Investigation of AlGaAs Top Cell Grown Using Molecular Beam Epitaxy for Silicon Based Tandem Photovoltaics

Ahmed Ben Slimane*[1], Amadeo Michaud[2,3], Carmen Gomez Carbonell[3], Walid Elhuni[4], Zakaria Djebbour[4,5], Stéphane Collin[1,3], Jean-Christophe Harmand[3]

[1] *Institut Photovoltaïque d'Ile-de-France (IPVF), Antony, France*
[2] *TOTAL new energies, Palaiseau, France*
[3] *Centre for Nanoscience and Nanotechnology (C2N), CNRS, University Paris-Sud/Paris-Saclay, France*
[4] *Laboratoire de génie électrique et électronique de Paris (GeePs), Gif-sur-Yvette, France*
[5] *Département des Sciences Physiques, UVSQ, 45 avenue des Etats-Unis, 78035 Versailles, France*
Email: ahmed.ben-slimane@ipvf.fr

With a bandgap ranging from 1.42 eV to 2.16 eV[1], lattice matched AlGaAs grown on GaAs substrate is a very attractive material for high efficiency multi-junction photovoltaics, particularly it can be used as a top cell for Si based tandem solar devices[2]. However, there have been few reports on the growth of such materials for solar cells using molecular beam epitaxy (MBE).

We report the study of $Al_{0.28}Ga_{0.72}As$ solar cells grown on GaAs substrate using a solid source MBE. We investigate five different structures: (a) our reference sample with a "linear-profile" at interfaces, (b) a "p-i-n" structure, (c) an "abrupt-profile" sample with a growth interruption at interfaces to create a step-like doping and composition profile, (d) a "gradual" Al composition sample, and (e) a "gradual at high-temperature" sample grown at 680°C with a graded Al composition; conventionally the growth temperature of our first four samples is at 560-570°C.

Material characterization was carried out using x-ray diffraction (XRD), hall-effect measurements and secondary-ion mass spectrometry (SIMS). EQE and I-V measurements demonstrate that the "abrupt-profile" has the highest efficiency of η=9.93% with J_{sc}=10.62 mA/cm^2, V_{oc}=1.14V and FF= 82.05%. The higher current collection is due to the better spectral response at shorter wavelengths, which is attributed to the decrease of carrier recombination at emitter-window interface. Only the "high-temperature" structure exhibited a higher V_{oc} than the "abrupt-profile" which is due to its better material quality; however, on the other hand, its J_{sc} was lower due to Ga desorption at high temperature leading to an increase of its bandgap.

An inverted AlGaAs structure of the "abrupt-profile" was grown on a GaAs substrate, lifted-off and transferred by BCB bonding technique onto a Si substrate. An anti-reflective coating (ARC) was deposited. We obtained an efficiency of η=13.31% with a J_{sc}=14.61 mA/cm^2, V_{oc}=1.15V and FF= 78.7%

Our work shows a proof of concept of a BCB bonding technique and that with further optimization our MBE grown AlGaAs will be a promising candidate for high efficiency multi-junction solar cells.

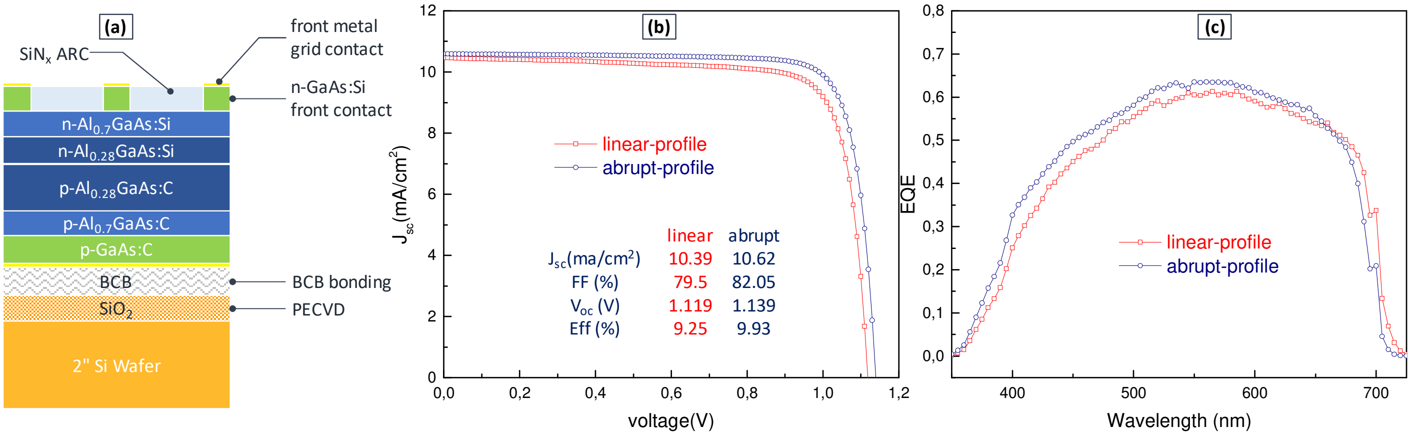

Figure 1. (a) Design of AlGaAs top cell BCB bonded to a Si wafer. (b) I-V characteristics of our reference sample "linear-profile" vs our best cell "abrupt-profile". (c) EQE of 'linear-profile" cell vs "abrupt-profile" cell.

---

[1] S. Adachi, "GaAs and Related Materials", World Scientific Publishing Co. (1994)

[2] S. Essig et al, "Raising the one-sun conversion effciency of III–V/Si solar cells to 32.8% for two junctions and 35.9% for three junctions", NATURE ENERGY 2, 17144 (2017)