UTAustin Portugal

Fabrication of pre-structured substrates and Cu-In-Ga precursor deposition for Cu(In,Ga)Se_2-based micro-concentrator solar cells

NANOTECHNOLOGIES

Marina Alves [1,2], Joaquim Carneiro [2], Sascha Sadewasser [1]

[1] International Iberian Nanotechnology Laboratory (INL), Av. Mestre José Veiga s/n, 4715-330 Braga, Portugal;
[2] Centre of Physics of Minho and Porto (CF-UM-UP), Gualtar Campus, 4800-058 Guimarães, Portugal

Introduction

- Cu(In,Ga)Se_2 (CIGS) concentrator solar cells have reached a record efficiency of 23.3%[1].
- The micro-concentrator concept combines thin-film photovoltaic technology with concentrator photovoltaic (CPV) technology, downscaling the solar cell to the micrometer range[2].
- The miniaturization of the CIGS absorber layer allows to reduce the use of critical raw materials In and Ga and enhances the efficiency[3].
- In this work, we demonstrate the fabrication process for pre-structured substrates with arrays of holes with 200 to 250 µm diameter inside a SiO_x insulating matrix. Followed by Cu-In-Ga (CIG) precursor deposition, thermal annealing of the precursor, and selenization to create CIGS absorber micro-dots.

Pre-structured substrate microfabrication

a) Mo deposition by sputtering
b) SiO_x deposition by PECVD
c) Photoresist coating
d) Exposure by Direct Write Laser
e) Photoresist development
f) Reactive ion etching of SiO_x
g) CIG deposition by sputtering
h) Photoresist removal
i) Selenization by CVD

Some processes needed to be adapted to the substrate used

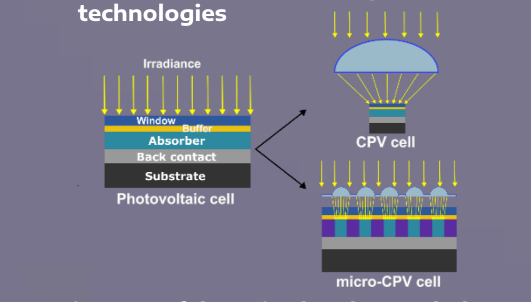
Cu-In-Ga precursor deposition

- 1 µm CIG deposition by sputtering.
- As-deposited CIG precursor with In-rich islands with height ~600 nm.
- Thermal annealing was performed to remove resist incorporated during sputtering, improve CIG quality and assess substrate stability.
- Thermal annealing at 500 ºC leads to less defined islands.
- SiO_x matrix stable during thermal annealing.

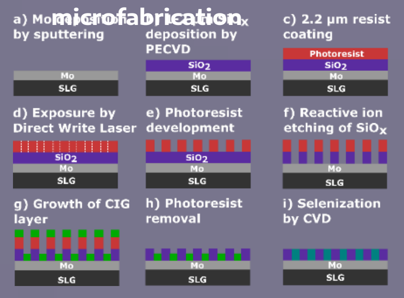
Selenization

- 1-stage selenization and/or rapid heating/cooling of the CVD system resulted in blisters, cracks and/or delamination.
- Less CIGS damage during selenization by heating up with a ramp of 10 ºC/min and a 2-stage selenization at 100/480 ºC.
- 1 µm SiO_x matrix presented significant damage after selenization.

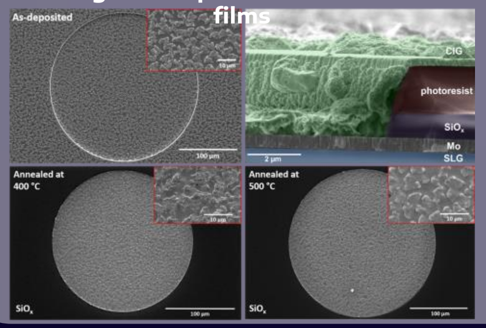
Schematic of photovoltaic technologies



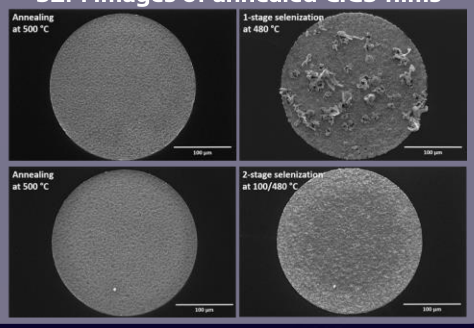
Schematic of microfabrication



SEM images of deposited and annealed CIG films



SEM images of annealed CIGS films



Conclusions

- Thermal annealing is crucial to improve CIG precursor before selenization.
- Selenization parameters strongly influence the CIGS absorber layer, such as heating/cooling ramp, temperature and amount of Se.
- Further optimization of the selenization process required to improve the CIGS micro-dots.

Acknowledgements

Marina Alves thanks the Fundação para a Ciência e a Tecnologia (FCT), República Portuguesa and União Europeia/FSE for the PhD grant 2020.06063.BD.

CF-UM-UP · fct Fundação para a Ciência e a Tecnologia · UNIÃO EUROPEIA · NORTE 2020 · REPÚBLICA PORTUGUESA CIÊNCIA, TECNOLOGIA E ENSINO SUPERIOR

References

[1] M. A. Green *et al.*, *Prog. Photovoltaics Res. Appl.* 31, 3 (2023).
[2] M. Paire *et al.*, *Energy Environ. Sci.* 4, 4972 (2011).
[3] M. Alves *et al.*, *J. Phys. Energy* 2,. 012001 (2020).