Development of Low Band Gap Copper Indium Gallium Diselenide Solar Cells by Coevaporation for Tandem Applications

Cécilia Tel[1], Amelle Rebai[1], Frédérique Donsanti[2], Jackson Lontchi[2], Damien Coutancier[1], Nathanaelle Schneider[1], Alexandre Crossay[1], Vincent Dufoulon[1], Baptiste Bérenguier[1], José Alvarez[3], Jean-Paul Kleider[3], Philip Schulz[1], Jean François Guillemoles[1], Daniel Lincot[1]

1-Institut Photovoltaïque d'Île de France, UMR CNRS 9006, 18 Boulevard Thomas Gobert, 91120 Palaiseau; 2-Institut Photovoltaïque d'Île de France, SAS, 18 Boulevard Thomas Gobert, 91120 Palaiseau; 3-GEEPS, 11 rue Joliot-Curie, 91192 Gif-sur-Yvette

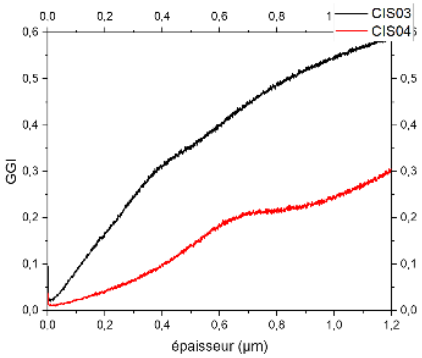
In view of the next generation of solar modules based on tandem devices, a strong focus is put on the accelerated development and industrialization of crystalline silicon/ Perovskite structures where silicon is used for the bottom cell (1.12 eV) and hybrid metal halide perovskite (PRK) for the top cell (1.6-1.7 eV). Another possibility is to replace the silicon bottom cell by pure CIS with a band gap of 1 eV to combine it with a perovskite top cell or high band gap CIGS. Record efficiency of CIS cells has been recently raised up to 19,2% [1] and 26.5% for f CIGS-PRK tandem cells [2]

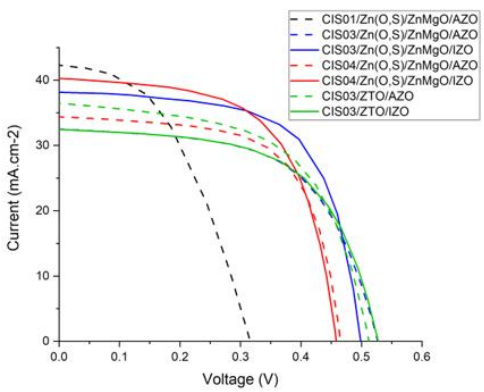
This work explores the fabrication and optimization of low band gap CIGS solar cells by coevaporation. A key parameter is related to the insertion of gallium and the optimization of the Ga/(Ga+In), noted GGI, composition profile in the films. A three-stage growth process has been used with varying the insertion of gallium in step one, leading to a targeted GGI of 0, 0.1 and 0.3. This addition of gallium at the back improves significantly the open circuit voltage allowing to reach values higher than 0.5 V, and also the efficiency of the cell from 6-8 % to 12% with Ga. A steeper profile is also observed for the best samples with GGI of 0.3. The shift in gallium composition is also related to a band gap shift from1 eV to 1.06 eV. The other research line which will be presented is the optimization of cadmium free front buffer and window layers. Zn(O,S) buffer layers by chemical bath deposition are successfully developed but more innovative zinc tin oxide (ZTO) layers deposited by atomic layer deposition are also giving very promising results. The key objective is the optimization of the conduction band offset by adjusting the relative composition between tin and zinc. For the top electrode, we also consider the substitution of Al doped transparent conductive oxide layers by indium zinc oxide with very promising results, related to a better transparency in the UV. Studies are also carried out to adapt the surface for depositing perovskite top cells in the frame of the European project PERCISTAND.

Acknowledgments: This work has been partly carried out in the frame of the PERCISTAND project as well as projects PROOF and InHyMat-PV of IPVF

[1]T. Feurer et al., Advanced Energy Materials 9(2019)1901428
[2]https://www.solliance.eu/2021/world-record-efficiency-on-a-tandem-solar-cell/

***Figures** : Characteristics for GGI=0 (CIS01), 0.1(CIS04),0.3(CIS03)*





	Voc (V)	Jsc (mA.cm-2)	FF (%)	Eff (%)
CIS01 - AZO	0,32	42,3	45,5	6,1
CIS03 - IZO	0,50	38,1	63,9	12,1
CIS03 - AZO	0,53	36,5	58,1	10,8
CIS04 - IZO	0.46	40.3	60.9	11.2
CIS04 - AZO	0,46	34,4	64,0	10,2
CIS03/ZTO/IZO	0.53	32.5	59.1	10.1
CIS03/ZTO/AZO	0,51	36,0	54,9	10,2