1.73eV AlGaAs/InGaP Heterojunction Solar Cell with >17% Efficiency Grown By Molecular Beam Epitaxy

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III-V semiconductors have received much attention for high efficiency multi-junction photovoltaics[1]. They show great promise for the realization of Si-based tandem devices because they can cover a broad range of photon energy[2]. The ternary $Al_xGa_{1-x}As$ compounds, with their tunable direct bandgap in the range of 1.42-1.9 eV and their lattice constant matched to GaAs substrate[3], are particularly promising. However, many studies report that AlGaAs suffers from oxygen contamination during growth and from the presence of DX centers which are detrimental to the solar cell lifetime and efficiencies. With a bandgap around 1.9 eV, lattice matched $In_{0.49}Ga_{0.51}P$ grown on GaAs is a good alternative, thus many efforts have focused on the growth of homojunction solar cells based on this alloy. However, only few reports have investigated heterojunction AlGaAs/InGaP cells.

We report on the study of an original III-V heterojunction structure for solar cell applications. We investigate an $In_{0.49}Ga_{0.51}P$ /$Al_{0.25}GaAs$ structure with an intrinsic emitter layer, grown by solid source molecular beam epitaxy (MBE). We compare four different structures: (a) a p-n AlGaAs/InGaP heterojunction, (b) a p-i-n AlGaAs/InGaP heterojunction, (c) an AlGaAs homojunction, and (d) an InGaP homojunction.

Material characterizations were carried out using X-ray diffraction, Hall-effect measurements, secondary-ion mass spectrometry (SIMS), and photoluminescence. EQE and I-V measurements were completed on different samples before and after anti-reflective coating (ARC) deposition. **We demonstrate that the AlGaAs/InGaP heterojunction p-i-n structure has the highest efficiency η=17.64% with J_{sc}=16.72mA/cm^2, V_{oc}=1.241V and FF=84.99%.** The increase in the current collection is due to the combination of AlGaAs materials and InGaP emitter layer in the junction, which improves the photon absorption. The introduction of an undoped layer with a low concentration of ionized impurities is beneficial for an efficient minority carrier collection. Additionally, it prevents the diffusion of Be dopant into the n-type layer during growth.

Our results using MBE-grown alloys are comparable to the performances of MOCVD-grown AlGaAs solar cells. Reintroducing AlGaAs materials in high-efficiency multi-junction commercial cells allows for a reduction of the rare indium element, highly used in InGaP alloys.

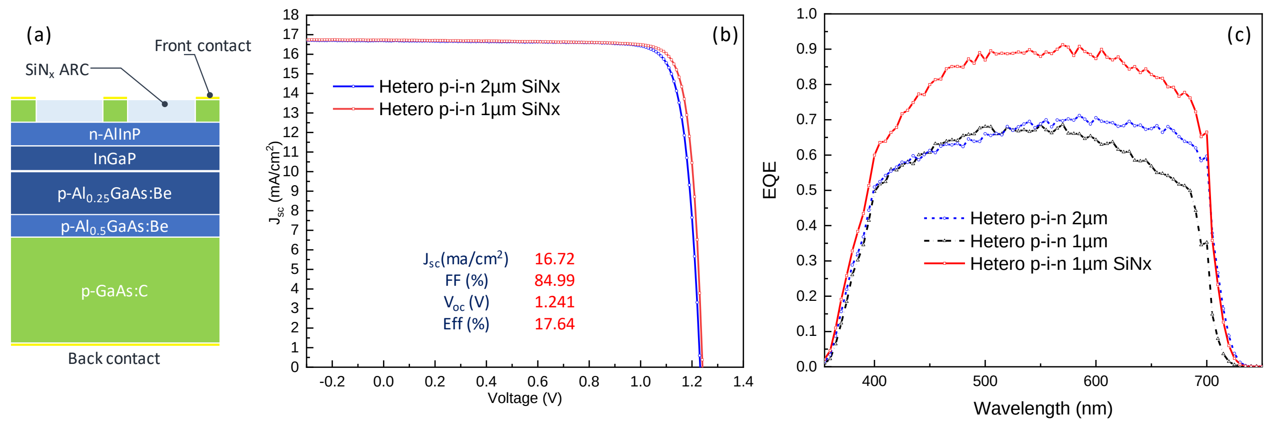

*Figure 1. **(a)** Design of AlGaAs/InGaP top cell. **(b)** I-V characteristics of our heterojunction sample with 1µm thick base vs 2µm thick base. **(c)** EQE of cells with and without ARC.*

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[2] R. Cariou et al, "III–V-on-silicon solar cells reaching 33% photo conversion efficiency in two-terminal configuration", Nature Energy volume 3, pages 326–333 (2018)
[3] S. Adachi, "GaAs and Related Materials", World Scientific Publishing Co. (1994)