Axial Silicon Germanium Silicon (Si/Ge/Si) Nanowire for Tunneling and Optical Source Devices

Oral talk preferred

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Modern vapor-liquid-solid (VLS) growth based on alloy catalysts can grow SiGe heteronanowires (hetero-NWs) with controlled axial heterojunction abruptness [1], see Fig. 1, combined with simultaneous control of material composition (Si and Ge) and doping profile. Previously, we reported on tri-gated p-Ge/i-Si/n-Si axial hetero-NWs tunneling FET with on-state tunneling current I_{ON} occurring in the Ge drain section and off-state leakage dominated by the Si junction in the source, see Fig. 2(a). The devices have high on current I_{ON} of 2 µA/µm, suppressed ambipolarity, and a sub-threshold slope *SS* of 140 mV/decade over 4 decades of current with lowest *SS* of 50 mV/decade [2], see Fig. 2(b). Device operation in the tunneling mode is confirmed by three-dimensional TCAD simulation. In addition, we observed the back-gate V_{BG} response of the device depends strongly on the presence of the tri-gate metal.

Recently, new growth conditions were established for a more complex Si/Ge/Si heterostructure. In the one hand, the double heterointerface promises further enhancement of TFET performance owing to the capability to engineer not only the tunneling junction but also contact regions independently. Figure 3 shows a ~50 nm Ge section grown in a narrow, 20 nm diameter Si nanowire by the same VLS technique using Au catalyst, together with the EDS analysis of the material composition. Such a short Ge inclusion, aligned with the gate in a vertical gate-all-around configuration demonstrated for all-Si devices would be promising for a Si-compatible high-current TFET. Preliminary results on the performance of axial p-Si/p-Ge/i-Si/n-Si nanowire TFET will be reported.

On the other hand, quantum confinement in a small diameter Si/Ge/Si NW could open a new paradigm for optoelectronics devices, where carrier confinement and zone-folded band structure will contribute to stronger optical transitions in the Ge [3] than are normally possible in homogenous indirect bandgap NWs. We will report on the growth and rectification of p-Si/i-Ge/n-Si nanowire with preliminary electroluminescence measurements.

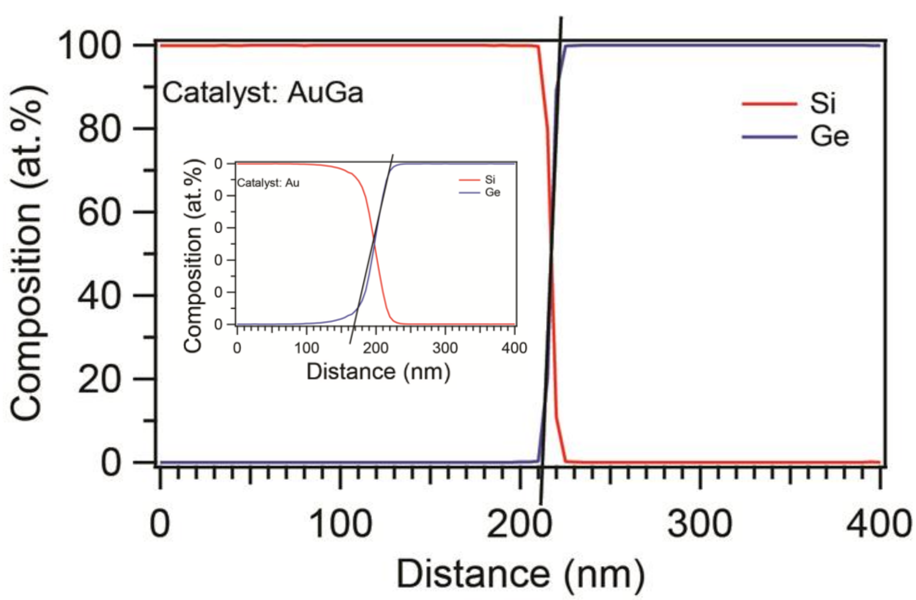

Figure 1: Composition profiles, obtained from atom probe tomography (APT) analysis, of the SiGe heteronanowire grown from AuGa alloy catalyst (~9 nm heterojunction width); inset: the SiGe heterojunction grown from Au catalyst for comparison (~44 nm heterojunction width).

