The Effects of B Doping on Al-Catalyzed Si Nanowire Formation and Their p-Si/i-Ge Core-Shell Nanowire Structures

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One-dimensional nanowires (NWs) have recently attracted great interest for high efficiency solar cells and high electron mobility transistors (HEMT) due to their remarkable electrical, optical and mechanical properties. From our previous reports [1-2], VLS growth using Al catalyst was proposed to create single crystalline SiNWs with the resolving of metal catalyst contamination problem. The SiNW-based solar cells with upon 9% efficiency were achieved. However, the unintentional Al doping from catalyst or intentional B doping as p-type dopants in SiNWs for HEMT applications using p-Si/i-Ge core-shell NW structure have not been observed yet. The advantage of this structure is low impurity scattering, as the induced carriers from p-Si core NW are confined and transported in i-Ge shell region [3-4]. In this study, the effects of B doping on Al catalyzed SiNW formation using VLS growth were investigated. The p-Si/i-Ge core-shell NW properties with various i-Ge shell thicknesses were examined.

All samples were fabricated on n-Si (111) substrates. Al-catalyst films were sputtered prior to VLS process. The SiNW formation was performed with the growth time of 30 min, SiH_4 gas flow of 19 sccm, various B_2H_6 gas flows of 0, 0.1, 0.2 sccm, and fixed substrate temperature of 700 °C [1-2]. The Ge shell layer for Si/Ge core-shell NWs was deposited at 500 °C with various formation times of 30, 60 and 90 sec, and GeH_4 gas flow of 10 sccm on both of Si core NWs with and without B doping. Figure 1 shows Raman spectra and SEM images of SiNWs formed by various B_2H_6 flow rates. The increasing of B_2H_6 gas flow reduced SiNW formation. Good NW structure could be maintained at 0.1-sccm B_2H_6 flow. The Si optical phonon peaks were more downshifted from bulk-Si, starting from without B-doped SiNWs toward to the higher B-doping. These SiNW peaks showed an asymmetric broadening, indicating the Fano effect (dopant atoms were electrically activated in SiNWs). Two peaks at 619 and 642 cm^{-1} of local vibrational mode of B were clearly observed in 0.2-sccm-B_2H_6 Si nanostructures.

Figure 2 showed Ge optical phonon peaks of the

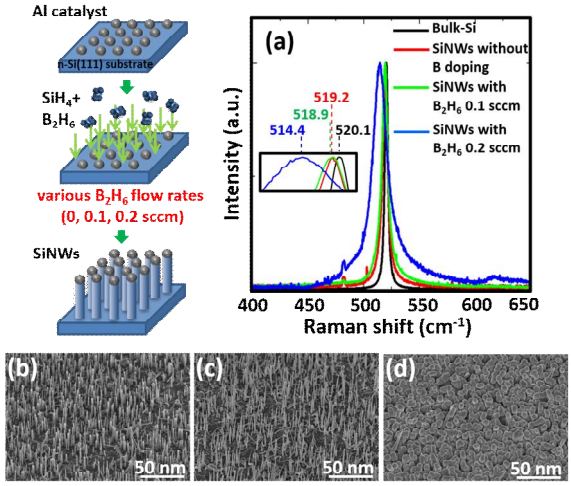

Fig. 1 Schematic of Al-catalyzed SiNW formation with B doping by VLS growth. Raman spectra (a) and SEM images of SiNWs formed by various B_2H_6 flow rates of (b) 0, (c) 0.1, and (d) 0.2 sccm.

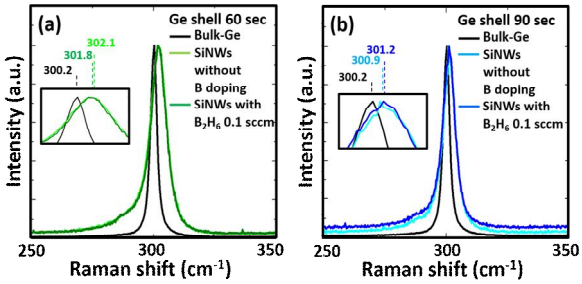

Fig. 2 Raman spectra of Ge optical phonon peaks with (a) 60 and (b) 90 sec Ge shells on with and without 0.1 sccm B_2H_6 p-Si/i-Ge core-shell NWs.

p-Si/i-Ge core-shell NWs with different Ge shell thicknesses of 60 and 90 sec (the Ge peak was not detected at 30-sec Ge shell formation). Comparable Ge peak positions of both unintentionally Al-doped and B-doped p-Si/i-Ge core-shell NWs were observed. The asymmetrical broadening clearly showed the induced hole gas accumulation by p-Si core NWs. The narrowing of phonon peak at 90-sec Ge shell is due to the decrease in the hole gas density on increasing the thickness of Ge layer. More characterizations are in progress.

[1] W. Jevasuwan, *et al.*, JSAP spring meeting, (2016) 20p-P7-6. [2] W. Jevasuwan, *et al.*, JSAP spring meeting, (2017) 16p-P15-14. [3] N. Fukata, *et al.*, ACS Nano. 9 [12] (2015) 12182-12188. [4] X. Zhang, *et al.*, Nanoscale 10 (2017) 21062-21068.

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