Photovoltaic Characteristics of PERC-Like CdTe Solar Cells

Etee Kawna Roy, Kaden Powell and Heayoung Yoon

Electrical and Computer Engineering, University of Utah, Salt Lake City, UT 84112, USA

Rapid progress has been achieved in thin film CdTe solar cells, reaching a power conversion efficiency of 22.1 %. Researchers demonstrated a short-circuit current density (J_{sc}) of ≈ 31 mA/cm^2 and a fill factor (*FF*) of ≈ 79 %, close to the theoretically calculated maximum values. However, the open-circuit voltage (V_{oc}) remains below 0.9 V, much lower than the estimated V_{oc} of 1.2 V. One strategy to improve the V_{oc} is to implement a passivated back-contact on CdTe that can reduce the recombination by repelling minority carriers at the surface (i.e., electrons in CdTe). An aluminum oxide thin film (Al_2O_3) is an attractive candidate owing to its innate fixed negative charges (10^{12}~10^{13} cm^{-2}).

Here, we use a patterned Al_2O_3 layer on CdTe to produce PERC-like CdTe solar cells (CdTe PERC). This device architecture is similar to a passivated emitter and rear contact (PERC) design, frequently used in high-efficient Si solar cells. Samples of a 20 nm Al_2O_3 coated CdTe (dopant: As) were provided by First Solar. Before lithography, the samples were thoroughly cleaned with acetone and isopropanol (IPA). We optimized the laser beam doses to pattern the positive photoresist (S1813) on a rough CdTe surface (power: 18 mW, pixel energy: 75 %). The exposed photoresist was developed in a solution (AZ 1:1 developer) for 60 s and soaked in deionized (DI) water. We conducted a selective Al_2O_3 etching in tetramethyl ammonium hydroxide (< 3 % TMAH; AZ 300 MIF) for 20 minutes. The remaining photoresist was stripped off, and the samples were cleaned with acetone and IPA. This selective etching exposes the CdTe surface in a hole array pattern, where the metal can directly contact the surface, collecting hole carriers in the PV operation. Finally, metal contacts (2 mm × 2 mm) were formed using an electron-beam evaporator (3 nm Cu / 85 nm Au) using a stainless-steel shadow mask.

Statistical analysis of dark/light current-voltage (*I-V*) of our CdTe PERCs reveals notably different trends of V_{oc} compared to I_{sc} and *FF*. The hole diameter of the CdTe PERC is 10 µm, 20 µm, or 40 µm, whereas the pitch (distance between holes) ranges from 10 µm to 320 µm. Each PERC device consists of stacks of CdTe/Al_2O_3/metal and CdTe/metal (i.e., "exposed CdTe"). We observe the I_{sc} increases proportionally to the exposed CdTe area, from ≈ 1.2 µA (0.13 cm^2) to ≈ 63.1 µA (19.6 cm^2) and the *FF* increases from 32 % to 49 %. In contrast, the V_{oc} remains relatively constant (600 mV ~ 630 mV), suggesting the Al_2O_3 acts as a passivation layer.

We attempt to understand the role of dopants (As) in CdTe PERC operation. Fully completed CdTe PERCs were annealed at 70 °C for two hours while collecting their *I-Vs* every 5 minutes. The I_{sc} increases with time during annealing, indicating activation of part of the dopants in the CdTe absorber. We measure the light *I-Vs* after the annealing and compare them to the initial *I-V* characteristics. Interestingly, the magnitudes of the saturation current (I_s), I_{sc}, and *FF* remain unchanged or show marginal changes after annealing. However, the V_{oc} increases as high as 8 % of its initial value (e.g., 600 mV to 650 mV). This preliminary result suggests that the electrically active Al_2O_3 coupled with the defect chemistry in CdTe could impact the V_{oc}. Further investigations are in progress to optimize the PERC structures for CdTe-based solar cells.

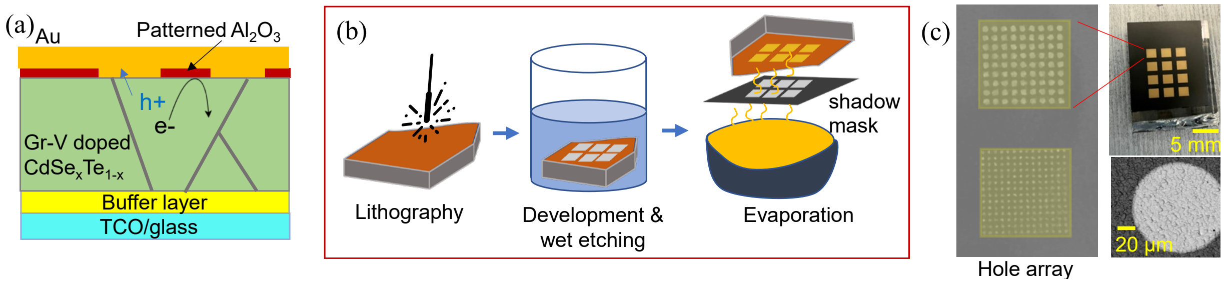

Figure 1. (a) Design of CdTe PERC solar cell. (b) Schematic of the fabrication. (c) Representative images of hole arrays on CdTe.

