Characterization of selective doping and stress in Si/Ge and Ge/Si core-shell nanowires

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Silicon and germanium nanowires (SiNWs and GeNWs) are anticipated for the realization of next-generation metal-oxide-semiconductor field-effect transistors and solar cells. Impurity doping is one of the key techniques for the NWs devices [1-3], while the retardation of carrier mobility due to impurity scattering has to be taken into account. Core-shell NWs composed of Si and Ge are key structures for realizing high mobility transistor channels, since core-shell structures separate the carrier transport region from the impurity doped region, resulting in the suppression of impurity scattering.

In this study, we grew four different types of Si/Ge and Ge/Si core-shell NWs and performed site selective doping in the core and shell regions. In order to clarify the status of impurity atoms such as the bonding states and the electrical activities of impurity atoms, we performed Raman measurements. The stress in the core and shell regions was also evaluated by XRD and Raman measurements

Four different types of Si/Ge (i-Si/n-Ge, p-Si/i-Ge) and Ge/Si (n-Ge/i-Si, i-Ge/p-Si) core-shell NWs structures were rationally grown on a Si substrate by CVD. Gold nanocolloid particles of 3 nm in diameter were used as seeds for vapor-liquid-solid (VLS) growth of core-SiNWs and core-GeNWs. X-ray diffraction (XRD) measurements (Cu Kα radiation) were performed to investigate individually the stress in the core and shell regions. The XRD data were collected with parallel beam geometry. Micro-Raman scattering measurements were also performed to investigate the stress in the core-shell NWs, at room temperature using a 100x objective and a 532-nm excitation light source. These methods were also used to clarify the states of dopant atoms, and finally the B and P doping in the shell region.

The growth of Si/Ge and Ge/Si core-shell NWs and site-selective doping within them were carried out by CVD. XRD and micro-Raman measurements clearly revealed stress in the core and shell regions and characterized the compressive and tensile stress present. The formation of the Ge shell applies tensile stress to the Si core, while the Si core applies compressive stress to the Ge shell. Conversely, the formation of the Si shell applies compressive stress on the Ge core, while the Ge core applies tensile stress to the Si shell. XRD and micro-Raman measurements also clearly demonstrated site-selective doping. XRD revealed peak shifts due to lattice contraction caused by doping with P and B atoms. The local vibrational peaks of P and B atoms and Fano broadening in the optical phonon peaks were observed using Raman scattering methods that showed the p and n-shells in the Si/Ge and Ge/Si core-shell NWs.

References

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Figures

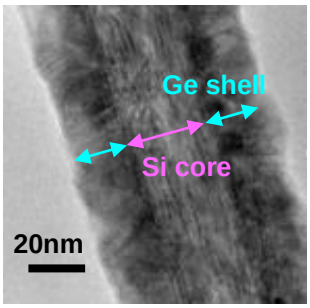

Figure 1: A TEM image of Si/Ge core-shell NWs.

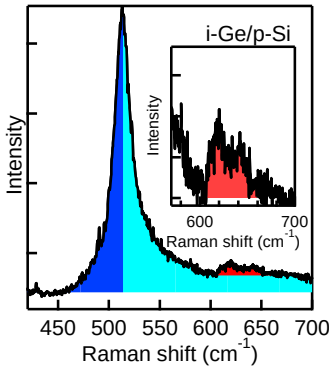

Figure 2: Raman spectra observed for i-Ge/p-Si core-shell NWs. Inset is the magnification of the ^{11}B and ^{10}B local vibrational peaks in the Si shell layer.