III-N-V based core-(multi)shell nanowires for photovoltaics

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The continuous demand for renewable and sustainable energy sources has posed an urgent need for photovoltaic systems with higher efficiencies, lower costs and reduced dimensions. Semiconductor nanowires (NWs) based solar cells (SCs) have long been considered a promising answer to such need. However, axial p-(i)-n junction III-V NW SCs led to very limited power conversion efficiency (PCE) [1,2].

We recently proposed [3] a new type of high-efficiency nanowire-based solar cells relying on intermediate band (IB) III-N-V semiconducting alloys (e.g., GaNAs or GaNP) within a radial GaAs-AlGaAs NW hetero-structure [4,5]; thanks to the combination of IB functionality with the unique physical properties associated with nanowires-based devices, SCs reaching theoretical PCE figures up to 56% at 1000 sun could be conceived. Light wave-guiding and nano-antenna effects in suitably-designed NWs can further raise these figures, while reducing the amount of costly III-V materials.
The growth of highly mismatched III-N-V compounds is very challenging, and studies on the growth of III-V-N based NWs are still very limited in the literature, mostly restricted to MBE. In the talk the very first results on the growth of GaAs-GaNAs core-(multi)shell NWs by MOVPE will be discussed. N-incorporation within GaNAs shells depends on the precursors V:III and N:As ratio in the vapour, growth temperatures, shell growth rates, NW array density, according to a validated shell growth model [6].
The predictive strength of our shell growth model is evaluated by application to GaAs quantum well tube (QWT) NWs, whose nano-scale optical (radiative) and inner structural properties will be presented, ultimately allowing to evaluate the truly 1-dimensional quantum confinement of charge carriers within the QWTs [7].

Dense arrays of core−shell NWs possess great potential as super-absorptive media for SCs applications. Despite the breath of different NW structures proposed for SCs, experimental estimates of light absorption enhancement in dense NWs have remained mostly limited to single or dense arrays of compositionally uniform NW. Here, the first ever experimental estimate of the GaAs near band-edge absorption enhancement factor in GaAs-AlGaAs core-shell NWs will be finally reported [8]; strong absorption enhancement (up to about 190× that of equivalent planar structures) will be demonstrated and ascribed to improved wave-guiding of incident light into the NW GaAs cores by the surrounding AlGaAs shells. Theoretical modelling will allow to generalize these findings and further estimate the optical absorptance of NW arrays as function of their geometry (NW density, lengths, etc.) of utmost importance for photovoltaic applications.
Present findings open the way to the future fabrication of high-efficient nanowire-based solar cells.

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