ANR EPCIS: first results on High-Efficiency Epitaxial CIGSu on Silicon Tandem Solar Cell.

O. Durand[1], E. Bertin[1,2], N. Barreau[2], M. Jullien[1], R. Bernard[1], A. Létoublon[1], C. Cornet[1], E. Gautron[2], L. Arzel[2], S. Harel[2], A. Crossay[3], J. Lontchi[4], A. Rebaï[3,4], B Bérenguier[3], J.-F. Guillemoles[3], N. Naghavi[3], A. Fave,[5] C. Tamin,[5] and D. Lincot[3,4].

[1] *Univ Rennes, INSA Rennes, CNRS, Institut FOTON - UMR 6082, F-35000 Rennes, France*
[2] *Nantes Université, CNRS, Institut des Matériaux de Nantes Jean Rouxel, IMN, F-44000 Nantes, France*
[3] *CNRS UMR 9006 IPVF, 18 Boulevard Thomas Gobert, 91120 Palaiseau, France*
[4] *Institut Photovoltaïque d'Ile de France (IPVF), 18 Boulevard Thomas Gobert, 91120 Palaiseau, France*
[5] *Univ. Lyon, INSA Lyon, CNRS, Ecole Centrale de Lyon, Université Claude Bernard Lyon 1, CPE Lyon, INL, UMR5270, 69621 Villeurbanne, France*

To date, the best conversion efficiencies have been obtained with multijunction solar cells on III-V substrates. However, maintaining the GaAs or Ge substrates to build these high-efficiency III–V solar cells is costly. The aim of the ANR EPCIS project is to explore tandem junctions associating single crystalline silicon bottom cell, with a bandgap of 1.12 eV and CIGS top cell, specially optimized for working in the visible range (bandgap around 1.7 eV). Our purpose is to grow wide band gap $Cu(In,Ga)S_2$ (CIGSu) films under quasi-epitaxial conditions on silicon, through a wide bandgap GaP intermediate layers epitaxially deposited on silicon. The epitaxy on GaP would improve the CIGSu top cell efficiency thanks to a reduction of the structural defects density detrimental for the cell performance, and taking advantage of the better structural and electronic matching than with the commonly-used Glass/Mo substrates. Therefore, quasi-epitaxial CIGSu-Si tandem solar cells has the potential to emerge as cost competitive for the next generation of PV modules.

In this paper, we present the first building bricks towards the development of high-efficiency CIGSu on silicon tandem solar cells, developed in the framework of the ANR EPCIS project.

First, IMN has developed $Cu(In,Ga)S_2$-based wide bandgap subcell with outstanding performance of 16.0% conversion efficiency, on conventional Mo/SLG substrate [1]. The CIGSu polycrystalline film was deposited following a modified three stage process consisting in decreasing (increasing) flux of gallium (indium) during the first stage, and the device was buffered with (CBD) CdS completed with standard ZnO:Al/i-ZnO window. [2]

Epitaxial GaP quasi-lattice matched have been grown on Si(001) substrate by Molecular Beam Epitaxy (MBE) in FOTON, to realize III-V/Si dislocation-free pseudosubstrates. Then, first results on the CIGSu growth on GaP/Si(001) pseudo-substrates are reported. To this end, a special care is given to the CIGS/GaP interface mastering [3]. In particular, x-ray diffraction and TEM measurements evidence the very good epitaxy of the CIGSu grown on the GaP/Si(001) platform, which illustrate the strong influence of the GaP(001) surface on the CIGSu structural quality, as expected. First results on AZO/i-ZnO/CdS/CIGSu top subcells on a pseudo-substrate GaP/Si(001) are also reported, and a comparison with the subcell deposited on Mo/Glass is described. [2]

Meanwhile, the fabrication of wide gap Ag-alloyed ACIGSu on glass/Mo was investigated at IPVF, since Ag alloying of CIGS is known to promote grain growth and ultimately cells efficiencies. The absorbers were deposited by sequential evaporation of Cu, Ga, In and Ag layers, followed by a sulfur annealing. The solar cells were completed with Cd-free Zn(O,S) buffer layer deposited by ALD, completed with ZnMgO/AZO window. Preliminary results display conversion efficiency subcells of 9,2% at 1,54 eV (V_{OC} = 773 mV, J_{sc} = 20.1 mA/cm², FF = 59.3%). [4]

Finally, INL is developing the Si bottom subcell in a passivated emitter rear totally diffused (PERT) configuration, and with an all-Si tunnel junction (TJ) on top. This TJ is obtained using the Proximity Rapid Thermal Diffusion method [5].

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