BAPVC Annual Project Report

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

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Summary:
This is a collaborative project between the University of South Florida (USF) and the University of Utah. The main goal is to develop high throughput laser-based solar cell processing techniques to improve manufacturability and performance, and lower the manufacturing costs of CdTe thin film PV. Work during year 2 focused on the development of post-deposition Laser-based $CdCl_2$ heat treatments (HT) using a NIR laser (808 nm) donated by Intevac. The baseline solar cell structure being utilized for this project is*: glass/TCO/CdS/CdTe/Back contact.*

Key Accomplishments:

A 60 Watt dual diode 808nm laser is being used for the laser based $CdCl_2$ HT. An X-Y stage was installed to control the speed and direction of the device/cell exposed to the laser beam. Initial results showed poor cell performance due to large temperature gradients (≈10-15 °C/mm) across the laser beam area (0.6 x 0.6 cm^2). This problem was addressed by upgrading the original optics resulting in a rectangular shaped laser beam with size 3 x 0.8 cm^2 and smaller temperature gradient (≈2 °C/mm); the laser annealing apparatus is shown in Fig. 1.

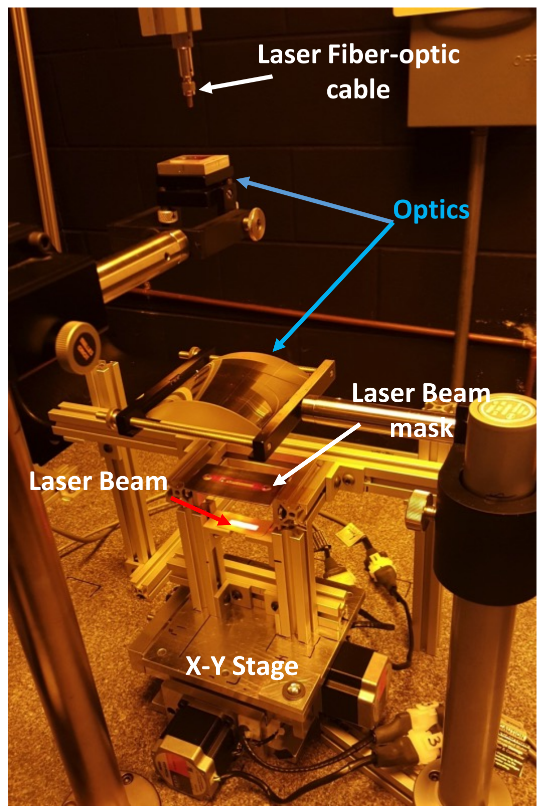

Figure 1. NIR Laser Setup

Devices were initially laser treated under a stationary beam to establish optimum conditions of laser power density. This approach was taken due to difficulties to directly measure the sample temperature. Figure 2 shows the spectral response data for devices treated for 5 and 15 minutes for various laser power densities. CdS thinning is observed at high power densities and long anneal times as seen by the increase in SR at short wavelengths (500 nm). There is also a shift in the SR at long wavelengths (>800 nm) due to bandgap narrowing from sulphur diffusion into CdTe (forms $Cd_{1-X}S_XTe$). These effects are also observed for cells treated using the conventional thermal $CdCl_2$ HT.

To simulate a typical manufacturing process, devices were *moved* under the laser beam with the use of an X-Y stage. Scan times (exposure of the cell under the laser beam) were varied from 1 to 7 minutes. Devices treated at low power densities exhibit the same behavior as with an as-deposited sample (implying that these devices were *under-treated*). The effects of the $CdCl_2$

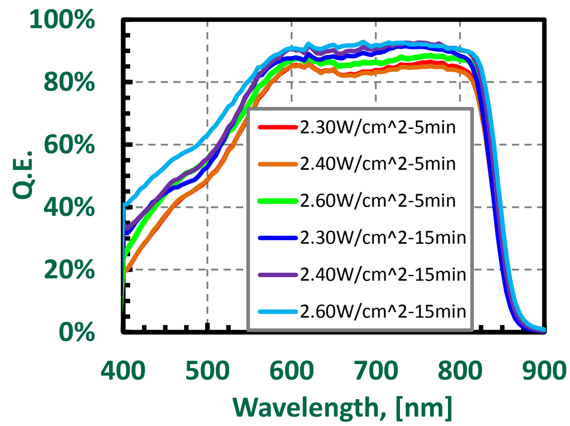

Figure 2. SR data for laser treated CdTe solar cells under different power densities and anneal times

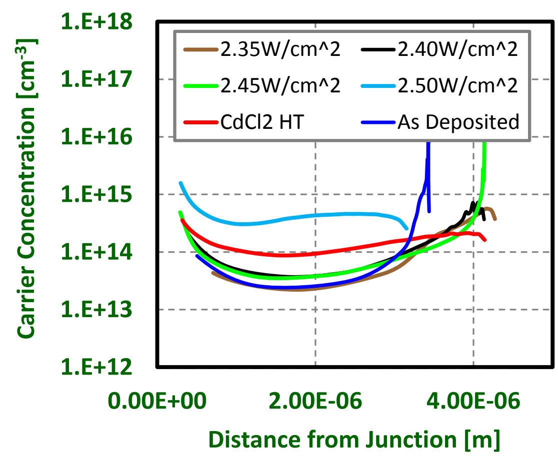

Figure 3. Net-doping concentration vs. laser power density

"activation" are realized at the highest power densities; presumably the improvement in the electronic properties of CdTe - increased carrier lifetime - resulted in improved carrier collection and therefore higher V_{OC} and FF.

It is also noteworthy that the net doping levels of Laser treated samples exhibit a correlation with power density. Doping concentration increases as laser power density increases (see Fig. 3). Even though higher doping than the conventional $CdCl_2$ treated devices was achieved this was not accompanied by an increase in V_{OC} as one would expected, suggesting that other mechanisms are more dominant.

The best cell fabricated to-date demonstrated an efficiency of 13.3% (V_{OC}=800mV, J_{SC}=23.3mA, FF=71.0%). The limiting factor for higher performance is the low V_{OC}'s 790-800 mV when compared to state of the art values of 840-850 mV. The V_{OC} limiting mechanism is currently under investigation.

Future Work:

Future work will focus on: (a) understand what causes the V_{OC} limitation and (b) further optimization of the Laser-based $CdCl_2$ treatment.