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Mechanical stress evaluation of Si MOSFET structure using UV Raman spectroscopy measurements and calibrated TCAD simulation

[1]Akira Satoh, [2]Tetsuya Tada, [2]Vladimir Poborchii, [2]Toshihiko Kanayama, and [1]Hiroshi Arimoto

[1]Fujitsu Microelectronics Ltd. (FML), 50 Fuchigami, Akiruno, Tokyo 197-0033, Japan
Phone: +81-42-532-1247 E-mail: aksatoh@jp.fujitsu.com
[2]National Institute of Advanced Industrial Science and Technology (AIST),
1-1-1 Higashi, Tsukuba, Ibaraki 305-8562, Japan

1. Introduction

Stress in the channel region of Si MOSFET is one of key parameter to estimate carrier mobility in Si MOSFET using local strain technique from viewpoint of modeling for layout variation [1]. Although NBD is useful technique to measure the local stress with high spatial resolution same as TEM, the obtained stress value corresponds to averaged value in the relaxed sample due to sample slicing. UV Raman spectroscopy is attractive technique to measure the local stress on the Si surface with small penetration depth [2-4]. However, both techniques cannot measure the actual mechanical stress in the channel region of MOSFET structure without relaxation during sample preparation. Therefore, to estimate the mechanical stress of MOSFET structure, the simulations using calibrated mechanical stress parameters should be important.

In this work, we have evaluated the mechanical stress in Si MOSFET structure using UV Raman measurements and TCAD simulations.

2. Raman measurements and TCAD simulations

Figure 1 shows schematic illustration of Si MOSFET structure with Poly Si gate electrode, silicide, STI and tensile SiN as stress liner.

In our work, Raman spectroscopy measurements were performed under the aa//[110] and ab//[100] polarization configurations on cleaved cross section of MOSFET structure in each process step. We used samples which dimensions were sufficient to follow the change of mechanical stress in channel region for Raman spectroscopy measurements. Polarized Raman measurements were performed using an UV confocal Raman microscope equipped with an Olympus 1.3 NA (x100) oil immersion micro-objective lens. The excitation wavelength was 364 nm. The diameter of the probed area is 130 nm. The peak positions of the measured spectra were determined by Lorentz curve fitting.

3D stress distributions in Si MOSFET structure were simulated using TCAD tool under the boundary condition considered front-face relaxation. Initial mechanical stress parameters for simulations were used values which were determined by wafer-bending technique.

3. Results and discussion

Figure 2 shows the cross-sectional RAMAN shift distribution of the cleaved Si MOSFET structure with different polarized measurements. Tensile stress was applied in the channel region due to covered tensile SiN and the gate structure. Near the edge of the gate structure, tensile stress was increased.

To calibrate the mechanical stress parameter, we calculated Raman shift from simulated strain tensor including shear stress components. The Raman shift ω of the optical phonons in the presence of strain are related to eigenvalues λ of following equation [5],

$$\begin{vmatrix} p\varepsilon_{11}+q(\varepsilon_{22}+\varepsilon_{33})-\lambda & 2r\varepsilon_{12} & 2r\varepsilon_{13} \\ 2r\varepsilon_{21} & p\varepsilon_{22}+q(\varepsilon_{33}+\varepsilon_{11})-\lambda & 2r\varepsilon_{23} \\ 2r\varepsilon_{31} & 2r\varepsilon_{32} & p\varepsilon_{33}+q(\varepsilon_{11}+\varepsilon_{22})-\lambda \end{vmatrix} = 0$$

by $\lambda = \omega^2 - \omega_0^2$, from which follows

$$\Delta\omega = \omega - \omega_0 \approx \lambda / 2\omega_0 .$$

p, q, and r are deformation potential constants for *c*-Si. ε_{ij} are the components of the strain tensor $\boldsymbol{\varepsilon}$.

Simple conversion of stress components from polarized Raman shifts ω_{aa} and ω_{ab} [4] were not applied to our calibration due to mismatch of each polarized Raman shift's spatial position and presence of shear stress components.

Figure 3(a) shows Raman shift distribution simulated using initial parameters and measured. The simulated Raman shifts were not represented the measured data. Figure 3(b) shows the case of calibrated parameters. The calibrated parameters were intrinsic stress and viscosity. The simulation using calibrated parameters were represented measured data well.

4. Conclusion

We have evaluated the mechanical stress of Si MOSFET structure. To use polarized Raman spectroscopy measurements and TCAD simulations considered cleavage effect, mechanical stress distribution in the complicated structures of Si MOSFET could be understood. Our proposed calibration using Raman shift converted from TCAD-simulated stress is useful to determine mechanical stress parameters of Si MOSFET structures.

References

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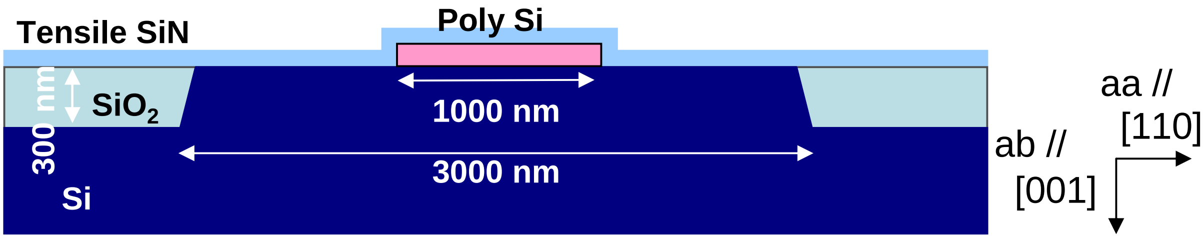

Figure 1 Schematic cross section of Si MOSFET structure.

