Temperature and Radiation Tolerance Studies of CdSe/CdTe Bilayer Solar cells on Space-Qualified Coverglass

Aesha P. Patel, Adam B. Phillips, Ebin Bastola, Nadeesha Katakumbura, Zachary Zawisza, Robert Snuggs, Manoj K. Jamarkattel, Abasi Abudulimu, Richard Irving, Michael J. Heben, Randy J. Ellingson

Wright Center for Photovoltaics Innovation and Commercialization (PVIC), Department of Physics and Astronomy
University of Toledo, Ohio, 43606, USA

Motivation and Background

- II-VI thin film solar cells are expected to show superior high energy radiation tolerance and achieve higher specific power with lower manufacturing costs than Si or III-V solar cells [1]
- Highest recorded efficiency for CdS/CdTe solar cell on flexible and ultra-thin glass superstrate has been 16.4% [2]
- Replacing CdS with CdSe significantly improves current collection at lower wavelength region in visible spectrum [3]
- Incorporation of novel Indium Gallium Oxide (IGO) as an emitter in CdSe/CdTe solar cell improves device efficiency under AM1.5G condition [4]
- Here, we demonstrate fabrication of CdSe/CdTe bilayer solar cell directly onto space coverglass and report preliminary results of thermal cycling and proton radiation tolerance on a 15% efficient CdSe/CdTe device

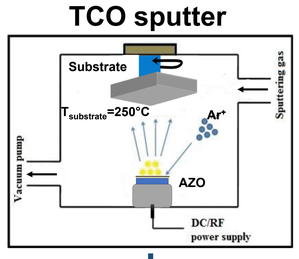
Methodology

Device fabrication

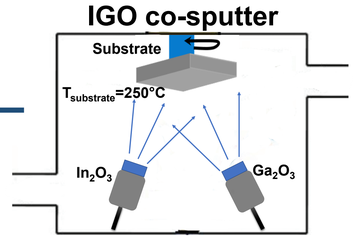
Glass cleaning

Corning 0214 (0.75% Ce-doped borosilicate)

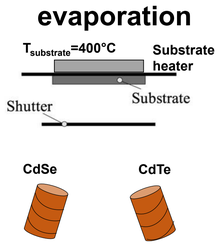
TCO sputter



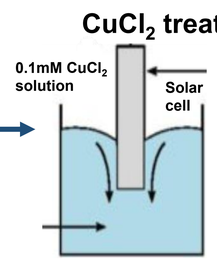
IGO co-sputter



CdSe/CdTe multisource evaporation



$CuCl_2$ treatment

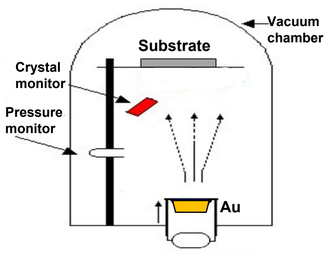


- **Heat treatment:** 250ºC for 10 min in hot oven
- **Purpose:** p-type Cu doping

$CdCl_2$ treatment

- **Solution:** $CdCl_2$ + CH_3OH saturated solution
- **Conditions:** 400ºC for 30 min in N_2 environment
- **Purpose:** Grain boundary passivation, grain growth

Au evaporation

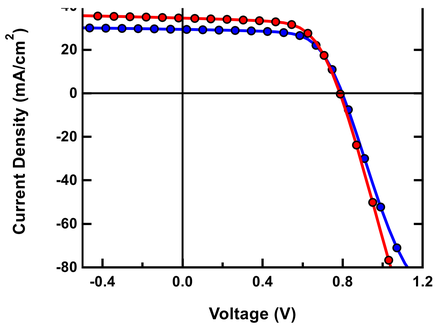


Schematic diagram of CdSe/CdTe solar cell



Results and Discussion

Device Performance



0214/AZO/IGO (4.02 eV)/CdSe/CdTe/Cu/Au

	V_{OC} (mV)	J_{SC} (mA/cm²)	FF (%)	η (%)
AM1.5G	798	29.4	66.5	15.6
AM0	787	34.6	64.9	13.1

Fig. 1: Current density (J)-voltage (V) curves for AM1.5G and AM0 conditions

Thermal Cycling: -20ºC to 80ºC under AM1.5G

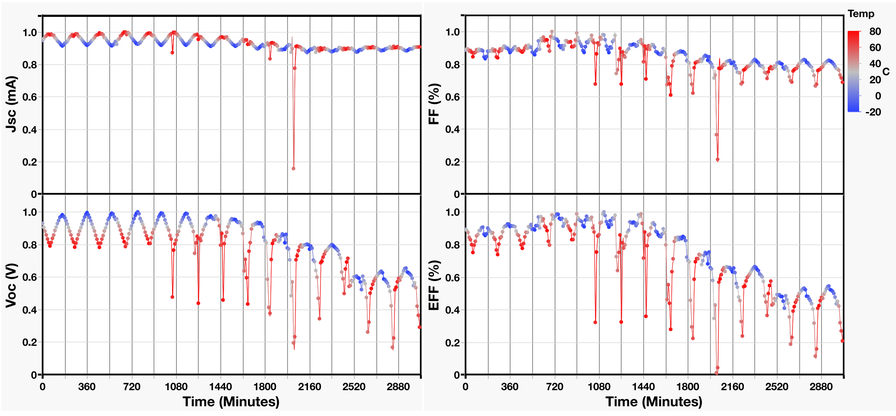


Fig. 2: Thermal cycling from -20ºC to 80ºC under AM1.5G

- ~16 cycles were performed over +3000 minutes
- Within first few cycles, no degradation observed in J_{SC} and V_{OC}

Proton Radiation (film-side):~50-240 keV, low & high fluence



Fig. 3: T(%) measurements for pre- and post-proton irradiated AZO/IGO films on space coverglass for low ($2x10^{12}$) and high ($1x10^{15}$) p/cm² fluences

- Films irradiated from film-side (no encapsulation). Higher T(%) for all irradiated samples. Minor increment in transmission with increase in energy

Conclusion

- Highest achieved device efficiency for multisource evaporated CdSe/CdTe bilayer solar cells, deposited directly onto 150 µm space coverglass is 15.6% and 13.1% under AM1.5G and AM0 conditions, respectively
- From thermal cycling results under AM1.5G, higher fluctuations observed in fill factor (*FF*) and V_{OC}, thereby lowering efficiency post 8-10 cycles
- Film-side proton irradiated 0214/AZO/IGO films showed higher transmission (%) than film that did not undergo irradiation
- Transmission(%) increased with increase in energy dosage and fluence

Next Steps

- Further experiments will be conducted to optimize IGO bandgap, $CdCl_2$ and $CuCl_2$ treatment conditions to improve bilayer device efficiency
- Thermal cycling to understand degradation mechanisms of CdSe/CdTe solar cells under AM0 condition
- Au stability must be determined
- Looking to collaborate for electron and higher energy proton irradiation experiments

References

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[3] E. Bastola et al., "Understanding the Interplay between CdSe Thickness and Cu Doping Temperature in CdSe/CdTe Devices," 2021 IEEE 48th Photovoltaic Specialists Conference (PVSC), 2021, pp. 1421-1426, doi: 10.1109/PVSC43889.2021.9518832

[4] M. K. Jamarkattel *et al.*, "Indium Gallium Oxide Emitters for High-Efficiency CdTe-Based Solar Cells," *ACS Applied Energy Materials*, 2022, doi: 10.1021/acsaem.2c00153

Acknowledgments

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