BAPVC Annual Project Report

Project Title: Low-cost and high-efficiency thin-film MgCdTe/Si tandem solar cells
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Summary:

In this program, a new type of low-cost and high-efficiency solar cell is proposed by marrying two established solar cell technologies: polycrystalline II-VI MgCdTe thin-films and crystalline Si solar cells. The overall device structure has been augmented from the originally proposed HIT structure to the higher performance II-VI/Si tandem solar cell design. We demonstrated MgCdTe double heterostructures with excellent crystalline and interface qualities with a bandgap of 1.7 eV and lifetimes reaching up to 11.1 ns promising an effective material system for the upper II-VI subcell.

Key Accomplishments:

In recent years, the popular Si, GaAs, and CdTe single-junction solar cells are showing great progress, reaching 25.6%, 28.8%, and 21.5% efficiency, respectively. However, it is difficult to enhance the efficiency of single-junction solar cells beyond 30% due to fundamental limits, poor material quality, and/or high manufacturing cost. The proposed HIT solar cell design has been redesigned during the reporting period to incorporate a second, II-VI, upper subcell. It is believed that the 1.7 eV MgCdTe alloy is the most promising candidate for the top subcell because of the recent excellent achievements in high quality CdTe/MgCdTe double heterostructure growth [1-2]. The group demonstrated high-quality 1.7 eV $Mg_xCd_{1-x}Te$ epilayers grown on InSb (100) substrates using a dual chamber MBE system at Arizona State University. The structures are characterized by high-resolution X-ray diffraction (XRD), steady-state photoluminescence (PL), and time-resolved photoluminescence (TRPL).

To grow $Mg_yCd_{1-y}Te$ /$Mg_xCd_{1-x}Te$/$Mg_yCd_{1-y}Te$ double heterostructures with large band offsets to effectively confine carriers, growth conditions were tuned to approach a Mg composition X of approximately 0.13 and a composition Y of 0.50. XRD results show a Mg composition of 0.135 and Pendellösung fringes indicating excellent crystalline and interface qualities. Steady-state photoluminescence indicates that the 0.135 Mg composition result in a bandgap of 1.7 eV (≈730 nm), as shown in Fig. 1. Further time-resolved photoluminescence studies show carrier lifetimes reaching up to a current maximum of 11.1 ns as shown in Fig. 2.

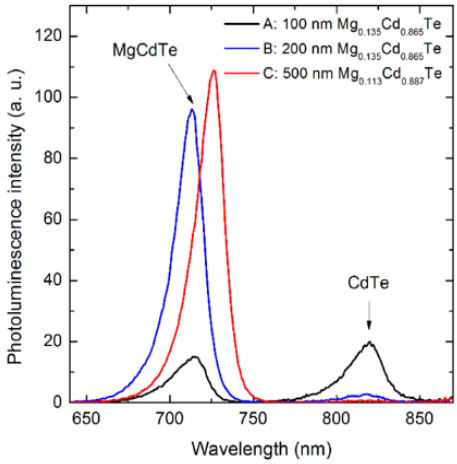

Fig. 1 Steady-state Photoluminescence results for various Mg compositions and absorber thicknesses.

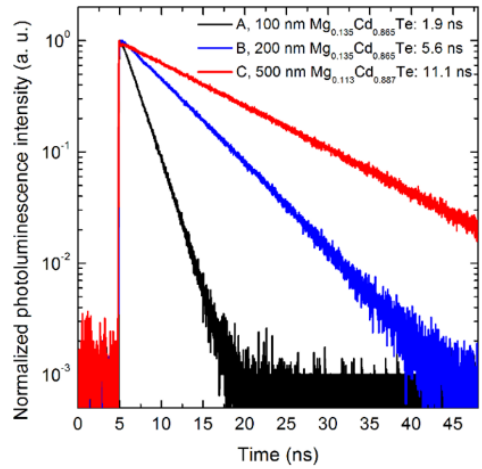

Fig. 2 Time-resolved Photoluminescence results and associated lifetimes for various Mg compositions and absorber thicknesses.

Future Work:

The fundamental research tasks are as follows: 1) demonstrate monocrystalline double-heterostructure $Mg_yCd_{1-y}Te/Mg_{0.15}Cd_{0.75}Te/Mg_yCd_{1-y}Te$ single junction solar cells, and 2) demonstrate polycrystalline CdS/ $Mg_{0.15}Cd_{0.75}Te/Mg_yCd_{1-y}Te$ single junction solar cells. Work within the group will focus on demonstrating a MgCdTe single-junction solar cell with a 1.7 eV bandgap on an InSb substrate; providing a foundation for future work on tandem systems.

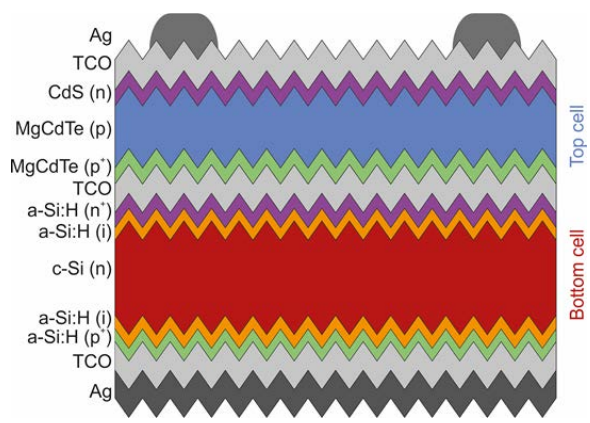

Fig. 3 Schematic of the proposed II-VI/silicon tandem solar cell.

Reference

[1] X.-H. Zhao, M. J. DiNezza, S. Liu, S. Lin, Y. Zhao, and Y.-H. Zhang, "Time-resolved and excitation-dependent photoluminescence study of CdTe/MgCdTe double heterostructures grown by molecular beam epitaxy," *Journal of Vacuum Science and Technology B*, vol. 32, p. 040601 (2014).

[2] X.-H. Zhao, M. J. DiNezza, S. Liu, C. M. Campbell, Y. Zhao, and Y.-H. Zhang, "Determination of CdTe bulk lifetime and interface recombination veocity of CdTe/MgCdTe double heterostructures grown by molecular beam epitaxy," *Applied Physics Letters*, vol. 105, p. 252101 (2014).