School of Electrical, Computer and Energy Engineering

PhD Final Oral Defense
Optimization of Monocrystalline Mg$_x$Cd$_{1-x}$Te/Mg$_y$Cd$_{1-y}$Te Double-Heterostructure Solar Cells

by
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Abstract
Polycrystalline CdS/CdTe solar cells continue to dominate the thin-film photovoltaics industry with an achieved record efficiency of over 22% demonstrated by First Solar, yet monocrystalline CdTe devices have received considerably less attention over the years. Monocrystalline CdTe double-heterostructure solar cells show great promise with respect to addressing the problem of low $V_{oc}$ with the passing of the 1 V benchmark. Rapid progress has been made in driving the efficiency in these devices ever closer to the record presently held by polycrystalline thin-films. This achievement is primarily due to the utilization of a remote p-n heterojunction in which the heavily doped contact materials, which are so problematic in terms of increasing non-radiative recombination inside the absorber, are moved outside of the CdTe double heterostructure with two Mg$_y$Cd$_{1-y}$Te barrier layers to provide confinement and passivation at the CdTe surfaces. Using this design, the pursuit and demonstration of efficiencies beyond 20% in CdTe solar cells is reported through the study and optimization of the structure barriers, contacts layers, and optical design. Further
development of a wider bandgap Mg\textsubscript{x}Cd\textsubscript{1-x}Te solar cell based on the same design is included with the intention of applying this knowledge to the development of a tandem solar cell constructed on a silicon subcell. The exploration of different hole-contact materials—ZnTe, CuZnS, and a-Si:H—and their optimization is presented throughout the work. Devices utilizing a-Si:H hole contacts exhibit open-circuit voltages of up to 1.11 V, a maximum total-area efficiency of 18.5\% measured under AM1.5G, and an active-area efficiency of 20.3\% for CdTe absorber based devices. The achievement of voltages beyond 1.1 V while still maintaining relatively high fill factors with no rollover, either before or after open-circuit, is a promising indicator that this approach can result in devices surpassing the 22\% record set by polycrystalline designs. Mg\textsubscript{x}Cd\textsubscript{1-x}Te absorber based devices have been demonstrated with open-circuit voltages of up to 1.176 V and a maximum active-area efficiency of 11.2\%. A discussion of the various loss mechanisms present within these devices, both optical and electrical, concludes with the presentation of a series of potential design changes meant to address these issues.