Controlling of interfacial intermixing of Ge/Si core-shell nanowires by thermal annealing

Xiaolong Zhang[1,2], ○Wipakorn Jevasuwan[1], and Naoki Fukata[1,2]
Email: s1636016@s.tsukuba.ac.jp; FUKATA.Naoki@nims.go.jp
[1]International Center for Materials Nanoarchitectonics, National Institute for Materials Science, Japan
[2]University of Tsukuba, Japan

Abstract:

One-dimensional nanostructures, Ge/Si core-shell NWs, have attracted considerable attention in the last decades. Many efforts have been done to optimize structures, selective doping, carriers' s concentration, and interface properties to be able to use NWs for nanodevices [1,2]. However, the formation of a sharp interface and good crystallinity for the i-Ge/p-Si core-shell structure 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, intermixing at the interface between the i-Ge core and p-Si shell layers, and crystallinity of the core-shell NWs were analyzed by controlling the annealing parameters.

All samples of p-Si/i-Ge core-shell NWs were grown by chemical vapor deposition (CVD). Metal catalyst (Au) was used for the vapor-liquid-solid (VLS) growth. The thermal annealing was applied after NW formation with the temperature control at 500-900 ℃ using a rapid thermal annealing (RTA) system. The annealing pressure was also optimized by controlling the N_2 gas pressure environments. The annealing time was changed from 1 min to 20 min. Raman spectroscopy and XRD measurements were used to estimate the crystallinity, stress, and compositions of Si and Ge at the intermixing region. The morphology and thermal stability of the i-Ge/p-Si core-shell NW were evaluated by SEM.

Figure 1 shows the detail SEM images of annealing temperature dependence on the core-shell NWs shapes. The clear cluster of NWs could be observed at 800 °C anneal, showing the transformation of NWs shapes. After annealing temperature at 900 °C, almost all NWs were broken down to block shapes. From Raman measurement, the Si-Ge peak were observed from all samples of 500-700 °C annealing due to intermixing at the interface between Ge and Si layers. The annealing pressure was also investigated as shown in Figure 2. The morphology of NWs has no change at low annealing pressures. The Raman spectra showed the intermixing can be suppressed at 6×10^{-6} Pa. The crystallinity of Ge can be successfully improved in this low-pressure annealing process.

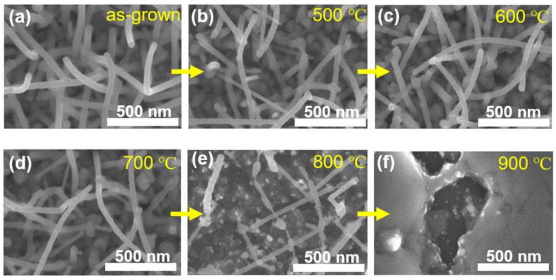

Figure1. SEM images of (a) as-grown i-Ge/p-So Si core-shell NWs and after RTA annealing at (b) 500 ℃, (c) 600℃, (d) 700℃, (e) 800 ℃, (f) 900 ℃ with fixed annealing pressure of 100 Pa and annealing time of 1 min.

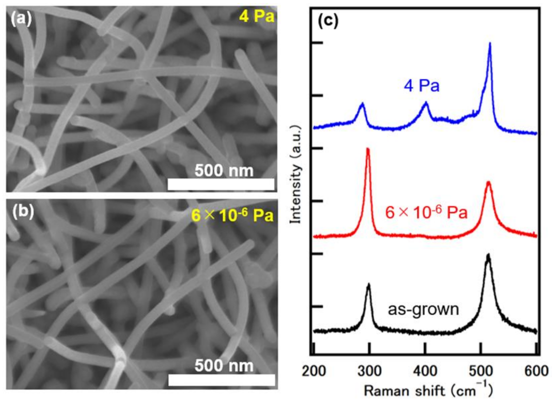

Figure2. The i-Ge/p-Si core-shell NWs under different pressure treatments; of (a) SEM images of NWs annealed under pressure of (a) 4 Pa, (b) SEM image of 6×10^{-6} Pa, and (c) their Raman spectra.

References:

[1] Zhang, X.; Jevasuwan, W.; Pradel, K.; Subramani, T.; Takei, T.; Fukata, N. Nanoscale 2018, 10, 21062–21068.
[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.