National Renewable Energy Laboratory
Innovation for Our Energy Future

A national laboratory of the U.S. Department of Energy
Office of Energy Efficiency & Renewable Energy

INVESTIGATION OF $Cd_{1-x}Mg_xTe$ ALLOYS FOR TANDEM SOLAR CELL APPLICATIONS

Ramesh Dhere, Kannan Ramanathan, John Scharf, Helio Moutinho, Bobby To, Anna Duda, and Rommel Noufi

National Renewable Energy Laboratory • Golden, CO 80401

Objectives

Fabrication and characterization of $Cd_{1-x}Mg_xTe$ (CMT) alloys and to determine their potential for device applications. Main emphasis is on the development of the devices in 1.5 to 1.8 eV range for the top cell of two-junction tandem solar cells.

Background

Earlier work on $Cd_{1-x}Zn_xTe$ devices hampered due to high reactivity of Zn with O_2 and Cl_2. CMT alloys cover a wide range of bandgaps from 1.5 eV to over 3 eV. Lattice constants of CdTe and MgTe are close so there is minimal lattice mismatch between CdTe and CMT alloys. Limited amount of work on CMT and none for polycrystalline CMT alloys

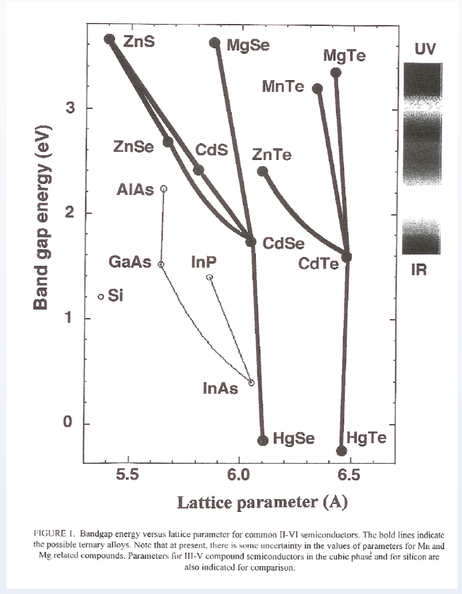
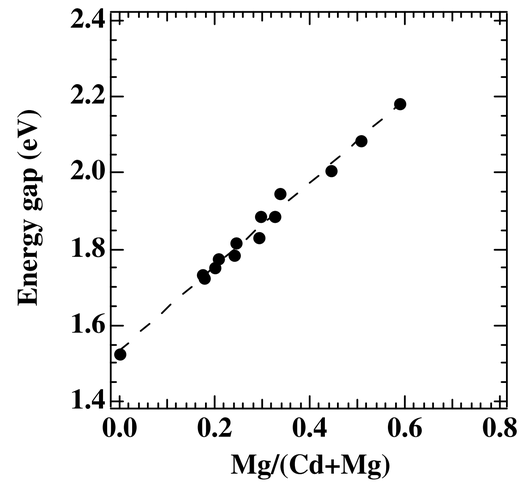


FIGURE 1. Bandgap energy versus lattice parameter for common II-VI semiconductors. The bold lines indicate the possible ternary alloys. Note that at present, there is some uncertainty in the values of parameters for Mn and Mg related compounds. Parameters for III-V compound semiconductors in the cubic phase and for silicon are also indicated for comparison.

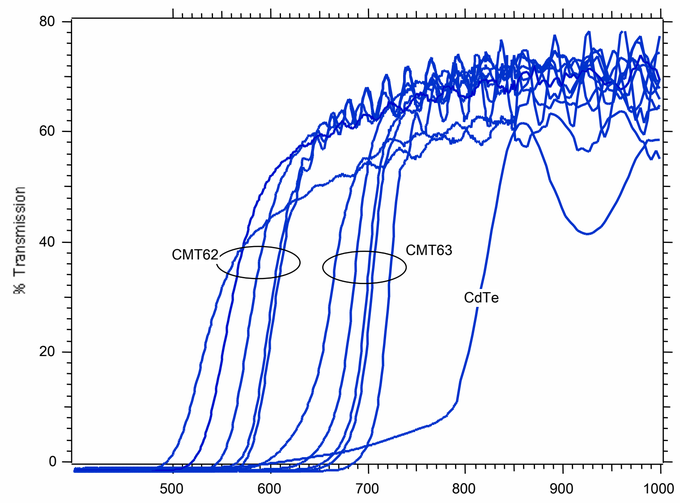
Optical bandgap as a function of Mg content for CMT alloy films

