited material analysis). An example of a CdTe film annealed with an excimer laser (@ USF) is shown in Fig. 1. Demonstrating the onset of melting. This melting is localized to the surface of the sample (a few nms), enabling the localized processing of the back contact. The results were verified with similar experiments, analysis, and modeling carried out at Utah.

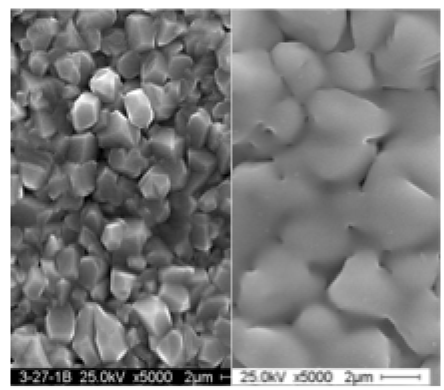

Figure 1. SEM micrographs of the surface of CdTe films before (left) and after *annealing* with an excimer laser (right)

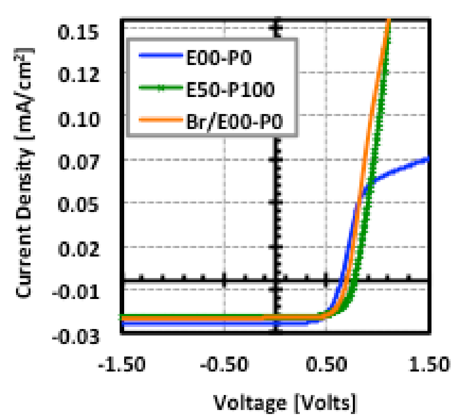

Figure 2. CdTe cells with untreated, bromine-etched, and laser-annealed surfaces

The most important cell results obtained to-date are summarized in Fig. 2; the light JV for CdTe cells where the CdTe surface received different *treatments* prior to the back contact formation are shown*:* (a) **blue data** - *no treatment*, (b) **orange data** - *typical Br-etch*, and (c) **green data** - *laser-annealed.* It is clear that laser-annealing results in eliminating the back barrier present in the sample that received no treatment at all, and the overall performance is similar to what is achieved by the Br etch; these results demonstrate that laser annealing has the potential to eliminate the need for wet chemistry, which could be an additional cost savings factor (to the higher throughput). The best cell fabricated to-date demonstrated an efficiency >13% (V_{OC}=800 mV; FF=75%; J_{SC}=22 mA/cm^2). The back contact work has focused on optimizing the laser annealing process for energy density and number of laser pulses.

Following the demonstration of the above described cell performance, a webinar was scheduled with Michael Woodhouse of NREL, during which the laser process and its impact on manufacturing costs were discussed. Although it was not possible to determine the exact cost of the laser process during the webinar (as equipment costs were not available at the time), one of the key conclusions of the webinar was that the costs for the various module manufacturing steps for today's CdTe technology are quite low, and new processes should aim at improving throughput (similar to the laser processing being developed under this project) along with *efficiency*. Future work will examine whether this particular laser-based contact can yield improved efficiencies over *conventional* processing.

Work on the post-deposition heat treatment was put on hold during year 1, as the installation of the NIR laser was not complete in time. The laser has been received from Coherent and the optics as well as an x-y stage for sample movement are in development and should be available for year 2.

Future Work:

Future work (year 2) will focus on two main goals: (a) better understand the effects of surface annealing with UV lasers and optimize device performance beyond what was achieved in Year 1, and (b) bring on line the NIR laser to begin development of a high throughput post-deposition $CdCl_2$-based annealing for CdTe cells.