# New challenges in the growth of GaAsP nanowires on Si for tandem solar cells

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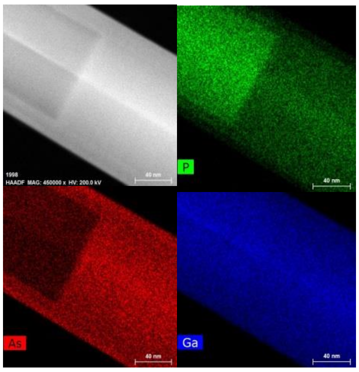
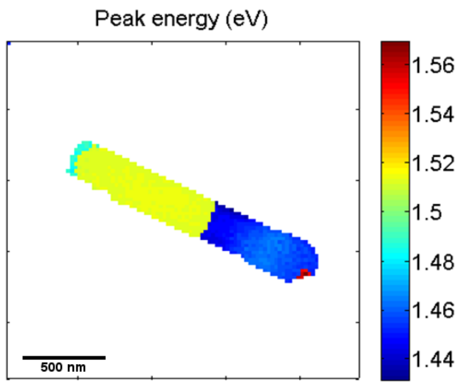
To achieve efficiencies beyond that of Si single junction solar cells, a possible pathway is to make double-junction solar cells which combine a top III/V cell onto a Si lower cell. Among III-V semiconductors, GaAsP is a possible material candidate which can reach the optimal energy gap of 1.7eV that could lead to efficiencies exceeding 33% at AM1.5G[1]. Direct epitaxy of III-V material on Si is an appealing concept but thermal- and lattice- match forbid epitaxy of GaAsP layers on Si. In this particular context, III-V nanowires (NWs) appear as an elegant solution in which the usual lattice-match constraints are relaxed so that high quality III-V material with the optimum band gap can be directly grown on Si substrates. However, several challenges still limit the use of NWs in real devices, including the variation of ternary alloy composition over the growth duration and the precise control of dopant incorporation in the axial and radial directions.

Self-catalyzed GaAsP nanowires were grown on a patterned Si(111) substrate in a solid-source Molecular Beam Epitaxy (MBE). We varied the ratio between arsenic and phosphorus fluxes in order to promote different GaAsP alloy compositions. Structural and chemical analysis (TEM-EDX) coupled with low temperature cathodoluminescence mapping (CL) confirmed that we could achieve different compositions along the growth direction and reach the 1.7 eV bandgap. However we also observed the presence of an unintentional As-rich parasitic shell which grows concurrently with the VLS core.

Beyond alloy composition, a precise control in material doping is required to obtain efficient carrier separation in typical solar cells. Here we study the properties of Si-doped GaAs nanowires grown on patterned Si. Silicon is typically an n-type dopant for planar GaAs(100) but it actually has an amphoteric behavior whether it substitutes group III or group V atoms in the material. Using low temperature CL, we observe striking differences in the spectral signatures of Si-doped GaAs shell, which suggests that Si atoms could incorporate as P- or N-type impurities on the NW sidewall depending on the substrate temperature. More importantly we observe that the crystal structure of the NW, cubic or hexagonal, may have a critical role in the incorporation of Si and in the resulting carrier concentration and doping type.




*TEM-EDX map of a GaAsP nanowire showing superposed core-shell structures of different alloy composition*




*Low temperature CL mapping of a GaAs nanowire with a Si-doped shell. A remarkable shift in the peak energy correlates with a transition from a zinc-blende phase (yellow) to a wurtzite phase (blue)*

References:

1. Lapierre, R. R. (2011). *Theoretical conversion efficiency of a two-junction III-V nanowire on Si solar cell. Journal of Applied Physics*, 110(1), 14310–34311. https://doi.org/10.1063/1.3603029