III-V GaP solar cells on silicon

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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, our 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 1.7 eV bandgap material on a 1.1 eV Si cell would reach efficiencies as high as 37% [1]. To this aim, we use GaP, grown by MBE, which is quasi lattice-matched with Si. In addition to reaching a perfect lattice matching with Si and improving its optical properties, As and N incorporation in GaP, leading to a GaAsPN absorber, reduces the bandgap from 2.3 eV to the required 1.7 eV pseudo-bandgap.

This study is an intermediate step towards III-V on silicon tandem cells. 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 n contacts are compared : top contacts on n-GaP using Ni-Au-Ge and bottom contacts on silicon substrate. Ionic implantation of phosphorus followed by thermal annealing has been performed to n-dope the silicon substrate after the MBE growth, and Al contact is used. A similar sample with absorbing layer in GaAsPN to reduce the bandgap has also been processed but leakage current is too important to perform solar cell characterization. Figure 1 shows the diode structure and the dark intensity-voltage characteristic while Figure 2 shows EQE measurements. Absorption only begins at 2.8 eV, corresponding to the direct bandgap of GaP. The use of GaAsPN should decrease the bandgap and the absoption threshold. The use of top-bottom contacts shows an EQE 10 times larger than the top-top contact. The low EQE obtained for top-top cells can be explained by the short carrier diffusion length in GaP compared to silicon. The use of silicon substrate bottom contact strongly enhances EQE.

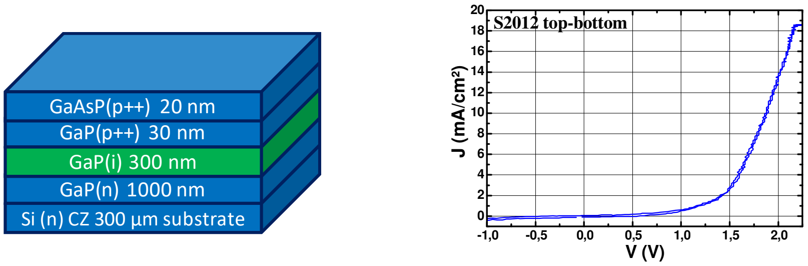

Figure 1. Solar cell structure and dark IV curve of the top-bottom sample

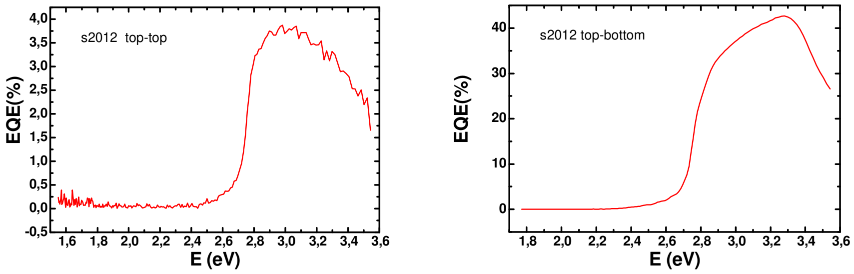

Figure 2. EQE measurement of top-top and top-bottom samples.

[1] Almosni, S., et al., Solar Energy Materials and Solar Cells 147 (2016): 53-60.