

Semi-Transparent Cu(In,Ga)Se₂ Solar Cells for Window Applications

Nanotechnologies

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Motivation and Background

Problems:

- The global energy demand and fossil fuel consumption is increasing;
- Buildings account for more than 35% of energy consumption and 38% emissions worldwide.

Proposed Solution:

- **Semi-Transparent Cu(In,Ga)Se₂ solar cells**, figure 1.

Advantages:

- Cost-effective and architecturally adaptative;
- **High Transparency**, in the form of photovoltaic windows;
- Takes advantage of large buildings' unused glass façades, which is crucial to developing **Net-Zero** structures.

Fabrication Approach

Bottom-up fabrication, figure 2:

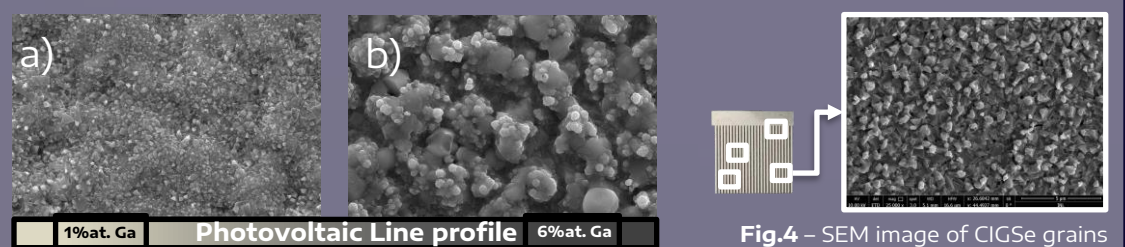
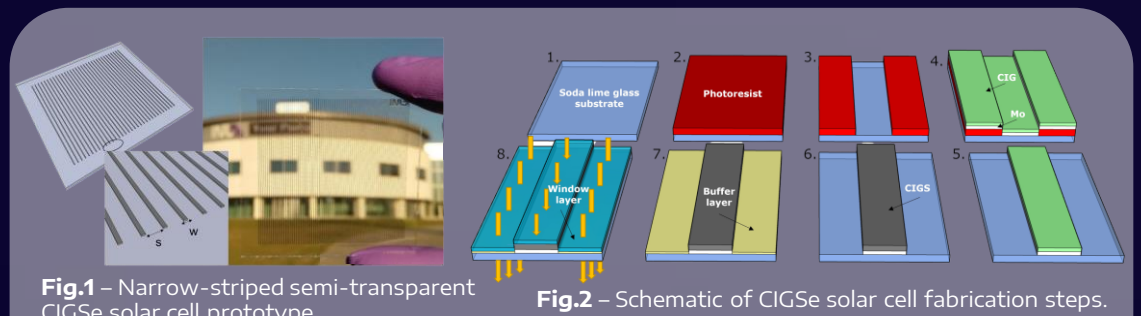
- **(1-3)** Photolithography to pattern narrow lines on photoresist-coated soda-lime glass (SLG);
- **(4)** Sputtering of Mo and CIG precursor;
- **(5)** Lift-off process leaving the spatially segmented lines of Mo/CIG on the substrate;
- **(6)** Selenization/crystallization of the CIGSe absorber lines;
- **(7)** CdS buffer deposited by chemical bath deposition;
- **(8)** Window layer deposition by RF sputtering.

Growth Paths

- **Se-rich** → Produces big Ga gradients. Selenium's diffusion is higher than Indium's, forming the preferred **In₃Se₄** phase underneath, trapping Ga.
- **Se-poor** → Can avoid Ga gradients and produce an equal film along the sample. In can reach the surface before reacting with Se, where the **In₃Se₄** is now formed.

Gallium Segregation

- Under higher Se amounts, **figure 3**: Different sized and shaped grains along the sample, due to varying Ga amounts. CuInSe₂ is predominant at the surface, as in figure 3 a).
- Under lower Se amounts, **figure 4**: Equal shaped and sized grains and composition along every PV line and position.



1%at. Ga Photovoltaic Line profile 6%at. Ga

Conclusions

- Cu(In,Ga)₂ solar cells can be fabricated by patterning them into micro-stripes;
- Lower amounts of Se, as long as enough, can improve the overall stoichiometry of the CIGSe thin-film;
- There are two main CIGSe growth paths, influenced by where the **In₃Se₄** layer is formed.

[1] Bäcker, Jan-Peter & Schmidt, Sebastian & Alvarez, H. & Wolf, Christian & Kaufmann, Christian A. & Hartig, Manuel & Mainz, Roland & Schlatmann, Rutger. (2017). 162. 120-126. 10.1016/j.solmat.2016.12.034.

[2] Launched: 2020 global status report for buildings and construction. globalabc. (n.d.). Retrieved December 23, 2022, from <https://globalabc.org/news/launched-2020-global-status-report-buildings-and-construction>

