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Al Thermal Diffusion in Ge and Si_xGe_{1-x} Nanowires: A Novel Approach towards 1D Heterostructure Fabrication

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Thermally activated solid state reactions forming metal silicides (germanides) nanowire heterostructures have recently received special interests as they could be either employed as a platform to study the Fermi-level pinning effect at metal- Si (Ge) junctions or used as building blocks for fabricating short-channel devices such as photodetectors, single-electron transistors by Coulomb blockade effect or state-of-the-art field effect transistors (FETs). We study the Al-Ge binary system, combining ex-situ and in-situ heating methods, and present a proof of principle experiment carried out in-situ in a transmission electron microscope where we precisely control the metal propagation speed and produce an axial Al/Ge/Al nanowire heterostructure with an ultra-short Ge segment down to 7 nanometers [1]. In the Al- (Ge, Si) ternary system, the thermal reaction results in the creation of a Si-rich region sandwiched between the reacted Al and unreacted Si_xGe_{1-x} part, forming an axial Al/Si/Si_xGe_{1-x} heterostructure. Upon heating or (slow) cooling, the Al metal can repeatably move in and out of the Si_xGe_{1-x} alloy nanowire while maintaining the rod-like geometry and crystallinity, see Fig. 1, allowing to fabricate and contact nanowire heterostructures in a reversible way in a single process step, compatible with current Si based technology [2].

(1) M. A. Luong, *ACS Appl. Nano Mater.* **2020**, *3* (2), 1891–1899.
(2) M. A. Luong, *ACS Appl. Nano Mater.* **2020**, *3* (10), 10427–10436.

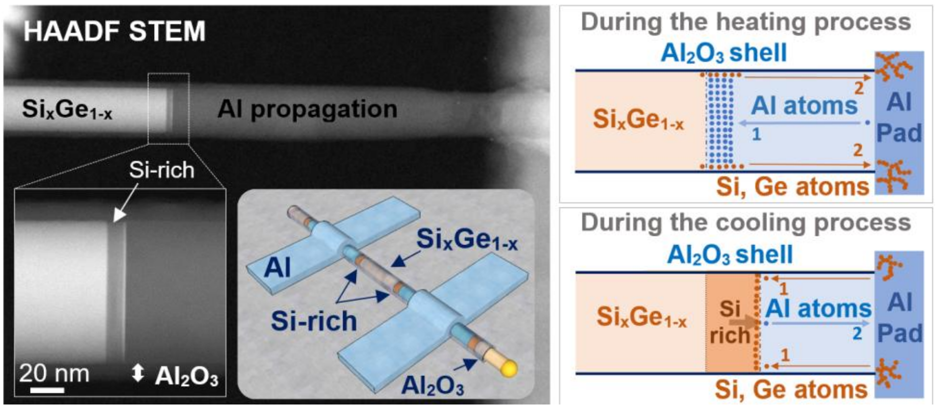

Figure 1: HAADF - STEM images of Al thermal propagation in passivated Si_xGe_{1-x} NW (with 20 nm Al_2O_3 shell) showing the formation of Al/Si-rich/Si_xGe_{1-x} heterostructure, and schematic illustrations of the diffusion paths of Si, Ge and Al atoms during the heating and cooling process, respectively.