Record Voc and quasi-Fermi level splitting in GaAs-based heterostructure nanowires on Si for tandem solar cells

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The direct growth of high structural quality III-V nanowires (NWs) on mismatched substrates such as Si, represents an elegant way to fabricate a III-V on Si tandem solar cell avoiding both the use of expensive III-V substrates and the difficult integration of III-V semiconductors on Si [1]. In principle, III-V NW based top cells with an optimal bandgap at 1.7 eV can be directly grown on a Si bottom cell and efficiencies exceeding 33% at AM1.5G have been predicted for such architecture [2]. The success of this strategy relies on the precise control of the NWs growth on Si(111), their crystal structure, doping, junction formation, passivation and opportune contacts as millions of nanometre-sized junctions are connected in parallel to form the NW-based solar cell. At present, state-of-the-art NW solar cells are based on gold catalysed axial GaAs homo-junctions grown on GaAs(111)B by MOCVD with an efficiency of 15.3% [3]. Ga-catalyzed GaAs NWs solar cells directly grown on Si(111) stays behind, with efficiencies of 7.58% for axial homo-junction [4] and 4.1% for radial homo-junctions [5], mainly limited by relatively poor V_{OC} (<0.39 V) and FF (<0.4).

In this work, we fabricate and characterize the top cell consisting of Ga-catalyzed III-V NWs radial homo- and hetero-junctions grown by Molecular Beam Epitaxy onto inactive p-type Si(111) substrates (Figure a). The detailed fabrication steps will be presented and the several challenges relating to it addressed. The optimization of key processing steps ensures a perfect selective growth and a high yield (>95%) of vertical NWs. Following from optoelectrical characterization of encapsulated and contacted NWs, the heterojunction devices demonstrated an efficiency of 3.7% under AM1.5G illumination, along with a V_{OC} of 0.65 V (Figure b), higher than the reported state-of-the-art GaAs NW core-shell junctions [5]. To assess the intrinsic quality of the NWs, the quasi-Fermi level splitting of as-grown NW arrays was determined without contact using hyperspectral imaging. Under a 1 sun illumination, we find values up to 0.92 eV (Figure c), representing the maximum achievable Voc. It confirms the NWs high crystalline quality and indicates a considerable scope for improvement in device processing.

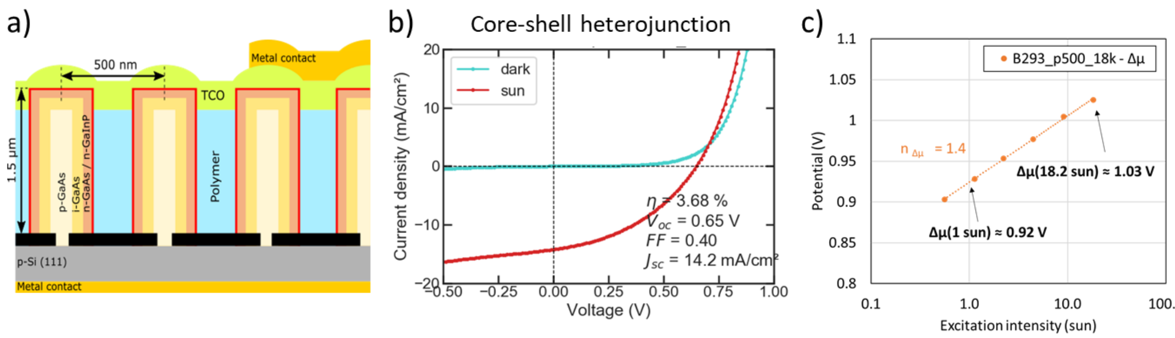

Figure a) Schematic of the NW-based top cell. **b)** JV-characteristics (dark and under AM1.5G) of a GaAs/InGaP NW core-shell heterojunction. **c)** Evolution of the quasi-fermi level splitting (measured using a hyperspectral imager) of an as-grown heterojunction nanowire array with excitation intensity.

References

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