Ge/Si core-shell Nanowires Fabrication and Investigation of the Relationship between Diameter and Fano Effect

International Center for Materials Nanoarchitectonics (MANA), National Institute for Materials Science (NIMS)[1], Univ. of Tsukuba[2]

°Chao Le[1,2], Yonglie Sun[1], Wipakorn Jevasuwan[1], Naoki Fukata[1,2]

E-mail: chaole0903l@gmail.com

Introduction

It is well known that there is an increasing demand for high-performance electronic devices in nowadays world, traditional types of metal-oxide-semiconductor field-effect transistors (MOSFETs) can no longer satisfy the performance requirements. The focus has shifted to pushing the limits of their structural physics scales and materials. In order to address impurity scattering, and short-channel effects (SCE) associated with device miniaturization, new structures have been developed. Gate-all-around (GAA) FETs supports significantly reducing SCE and being able to separate the doping region from the conducting region while enhancing drive current[1]. Undoped Ge and Boron-doped Si are decided as core and shell. The reasons are the high mobility of Ge and energy band-offsets in the heterojunction. Depending on the Fermi level position, hole gas can be accumulated in the quantum well [2]. (Fig.1)

In this study, we focused on top-down method to fabricate vertical type Ge/Si core/shell NWs, demonstrate hole gas accumulation in the NW as evidence of successful fabrication and compare the level of Fano effect produced between different size NWs.

Experimental section

500~600 nm Ge layer were deposited onto p-Si substrate by Chemical Vapor Deposition (CVD). Then the Ge layer was covered by a resist layer using spin coating and patterns with five kinds of different diameters were formed by EB lithography. MgO layers were then deposited on to the resist as a mask. After lifting off the mask, Bosch Etching process was performed to remove the area without MgO to form NWs. The NWs were loaded into CVD chamber again to form i-Ge shell and p-Si shell. (Fig.2)

Results and discussion

SEM observation and Raman spectra analysis were used to characterize the fabricated structure and demonstrate Fano effect. The SEM images showed the comparison between before & after the shell formation (Fig.3). The Raman result showed the change of Ge peak position and asymmetric broadening due to the Fano effect after the shell formation. Ge optical phonon peak was fitted by Fano equation[3] and the tendency change of Fano parameters q and Γ were analyzed. (Fig.4). As a result, we successfully demonstrated the hole gas accumulation in the i-Ge region of the i-Ge/p-Si core/shell NWs and indicate Fano effect becomes smaller with the increase of the NWs' diameter.

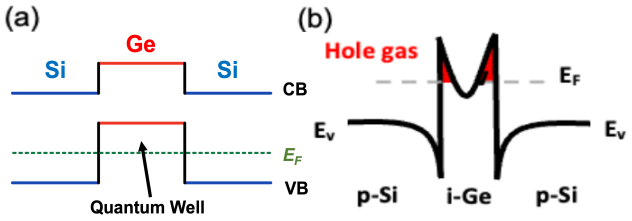

Fig 1. (a) Quantum well formation caused by the connection of Ge and Si with different band energy level, it can confine carriers. The quantum well in this Si/Ge/Si structure has a raised shape, indicate the main carriers are holes. **(b)** Energy band curving caused by the Si/Ge/Si heterojunction, due to the hole gas accumulation in quantum well.

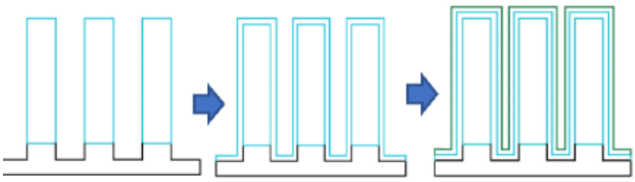

Fig 2. The experiment process of fabricating i-Ge/p-Si core/shell NW by using Chemical Vapor Deposition

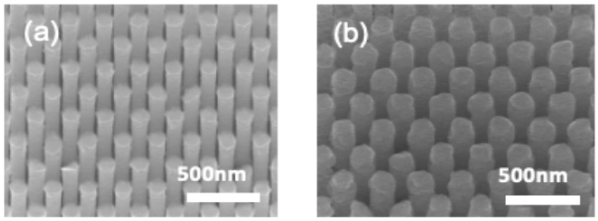

Fig 3. SEM figures of group 4 (actual diameter: 90 nm) Ge nanowire (GeNW) array compare between **(a)** before shell growth, **(b)** after shell growth.

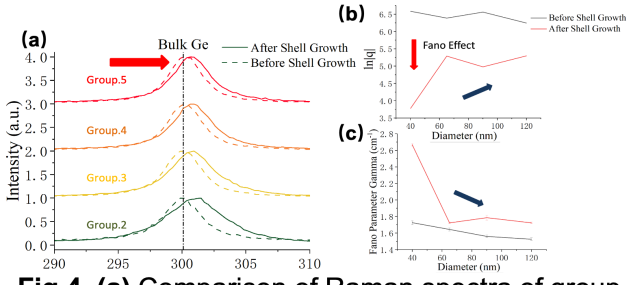

Fig 4. (a) Comparison of Raman spectra of group 2~5 GeNW arrays between before & after shell formation. The Ge peak shows an upshift after the shell growth due to different lattice constants. **(b)** The change tendency of the Fano parameter q with the increase of nanowire size. **(c)** The change tendency of the Fano parameter Γ with the increase of nanowire size. Both the change of q and Γ Indicates Fano effect increases significantly after shell growth, but gradually decreases with the increase of size.

References

[1] Xiang J, Lu W, Hu Y, et al. Nature, 441 (2006) 489.
[2] Fukata N, et al. ACS Nano, 9 (2015) 12182.
[3] Zhang X, Jevasuwan W, Sugimoto Y, et al. ACS Nano, (2019) 13403.