Low-temperature deposition process and Ag incorporation for co-evaporated CIGS flexible solar cell fabrication on polyimide

Jackson Lontchi[1], Vincent Dufoulon[1], Amelle Rebai[2], Thomas Tom[1], Alexandre Crossay[3], Jean-François Guillemoles[1], Daniel Lincot[3], Negar Naghavi[1]

[1]: Centre national de la recherche scientifique (CNRS) – UMR 9006, 91120 Palaiseau, France
[2] : Institut photovoltaïque d'Ile-de-France (IPVF), 91120 Palaiseau, France
[3] : SOY PV, 91405 Orsay, France

$CuInGaSe_2$ (CIGS) solar cells are a leading choice for lightweight, flexible, and high-efficiency photovoltaic devices, particularly when integrated on flexible substrates like polyimide (PI). However, the thermal limitations of PI, which cannot withstand the high temperatures (550°C) needed for top-performing devices on glass, pose a significant challenge. Within the PRINCIPE project, we aimed to optimize the deposition of CIGS at a reduced temperature of 400°C, a level more compatible with the thermal stability of polyamide substrates. While this lower temperature preserves the integrity of the polyamide, it negatively impacts the composition and performance of the CIGS absorbers.

The lower deposition temperature required for polyamide substrates leads to the formation of a notch in the Ga/(Ga+In) profile within the bulk composition of CIGS absorbers, which significantly reduces the open-circuit voltage (Voc) of solar cells. To address this challenge, we implemented several optimization strategies. First, we refined the Ga distribution by adjusting the GGI ratio to mitigate the impact of the notch. We also explored the effects of partially substituting Cu with Ag and introduced alkali metals like KF and RbF to enhance performance. Additionally, we optimized the temperature profiles to improve absorber quality. These combined efforts led to a power conversion efficiency (PCE) of 17.5% and an improvement in Voc up to 620 mV.

This study provides a comprehensive analysis of the impact of these parameters using GDOES, XRD, Raman, PL, IV, and EQE techniques. The findings reveal the intricate relationship between absorber layer composition, growth conditions, and device architecture, emphasizing the potential for achieving high-efficiency CIGS solar cells on flexible substrates at lower deposition temperatures.

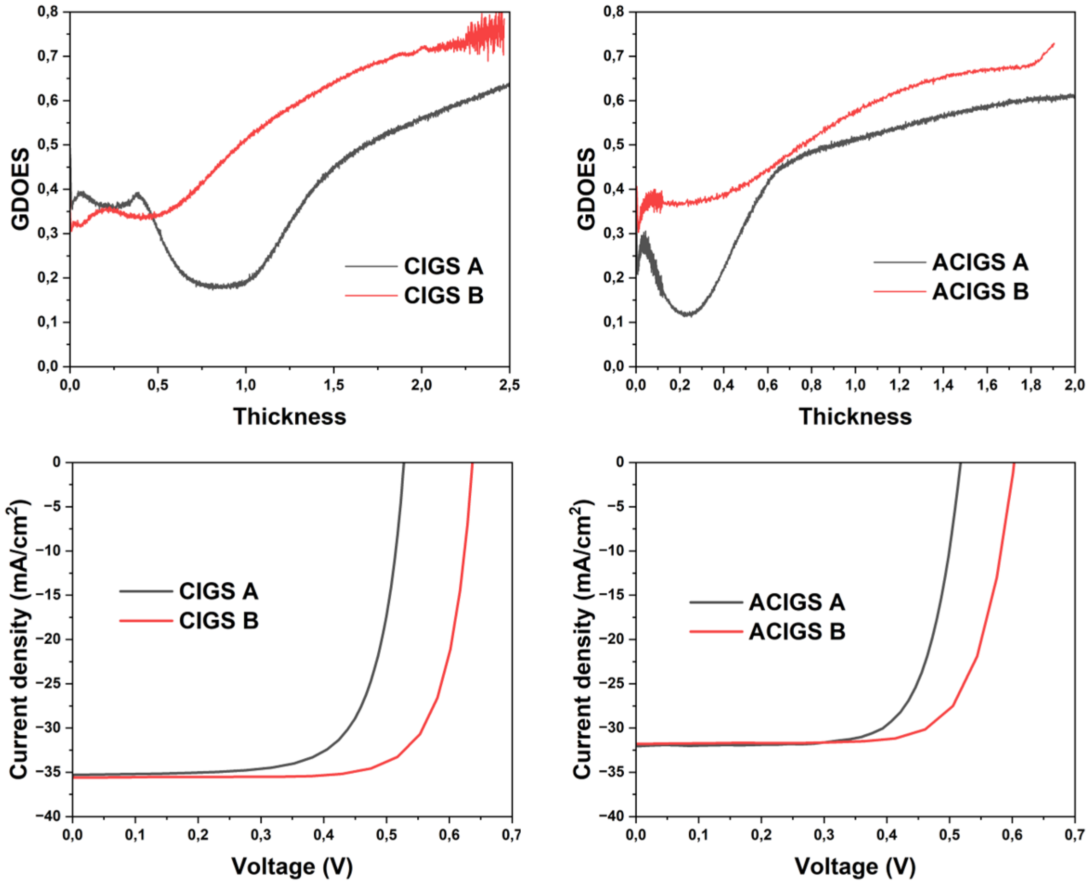

Figure: illustration of gallium grading composition and IV curves showing the impact of the proposed optimization