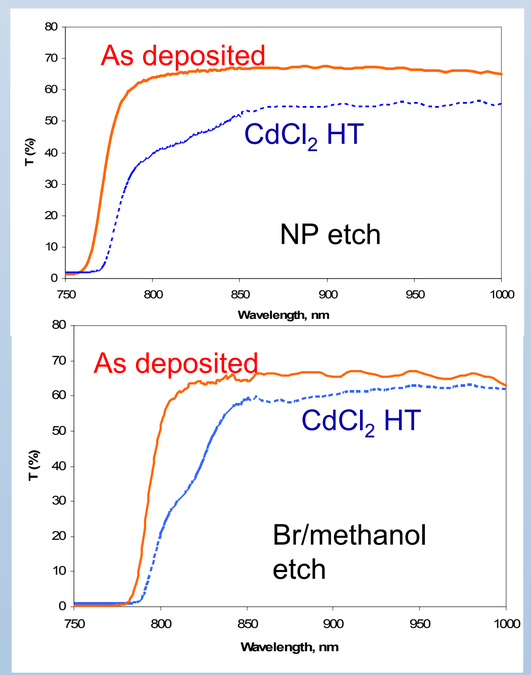


Experimental

Fabrication of CMT alloys by vacuum co-evaporation of CdTe and Mg at T_{sub} = 300°-400°C on glass or glass/SnO_2/CdS substrates. Post deposition vapor $CdCl_2$ heat treatment in He/O_2 ambient at 380°C to 420°C for 15 min. Pre contact Br/methanol etch for 2 sec. 10 nm Cu/180 nm Au contact by evaporation. Contact anneal in He from 175°-250°C for 30 min.

Transmission characteristics of different CMT films





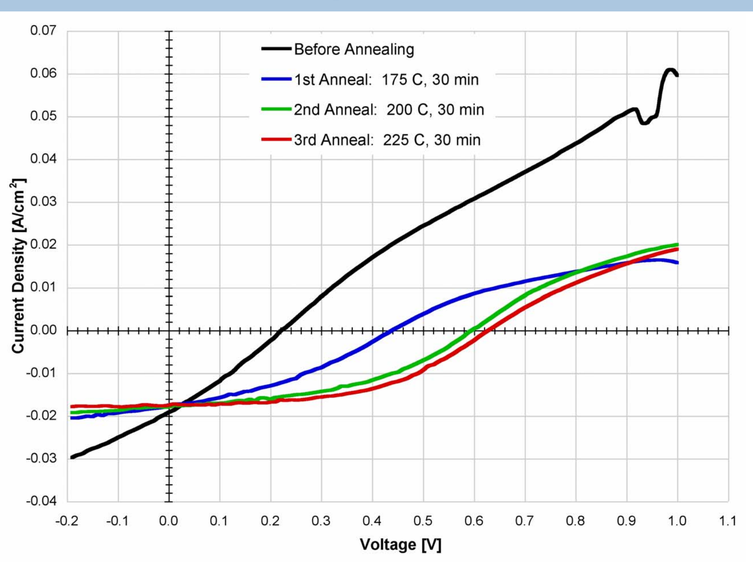
$CdCl_2$ heat treatment

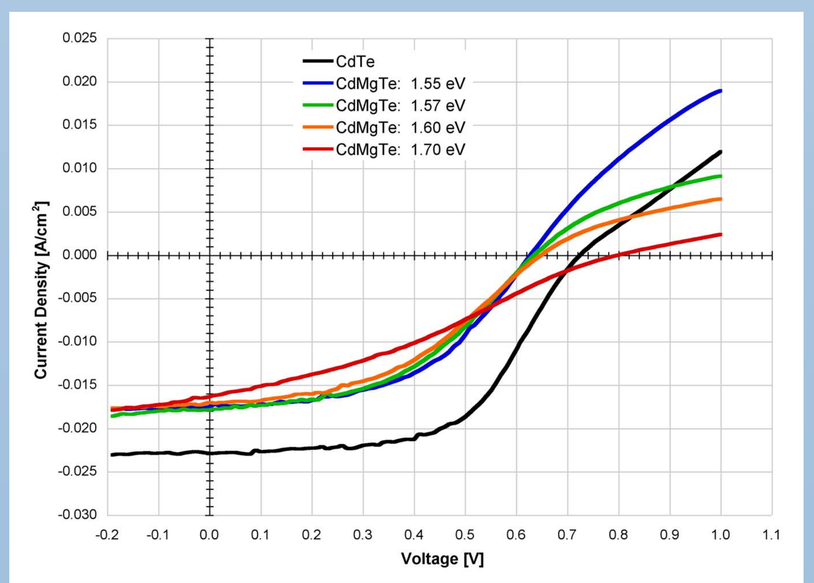
- **CMT films did not show significant effect of $CdCl_2$ treatment up to 400°C.**
- **The absorption edge of the samples treated at 420°C shifted towards longer wavelengths, indicating some loss of Mg from the alloy. Shoulder at 850 nm implies conversion of top thin layer to CdTe**
- **NP etched samples exhibit wavelength independent transmission loss, due to the formation of Te rich layer. Negligible loss for Br etched samples**

Back Contact

Back contact processing has a major influence on the device performance. Devices with as deposited Cu/Au contacts show poor diode characteristics and low FFs. With progressive anneals, there is an improvement in diode quality and device performance. The data presented here is preliminary and we expect to enhance the device performance by further optimization of back contact.

Effect of contact annealing on device performance





Conclusions

- **CMT alloy films with a wide composition range were fabricated.**
- **The optical band gap shows a systematic variation with composition and CMT alloy films withstood the commonly used device processing steps for CdTe.**
- **We have fabricated cells with 5% efficiency in the energy gap range of 1.5 to 1.7 eV and established the viability of CMT for device applications**

2006 IEEE 4th World Conference on Photovoltaic Energy Conversion • Waikoloa, Hawaii • May 7-12, 2006 • NREL/PO-520-39969