Radiation Effects in CdTe Solar Cells with Micro/Nanoscale Point Back Contacts

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Thin-film CdTe solar cells are promising for space applications due to their high specific power (> 5 kW/kg), low cost, and radiation tolerance[1]. To further improve efficiency, Al_2O_3 back-surface passivation has been proposed, where its negative fixed charge reflects minority carriers and suppresses back-contact recombination. An efficient CdTe solar cell, however, requires the Al_2O_3 layer to be properly patterned to enable majority carrier transport[2]. Nanoscale lithography is challenging on polycrystalline CdTe due to its large surface roughness (peak-to-valley > 1 µm). In this work, we present an optimized Al_2O_3 micro/nanoscale patterning approach for CdTe solar cells.

An Al_2O_3 film was deposited on CdTe by e-beam evaporation, patterned with a laser-writer, and then wet-etched in tetramethylammonium hydroxide (TMAH) solution. Lower laser power improved pattern resolution but caused photoresist residue, particularly at grain boundaries. To mitigate this effect, an over-etching strategy was investigated. ***Figure 1a*** shows representative scanning electron microscope (SEM) images of fabricated point-contacts after etching using optimized conditions. X-ray photoelectron spectroscopy (XPS) confirmed the complete removal of Al_2O_3 after 30 min etching (***Figure 1b***). Device performance was evaluated by dark and light I-V measurements prior to neutron irradiation in a reactor at the University of Utah.

After irradiation, the cathodoluminescence (CL) intensity decreases with increasing dose (***Figure 1c***), attributed to the large neutron capture cross-section of Cd. Irradiation creates metastable defects that reduce carrier lifetime and degrade short-circuit current (I_{SC}) and open-circuit voltage (V_{OC})[3]. These metastable defects are partially recovered by post-annealing at 70 °C after 4 hours, as shown in ***Figure 1d***.

We will further discuss the influence of Al_2O_3 point contacts at the grain interior and boundaries, and their coupling with the patterning fidelity.

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[2]E. K. Roy et al., Adv. Mater. Interfaces 11, 2400501 (2024). doi: 10.1002/admi.202400501.
[3]T.-Y. Lin et al., J. Mater. Chem. A 12, 7536 (2024). doi: 10.1039/D3TA06998B.

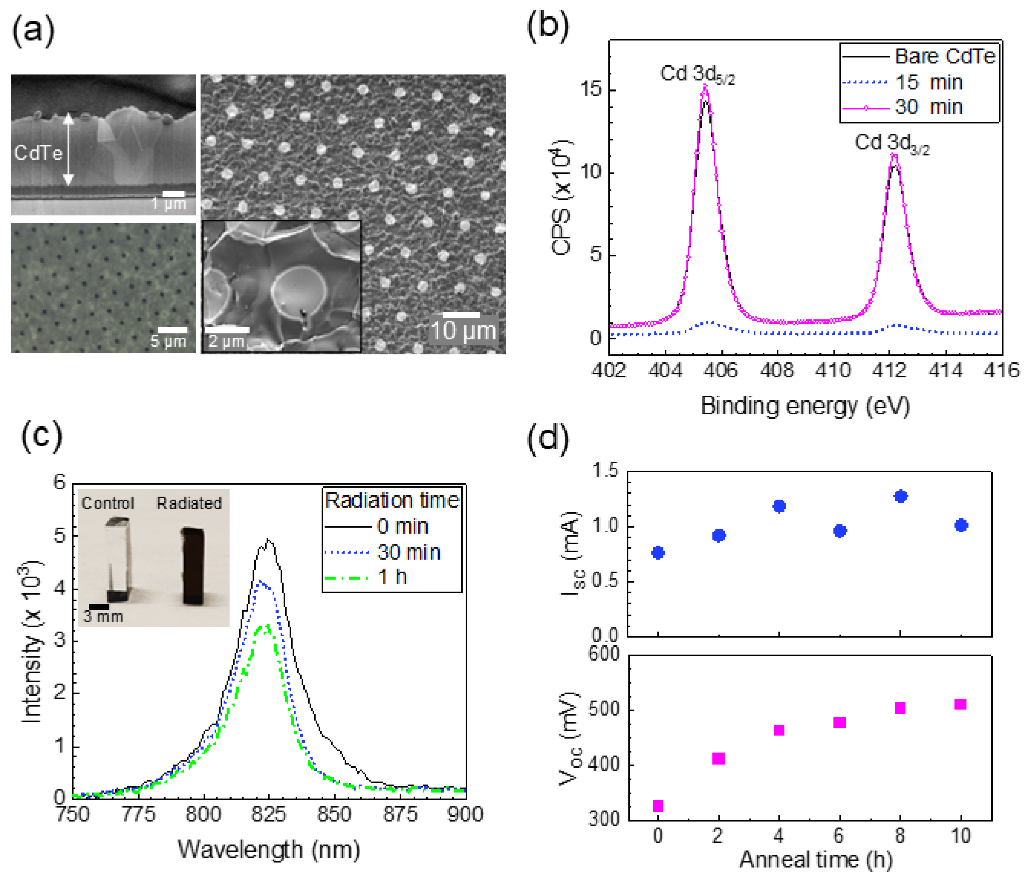

Figure 1: (a) SEM images of micropatterned Al_2O_3 point-contact arrays on CdTe. Insets: Cross-sectional SEM image after focused ion beam (FIB) etching (top-left), microholes after development (bottom-left), and a single microhole located within a CdTe grain (bottom-right). *(b)* Cd 3d XPS spectra of bare CdTe and Al_2O_3/CdTe after 15 min and 30 min etching. *(c)* CL spectra before irradiation and after irradiation for 30 min and 1 h. The inset shows darkening of the glass substrate. *(d)* Evolution of I_{SC} and V_{OC} after irradiation (0 h) and during post-irradiation annealing up to 10 h.