Interfacial intermixing controls of Ge/Si core-shell nanowires using thermal annealing treatment

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The heterostructure Ge/Si NWs have been suggested as potential building blocks to realize future high-performance transistor applications. Many efforts have been done to optimize structures, selective doping, carrier concentrations, and interface properties to be able to use NWs for nanodevices [1,2]. However, the formation of a sharp interface and good crystallinity have not yet been optimized to enhance hole carrier accumulation. In this study, the thermal annealing effects on i-Ge/p-Si core-shell NWs were investigated. The morphology, interface, and crystalline property were analyzed by controlling the annealing parameters.

All samples of p-Si/i-Ge core-shell NWs were grown by chemical vapor deposition. Au catalyst was used for the vapor-liquid-solid growth. The thermal annealing was applied after NW formation with the varying temperature (500-900 °C), time (1-20 min), and pressure (6×10^{-6}-50 Pa). Raman and XRD measurements were used to estimate the crystallinity, stress, and composition of Si and Ge at the interface region. The morphology, thermal stability, and interfacial intermixing of the i-Ge/p-Si core-shell NW were evaluated by SEM and TEM.

From the results, the NW morphology was changed at high annealing temperature and pressure from NW structure to block shape with alloy properties. These appearances of NW shape transformation occurred at temperature and pressure higher than 800 °C and 50 Pa, respectively. With the varying of annealing times, NW structure and properties were unaffected. The intermixing at Ge/Si interface was detected even the annealing period was done for 1 min. The annealing performed under very low-pressure condition could

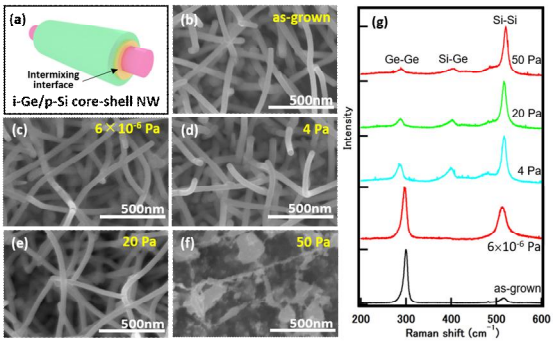

Figure1. (a) Schematic of i-Ge/p-Si core-shell NW with an interfacial intermixing. SEM images of (b) as-grown and after RTA under the pressure of (c) 6×10^{-6} Pa, (d) 4 Pa, (e) 20 Pa, (f) 50 Pa with a fixed annealing temperature of 800 °C for 5 min. (g) Raman spectra of core-shell NWs with various pressure annealing.

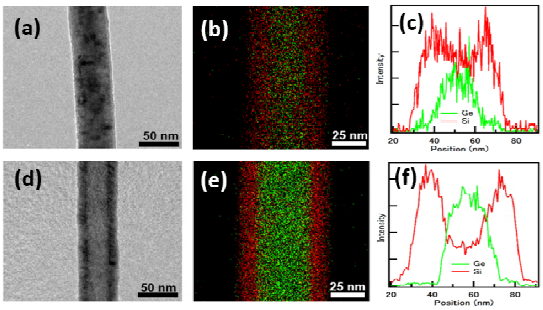

Figure2. The comparison of (a), (b), (c) intermixing and, (d), (e), (f) no-intermixing samples observed by using TEM, EDX mapping, and line scan measurements.

successfully suppress the intermixing at Ge/Si interface with maintained NW morphology while high-pressure enhanced this intermixing as shown in Figure 1. The Raman spectra confirmed no Si-Ge alloy peak and the improvement of Ge crystallinity at 6×10^{-6} Pa with a fixed annealing temperature of 800 °C for 5 min. Figure 2 clearly shows TEM and EDX results of good i-Ge/p-Si core-shell NW structure with a sharp interface.

References:

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[2] Fukata, N.; Mitome, M.; Sekiguchi, T.; Bando, Y.; Kirkham, M.; Hong J.; Huang Z. L.; Snyder, R. ACS Nano 2012, 6(10), 8887-8895.