III-V based Tunnel Heterojunction for Multijunction Solar Cells

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Abstract – Multijunction solar cells (MJSC) based on III-V materials are designed so that each junction absorbs a separate portion of the solar energy spectrum, allowing the highest efficiencies for solar energy conversion as high as 46% [1]. The different junctions are monolithically stacked and electrically interconnected in series by tunnel junctions (or Esaki diodes). Such devices allow the photo-generated carriers to travel from one junction to another with a very low resistivity by interband tunneling effect, and then to collect all the current contributions from the different MJSC stages. Therefore, the electrical and optical properties of tunnel junctions are key parameters for high conversion efficiency in MJSCs.

An Esaki diode consists of a PN junction formed with two degenerated semi-conductors, which results in a "broken gap" band diagram. The I-V characteristics of a tunnel junction exhibit a very low resistive region at low applied bias, followed by a saturation of the IV curve at the peak current density. This operating point with maximized current is of first importance to limit the voltage drop induced by the tunnel junction. Two main tunnelling phenomenons are considered for modelling the I-V characteristics of the tunnel junction: the direct band-to-band tunnelling and the trap assisted tunnelling.

The direct band-to-band tunnelling effect in the tunnel junction had been successfully modelled using a non-local tunnelling model with the Silvaco software [2]. High doping levels and low band gap materials increase significantly the performances of the tunnel junction. A first GaAs tunnel homojunction with moderate doping levels (around 6.10^{18} cm^{-3}) has been grown by Molecular Beam Epitasy (MBE) and characterized electrically in order to calibrate the band-to-band tunnelling model. Our simulations indicate that a GaInAs/GaAsSb heterostructure-based tunnel junction with suitable band offsets can reach peak current density 10^7 times higher than for a classical GaAs based tunnel junction.

Traps inside the depletion area of a tunnel junction are also strongly involved in the carrier tunneling from one band to another [3]. We are pursuing an ambitious experimental study of such traps-related phenomenon in GaAs tunnel junctions by combining Deep Levels Transient Spectroscopy (DLTS) characterization technique with optimization of the tunnel junction epitaxial growth and with numerical simulations.

In perspective, such GaAs and novel GaInAs/GaAsSb based tunnel junctions are intended to be grown monolithically in a GaAs-based tandem cell employing AlGaAs and GaInAsN absorbing materials.

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