III-V GaP solar cells on silicon

F. Fan, S. Boyer-Richard, A. Beck, C. Levallois, K. Tavernier, T. Rohel, R. Bernard, A. Létoublon, C. Cornet, and O. Durand

Univ Rennes, INSA, CNRS, Institut FOTON - UMR 6082, F-35000 Rennes, France

Nowadays, the best solar conversion efficiencies have been reached thanks to multijunction solar cells consisting of a stacking of III-V semiconductor single junctions on GaAs or Ge substrates. While displaying high conversion efficiencies, these solar cells suffer from the high cost of such substrates. Therefore, a strategy is to develop a tandem cell on silicon, in order to benefit from both the low cost and technological maturity of silicon cells. Furthermore, this route would surpass the theoretical efficiency limit of the Si single cells. Indeed, theoretical studies have shown that a tandem cell consisting of a large bandgap material (ideally 1.7 eV) on a 1.1 eV Si cell would reach efficiencies as high as 37% [1] [2]. To this aim, we use GaP, grown by MBE, which is quasi lattice-matched with Si and which displays a large bandgap of 2.2 eV.

A GaP n-i-p photodiode has been grown on silicon substrate. A 20 nm-thick layer of GaAsP p++ allows to obtain ohmic contacts on p-type GaP using Ti/Pt/Au metals. Two types of electrical contacts configurations have been studied:a top-top configuration in which the current does not see the GaP/Si interface and the top-bottom configuration where the electric current crosses the interface. To this end two types of n electrical contacts have been used : top contacts on n-GaP using Ni-Au-Ge and bottom contacts on silicon. In the top-bottom configuration, ionic implantation of phosphorus has been performed to n-dope the silicon substrate after the MBE growth, and Al contact is used. Figure 1 shows the diode structure while figure 2 shows Dark I-V and Light I-V (under solar illumination) experiments. A comparison of EQE measurements on both configurations is also reported in fig. 3. Absorption begins at 2.25 eV (indirect bandgap) and increases at 2.8 eV, corresponding to the direct bandgap of GaP. The use of top-bottom contacts shows an EQE a little bit lower than the top-top contact one, likely due to lower carrier diffusion length or recombination at the lower interface. However, the result on the EQE of the top-bottom configuration is encouraging for the development of the GaP/Si tandem solar cells.

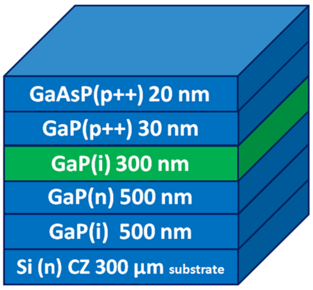

Fig. 1: Structure of III-V GaP solar cell on silicon

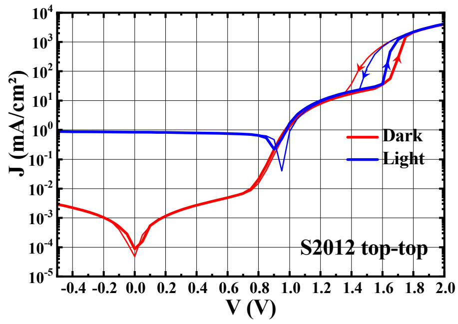

Fig. 2 L-I-V and D-I-V curves in a logarithmic scale, left: on the top-top configuration, right: on the top-bottom configuration

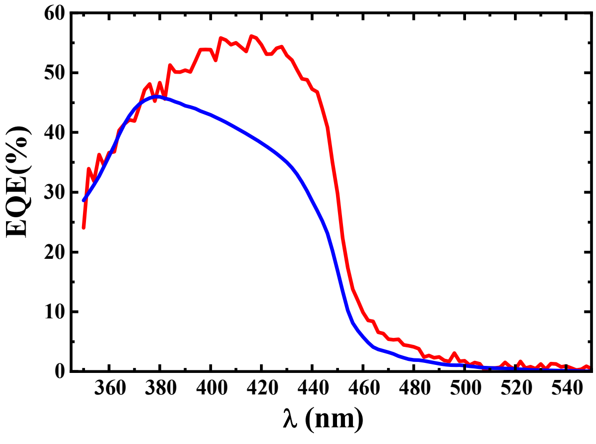

Fig. 3: Comparison between the EQE curves of the top-top configuration (red curve) and the top-bottom one (blue curve).

[1] S. Almosni, et al., Solar Energy Materials and Solar Cells 147 (2016): 53-60.
[2] K. Yamane at al, J. Cryst Growth 473 (2017) 55-59