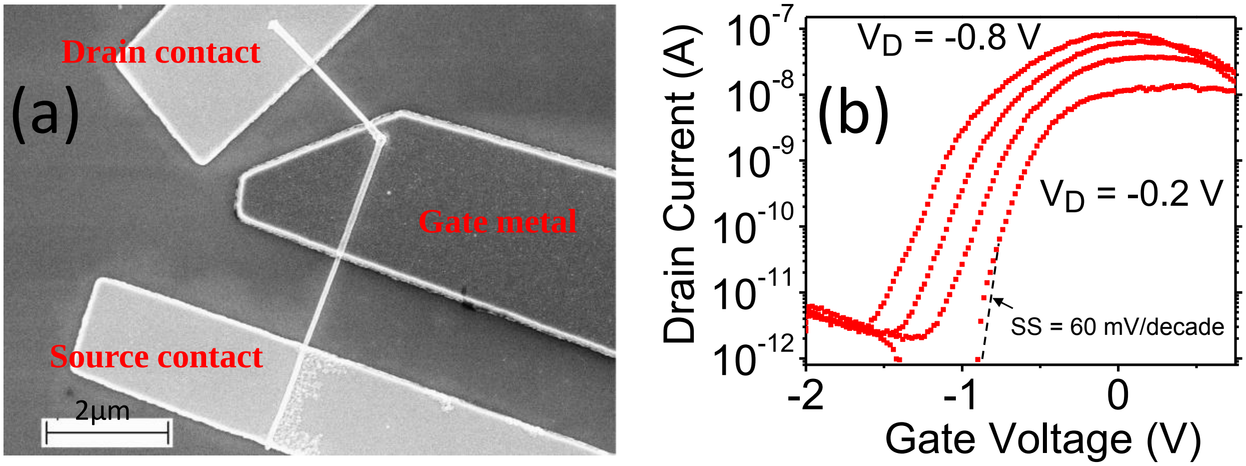

Figure 2: (a) SEM image of the SiGe hetero-NW TFET with D ~ 50 nm, grown at Los Alamos National Lab. (b) $I-V$ characteristic of the device in tunneling operation mode at T = 300 K.

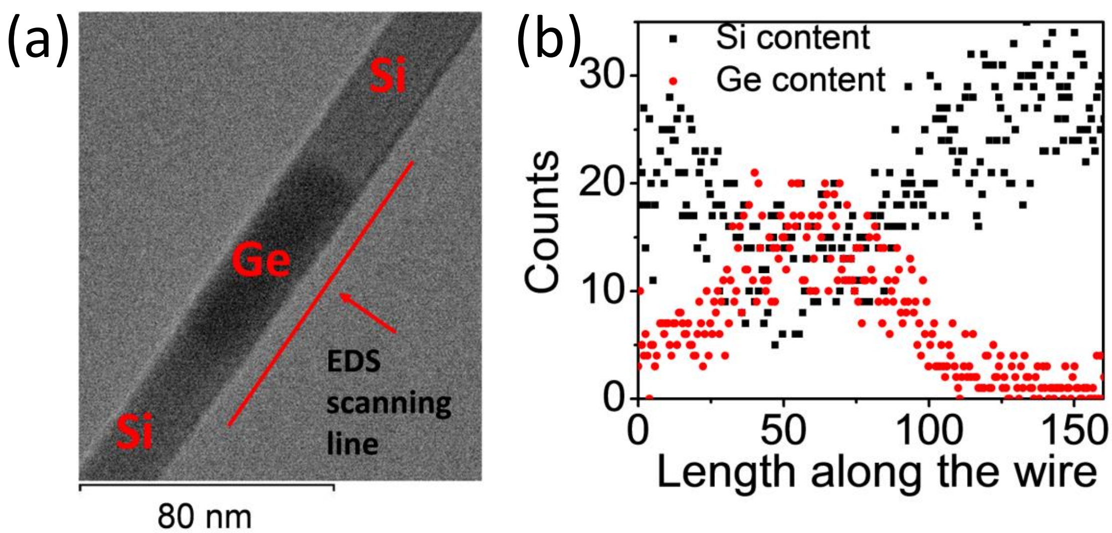

Figure 3: (a) TEM image of the Si/Ge/Si hetero-NW p-n junction of D ~ 20 nm, grown at Los Alamos National Lab. (b) EDS analysis of the hetero-NW confirms the composition modulation along the wire, from Si to Ge to Si.

References

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