In-Plane Germanium Nanowire Networks: Growth and Hole Transport

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Holes in Ge-Si core-shell nanowires are promising candidates for realizing spin-based quantum computers. The strong and tunable spin-orbit interaction of holes enables fast qubit manipulation, and the low susceptibility to hyperfine noise improves coherence [1]. In addition, the shape and orientation of the nanowires can be tailored to eliminate the influence of charge and hyperfine noise on qubit coherence.

The conventional method for producing Ge-Si nanowires employs the Au-catalyzed vapor-liquid-solid (VLS) process, which restricts the growth of nanowires to an out-of-plane configuration [2]. In contrast, selective area epitaxy (SAE) is a reliable method to obtain in-plane nanowires at the site of future devices in a scalable manner [3][4].

This work presents the first report of SAE of in-plane Ge nanowires inside raised Si membranes with a V-groove. Figure 1, in the inset, shows the cross-section of the Ge nanowire. The Ge nanowires, grown inside a Si V-groove, can be entirely encapsulated by the Si shell, thus avoiding direct contact between the Ge channel and the silicon dioxide (SiO_2) dielectric (see Figure 1 inset). Additionally, the triangular shape of the nanowire tip helps to induce anisotropic strain in the Ge channel. Finally, having Ge nanowires on elevated structures facilitates the development of conformal gating schemes, allowing better control and tunability of charge carriers.

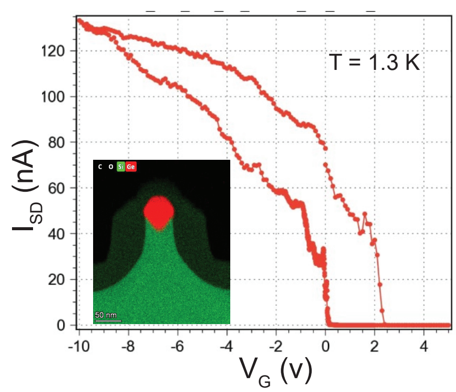

Fig. 1. I versus V_G plot of nanowire field-effect measurement at 1.3 K. The inset figure shows the cross-section of the Ge nanowire on an elevated Si V-groove.

We investigated the underlying growth mechanism and the electrical properties of the Ge nanowires. Using scanning electron microscopy (SEM) and atomic force microscopy (AFM), we report the temporal evolution of Ge nanowire growth. The growth of the nanowires within the V-groove occurs through the nucleation and coalescence of the Ge islands. In addition, the nanowires were analyzed under high-angle annular dark-field scanning transmission electron microscopy (HAADF-STEM) to assess their crystal quality and faceting. The fully grown Ge nanowires exhibit a zinc-blende structure with twins at the Ge nanowire Si(111) interface.

The electrical properties of the nanowires were evaluated using field effect and Hall measurements on Ge nanowire networks. The nanowires exhibit p-type conductivity. Magnetotransport measurements at low temperatures reveal quantum diffusive transport phenomena such as universal conductance fluctuations and weak antilocalization. Finally, we demonstrate the fabrication of electrostatically defined quantum dots in SAE Ge nanowires.

References

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