BAPVC Annual Project Report

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

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Summary:

The project focused on post deposition laser processing of CdTe absorbers. Laser driven cadmium chloride treatment of CdTe was achieved by using a continuous wave infrared laser with a dwell time of 15 s. Also, effects of laser treatment on the surface passivation was investigated. Reduction of surface states resulted in un-pinning of the Fermi energy and reduction in surface recombination velocity were observed following laser treatment of CdTe with and without chlorine passivation.

Key Accomplishments:

$CdCl_2$ treatment of CSS deposited CdTe on glass was carried out by using a 1064 nm continuous wave infrared laser. Photoluminescence studies showed a strong A-center peak associated with chlorine passivation on laser treated samples accompanied by a quenching of defect states. Figure 1 shows the spectrally resolved photoluminescence (PL) at 10 K from laser treated CdTe with and without $CdCl_2$. Significant increase in PL yield was observed for laser treated samples accompanied by quenching of the DP peak at 1.55 eV. A prominent 1.43 eV peak, generally associated with A-center, was observed in the laser treated sample in presence of $CdCl_2$. These signatures are also seen in conventional $CdCl_2$ treated samples indicating that the laser process affects similar changes to point defects. This was achieved with a laser dwell time of 40 s on CdTe samples deposited on glass. Similar results were achieved on CdTe samples deposited on alumina with a laser dwell time of 15 s. This work was presented at the recent 42nd IEEE Photovoltaic Specialists Conference [1].

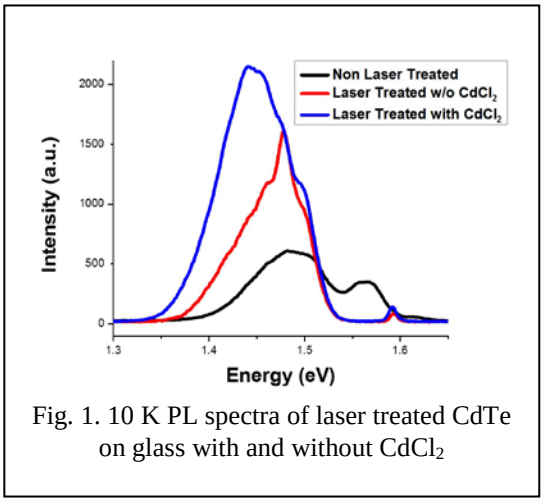

Fig. 1. 10 K PL spectra of laser treated CdTe on glass with and without $CdCl_2$

Surface photovoltage spectroscopy (SPS) and time resolved photoluminescence (TRPL) were used to investigate the effects of laser treatment on CdTe solar cell stacks. The studies showed that a laser dwell time of 20 s with a power density of 250 W/cm^2 is sufficient to reduce surface Fermi level pinning of CdTe by reducing surface defects. Figure 2 shows the SPS of as-deposited and laser treated CdTe stacks (Glass/TCO/CdS/CdTe). Removal of the local minimum just above 1.5 eV

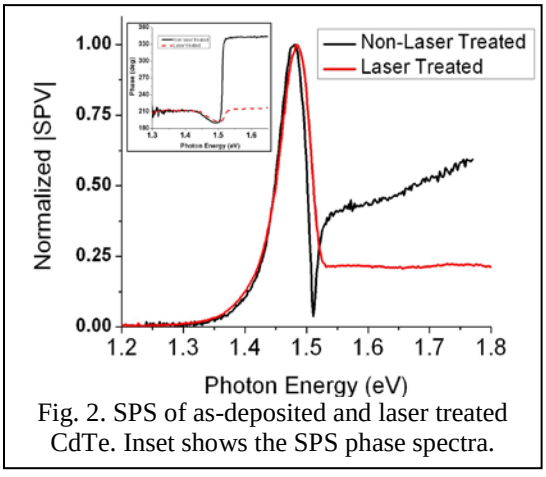

Fig. 2. SPS of as-deposited and laser treated CdTe. Inset shows the SPS phase spectra.

for laser treated samples is attributed to a reduction in number of surface states (reduced Fermi-level pinning). The sub-bandgap photon energies probe both the bulk and surface, while the super-gap energies probe only the depletion width induced by surface Fermi level pinning. This interpretation is supported by the SPS phase spectra (inset of Figure 2) which shows a phase change only near the bandgap and the laser treated sample surface in-phase with the bulk. Single photon TRPL was carried out at 10 K. This experiment is known to be very sensitive to surface recombination so the fact that the TRPL lifetime increases from 7 ns in non-laser treated samples to 15 ns in laser treated samples is also consistent with a reduction in surface recombination. This work was published in Journal of Applied Physics [2].

Future Work:

In the next period, we will focus on studying the use of laser annealing to activate group-V dopants in CdTe as well as investigating athermal effects of light on defect equilibrium and diffusion.

References:

[1] S. Misra, M.I. Khan, V. Palekis, C. Ferekides and M.A. Scarpulla, "*Continous wave laser assisted post deposition chlorine treatment of CdTe*", 2015 IEEE 42nd Photovoltaic Specialists Conference, June 2015. (in press)

[2] B.J. Simonds, V. Kheraj, V. Palekis, C. Ferekides and M.A. Scarpulla, "*Reduction of Fermi level pinning and recombination at polycrystalline CdTe surfaces by laser irradiation*", Journal of Applied Physics **117** 225301 (2015).