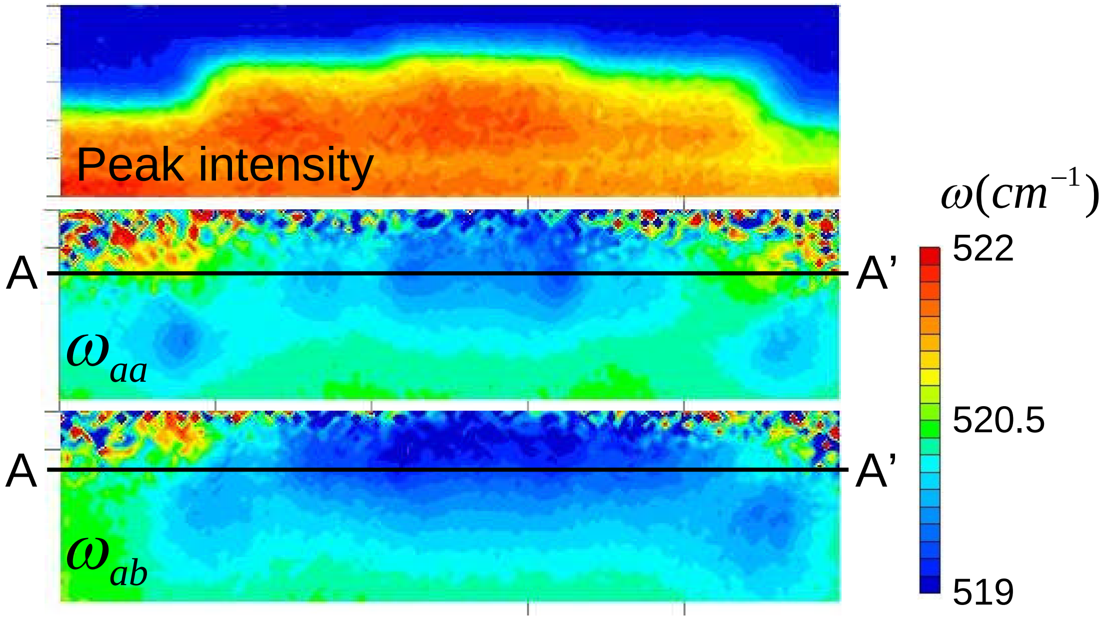

Figure 2 Measured Raman shift and peak intensity distribution on cleaved cross section of Si MOSFET structure.

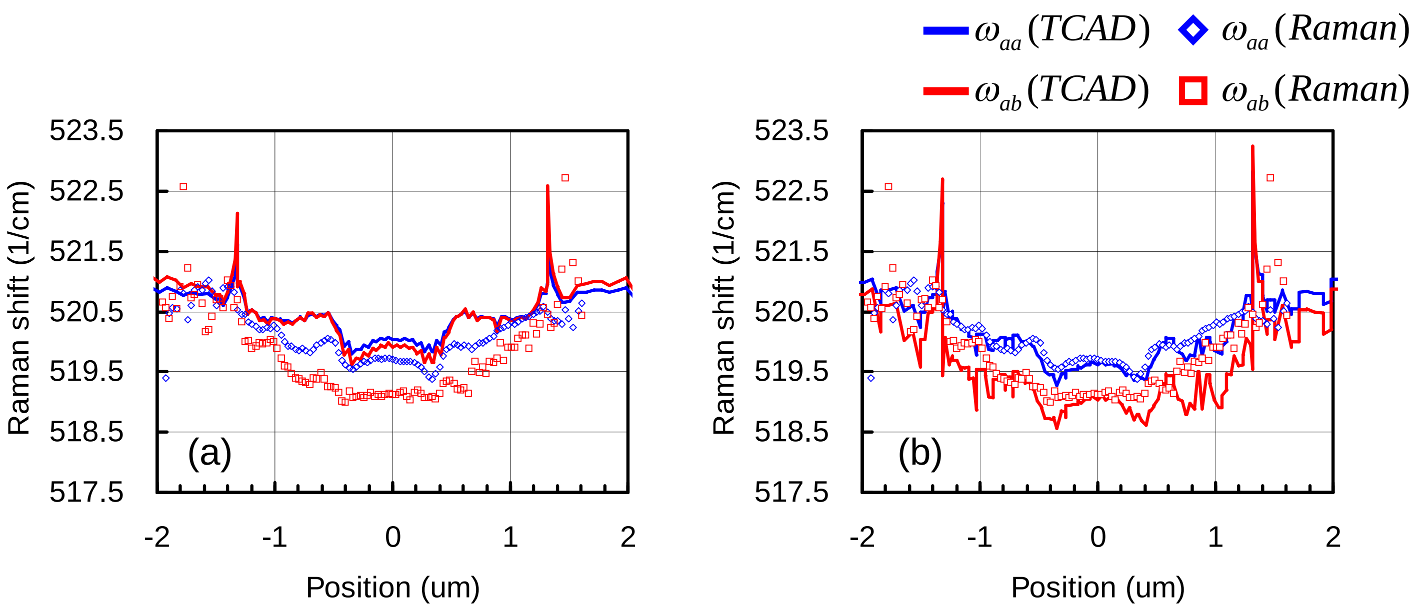

Figure 3 Raman shift distribution along the line AA' in figure 2 for TCAD simulation set to (a) initial parameters and (b) calibrated.