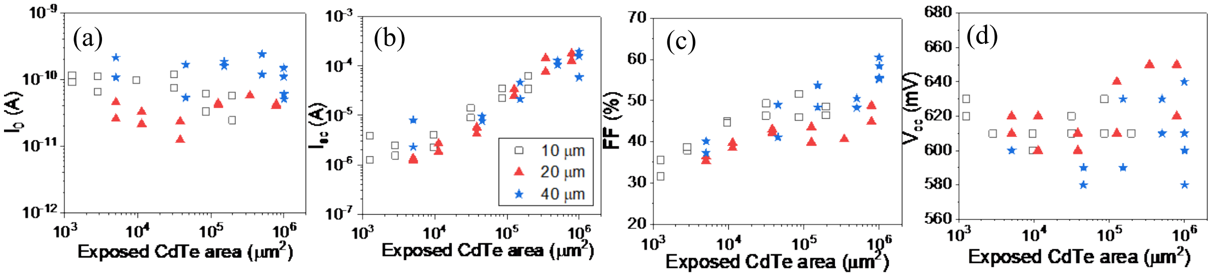

Figure 2. Comparison of I_0, I_{sc}, FF, and V_{oc} extracted from the I-Vs of CdTe PERCs.

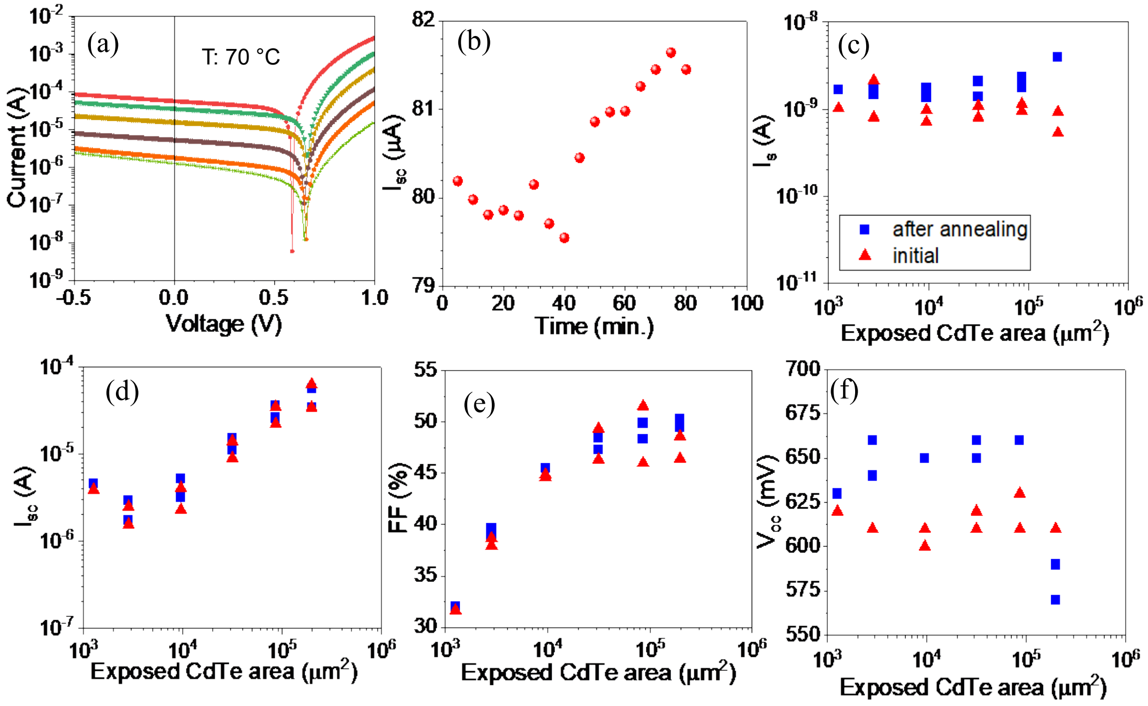

Figure 3. (a) The I-Vs after annealing at 70 °C. (b) I_{sc} measured during the annealing process (0.2 sun). (c-f) Comparison of I_s, I_{sc}, FF, and V_{oc} before and after annealing (1 sun).