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Scaling Properties of High Performance Ge-Si_xGe_{1-x} Core-Shell Nanowire Field Effect Transistors[1]

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Semiconductor nanowires (NWs), namely highly anisotropic crystals with diameters of the order of a few tens of nanometers, have received increased interest recently as a platform for electronics devices, motivated in part by issues associated with end of the roadmap of complementary metal-oxide-semiconductor (CMOS) device scaling. The performance advantage of such devices stems from superior electrostatic properties compared to planar devices, which in turn help increase their on-state current and on/off-state current ratio. We present recent results on the growth and fabrication of a few key NW device structures, which can potentially outperform conventional CMOS devices. By combing axial Ge NW growth, via the vapor-liquid-solid mechanism, with conformal Si_xGe_{1-x} growth by ultra-high-vacuum chemical vapor deposition, we demonstrate Ge-SixGe1-x core-shell NW heterostructures. Transmission electron microscopy combined with energy dispersive X-ray spectroscopy show that the Si_xGe_{1-x} shell can be grown in-situ, epitaxial onto the Ge NW core, and that the Si/Ge shell content can be tuned depending on the growth conditions, effectively enabling band engineering in these one dimensional nanowire heterostructures. A key component in fabrication high performance nanowire field effect transistors, namely high on-state current and high on/off-state current ratio, is the fabrication of low resistance, unipolar contacts to a semiconductor nanowire. Using low energy ion implantation we demonstrate dual-gated Ge-Si_xGe_{1-x} core-shell nanowire field effect transistors with highly doped source and drain. We discuss the scaling properties as a function of channel length, and intrinsic carrier mobility in these devices.

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