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Analysis of Electrical Field in Surface Enhanced Raman Spectroscopy Using Strained-Si Substrate

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【Background and Objective】Strained-Si technology is essential for high performance transistors. The strained-Si has been proposed as a next-generation substrate because it can enhance carrier mobility. Surface Enhanced Raman Spectroscopy (SERS) is useful to measure stress at the surface of the Si substrate. SERS effect is defined when light is shed onto metal particles thus generates the surface plasmon resonance which strengthens the optical electric field. In our previous study, the biaxial stress state in strained-Si on SiGe-on-insulator (SGOI) was evaluated using SERS [1]. Furthermore, transverse optical (TO) phonon modes as well as a longitudinal optical (LO) phonon mode were able to be excited in the SERS measurements. In this study, the Raman spectra obtained by the SERS measurements were analyzed in detail for the strained-Si on SGOI.

【Experimental Procedure】Figure 1 shows the schematic of the sample for with-SERS technique. The thickness of the strained-Si layer on SGOI was approximately 17.5 nm. Ag was evaporated on the outermost surface of the sample. For without-SERS, we used strained-Si on SGOI sample without Ag evaporation. We used oil-immersion Raman measurement for SERS technique while for without-SERS technique, we used dry Raman spectroscopy. ND: YAG laser with 532 nm wavelength was used as the excitation light for both with and without SERS. The polarizations of the incident and scattered lights were both [110] in the SERS measurements, which is the configuration to excite the LO phonon mode for dry Raman spectroscopy.

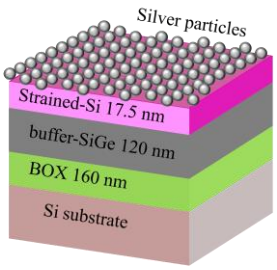

Fig. 1 Schematic of Sample

【Results and Discussions】Figure 2 shows Raman spectra of the strained-Si on the SGOI substrate obtained by the SERS and without-SERS. The Raman spectra were normalized by the Si substrate peak at 520 cm^{-1}. It is clearly shown that the intensity of the strained-Si peak obtained by SERS is larger than that obtained by without-SERS. Figure 3 (a) shows the peaks of strained-Si obtained by the SERS and without-SERS measurements after the peaks of the SiGe layer and Si substrate are subtracted from raw data. It can be observed that full-width at half-maximum for the SERS spectrum is larger than for without-SERS. Figure 3 (b) shows the SERS peak of strained-Si with fitting curves. From the results, it is shown that the TO phonon modes was also excited even though the configuration was TO-inactive (LO-active) for the without-SERS measurements.

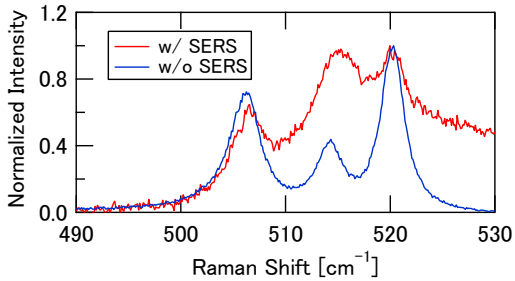

Fig. 2　Raman spectra for strained-Si on SGOI obtained by with-SERS and without-SERS

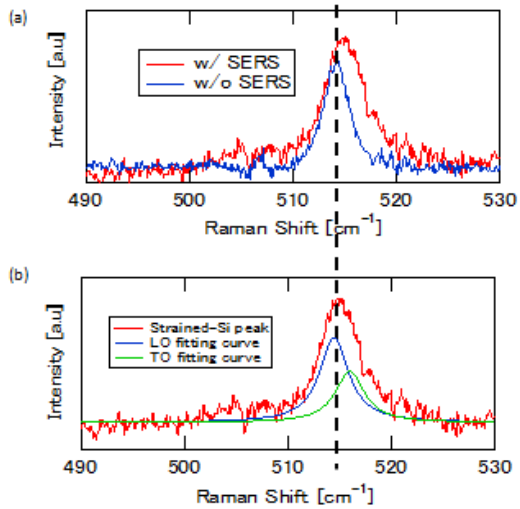

Fig.3 (a) Strained-Si peaks obtained by with-SERS and without-SERS, (b) Strained-Si peak obtained by with-SERS with fitting curves.

The values of the Raman wavenumber shifts $\Delta\omega_{LO}$ and $\Delta\omega_{TO}$ are –5.761 and –4.241 cm^{-1}, respectively. Using $\Delta\omega_{TO}$ and $\Delta\omega_{LO}$, the biaxial stresses σ_{xx} and σ_{yy} were calculated to be 1.234 and 1.270 GPa, respectively [2]. We conclude that the depolarization clearly occurred by SERS technique.

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[1] H. Hashiguchi *et al*, Appl. Phys. Lett., **101,** 172101 (2012)
[2] D. Kosemura *et al*., Jpn. J. Appl. Phys. **51**, 02BA03 (2012)