Soutenance de thèse

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III-V-on-Si nanowire-based solar cells for tandem applications

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Abstract

Tandem PV technologies combining a III-V semiconductor cell over a silicon (Si) cell offer a promising pathway to exceed the efficiency limit of single junction Si solar cells (29.4%). Owing to their small diameters, nanowires (NWs) allow to mitigate the lattice constant and thermal coefficient mismatch issues associated with the direct growth of high-quality III-V layers on Si. The goal of this PhD work is to fabricate a high-efficiency solar cell consisting of first GaAs NWs, and ultimately GaAsP NWs, directly grown on Si by molecular beam epitaxy. First, the patterned Si substrate preparation process was optimized to obtain ordered GaAs NW arrays with near-perfect and reproducible vertical yields. Our champion core–shell GaAs/GaInP NW solar cell demonstrated a high Voc of 0.65 V, and an efficiency of almost 3.7%, at the state-of-the-art of radial junction GaAs NW solar cells grown on Si.
The calibrated photoluminescence characterization of these NW arrays indicated good optoelectronic properties, with a quasi-Fermi level splitting of 0.84 eV at 1 sun, and we identified significant room for device improvement. Increasing the n-type doping level in the NW shell could be one way of enhancing device performance. To this end, we used cathodo-luminescence to study the incorporation efficiency and homogeneity of tellurium in self-catalyzed GaAs NWs. Finally, GaAs/GaAsP/GaP axial junction NW solar cells were fabricated for the first time in our group. Luminescence characterization indicated promising optoelectronic properties. Using electronic simulation, we attributed the limited performances to energy barriers at the n-type contact. Overall, this PhD work contributed to significant technological advances, and the detailed characterization experiments and simulation results presented shed light on the potential and challenges of III-V-on-Si NW-based solar cells.