UT AUSTIN PORTUGAL ANNUAL CONFERENCE 2023
MODELLING THE FUTURE

Designing superior $Cu(In,Ga)Se_2$ solar cells through understanding and controlling growth

NANOTECHNOLOGIES
José Fonseca[a,b], Sascha Sadewasser[b]
[a]Centre of Physics, Campus de Gualtar, University of Minho, 4710-057 Braga, Portugal
[b]International Iberian Nanotechnology Laboratory, Avenida Mestre José Veiga s/n, 4715-330 Braga, Portugal

Motivation

- **$Cu(In,Ga)Se_2$** (CIGSe) **solar cells** offer a stable, cost-effective alternative to mainstream Si photovoltaics, with versatility, efficient manufacturing, and reduced CO_2 footprint.
- The best CIGSe cells and modules use **complex multi-stage processes**, with material composition and temperature adjustments via empirical optimization.
- To further increase efficiency, a detailed understanding of material properties during deposition and operation is essential.
- Studies on material formation typically rely on **pre/post-growth** analyses or snapshots of the growth process by **quenching the reaction**.
- We conduct **in-situ experiments** focusing on phase transformations during deposition, defect formation and annihilation, element segregation, and their impact on crystallinity and electronic properties.

Methods and Results

- Amorphous CIGSe was deposited in a home-built hybrid sputtering-evaporation deposition system by sputtering of a **Cu-In-Ga alloy at room temperature with simultaneous supply of Se** by evaporation.
- A temperature stage was used to perform **in-situ Raman** measurements.

1. The **shift to lower frequencies** of the peaks with increasing temperature is ascribed to effects of **thermal expansion** and **changes in phonon occupation numbers** and not compositional changes.

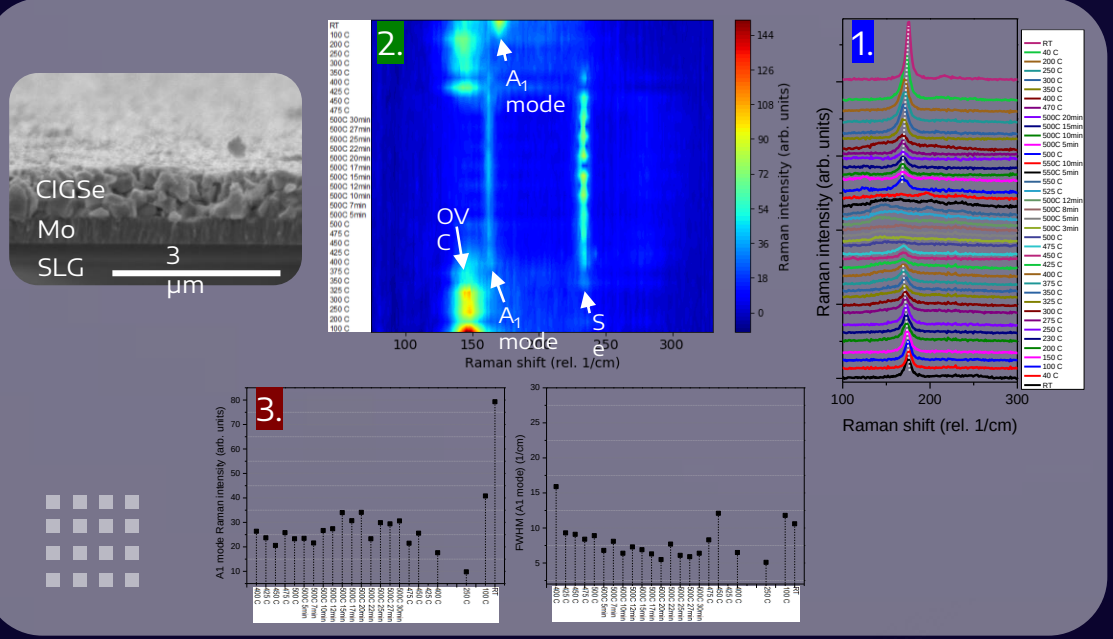
1. The **intensity** of the Raman signal **decreases** with increasing temperature due to **increase of optical absorption**

Results

2. As-deposited CIGSe shows an **ordered vacancy compound** (OVC) peak.

2. At 350 °C a **Se peak** starts to appear at ~137 cm^{-1} and at 400 °C the **A_1 mode of CIGSe** appears at ~166 cm^{-1}.

3. During annealing, after **20 minutes at 500 °C** the A_1 mode has a **maximum intensity** and **minimum FWHM**.



Conclusions and future work

- Annealing for **20 minutes at 500 °C** is optimal to get good CIGSe structure.
- After cooling down the main mode is the A_1. Studies at different temperatures should be performed to find the optimal annealing temperature.
- In-situ XRD experiments can be conducted to complement previous results.

Acknowledgement

Fundação para a Ciência e a Tecnologia