Evaluation of Strain in the Oxide Covered Silicon Nanowires for Thermoelectric Devices by Raman Spectroscopy

R. Yokogawa,[a, c] **S. Hashimoto**,[b] **M. Tomita**,[a,b,c] **T. Watanabe**,[b] **and A. Ogura**[a]

[a]*School of Science and Technology, Meiji University, 1-1 Higashimita, Tama-ku, Kawasaki, Kanagawa 214-8571, Japan*

[b]*Faculty of Science and Engineering, Waseda University, 3-4-1 Okubo, Shinjuku, Tokyo 169-8555, Japan*

[c]*JSPS Research Fellow DC, 5-3-1 Kojimachi, Chiyoda-ku, Tokyo 102-0083, Japan*

Silicon nanowires (SiNWs) are promising candidates for the thermoelectric devices as well as next-generation channel materials of surrounding gate field-effect transistors [1]. Especially SiNWs with cover oxide is recognized as a promising new thermoelectric material owing to their low dimensionality and the disorder strain induced at the SiO_2/SiNWs interface. To realize SiNW devices with high electric and thermoelectric performances, further improvements through the optimization of strain in the NWs are necessary to achieve a higher mobility and a lower thermal conductivity. Raman spectroscopy is a powerful strain evaluation technique in the nanostructures, because it has advantages such as a high spatial resolution and a nondestructive measurement [2]. In this study, we evaluated the strain in the oxide covered SiNWs. We fabricated SiNWs using silicon-on-insulator (SOI) wafers with thermal oxidation under various conditions. We also performed small amount of Ar^+ ion irradiation to modify the SiO_2/SiNW interface (25 keV, 1.0×10^{14} cm^{-2}).

Figure 1 shows the σ_{xx} and σ_{yy} components of the biaxial stresses of the along the SiNW length and width directions evaluated by water-immersion Raman spectroscopy before and after Ar^+ ion irradiation. Before Ar^+ ion irradiation, the anisotropic biaxial stresses σ_{xx} and σ_{yy} in SiNWs were confirmed to be compressive and tensile stress, respectively. On the other hand, after Ar^+ ion irradiation, we confirmed that σ_{xx} became tensile stress, and σ_{yy} was almost completely relaxed. We consider that an oxide-induce lattice disorder of the SiNW is relaxed by breaking strained bonds at SiO_2/SiNW interface by the ion irradiation, and tensile stress along the long direction (σ_{xx}) in the SiNW is induced by SiNW lattice disorder. In conclusion, we evaluated the strain induction mechanism in the SiNW by Raman spectroscopy, sensitively.

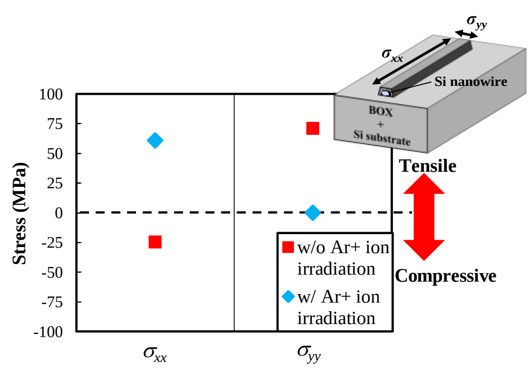

Fig. 1. Biaxial stresses along the SiNW length and width directions.

+ Author for correspondence: r_yokogawa@meiji.ac.jp

[1] A. I. Boukai, Y. Bunimovich, J. Tahir-Kheli *et al.*, Nature **451**, 168 (2008).

[2] R. Yokogawa, S. Hashimoto, S. Asada *et al.*, Jpn. J. Appl. Phys. **56**, 06GG10 (2017).