Improving reliability and quantitative property of Raman measurements for wide bandgap semiconductors

Raman spectroscopy is widely used for stress evaluation in semiconductor devices. For reliable stress measurements, accurate and highly reproducible measurements and deep understanding of the theory of Raman scattering are essential.

1. Raman scattering and stress evaluation

Raman spectra of semiconductor crystals reflect the lattice vibrations. The peak position of the Raman line is highly sensitive to stress, temperature, etc.
The stress measurement can be done via Raman spectroscopy.

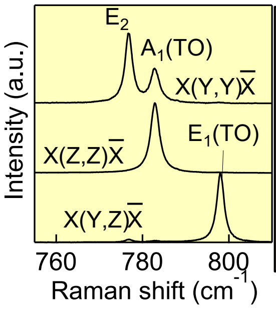

Fig.1 Polarization dependence of Raman spectra in 4H-SiC.

Raman scattering
- Reflect crystal symmetry. The less symmetrical crystals, the more Raman lines are observed.
- Observable vibration modes vary depending on the measurement configuration and polarization of light.

A deep understanding of the Raman scattering is important for correct and proper stress evaluation of the crystals with low symmetry.

2. Long-term fluctuation of the peak position

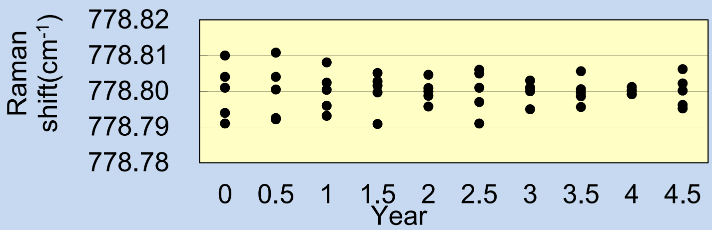

Fig. 2 Long-term reliability of peak position in E_2 band of 4H-SiC.
Variation is within ±0.01 cm^{-1} (± 3MPa (in stress))

3. Temperature dependence

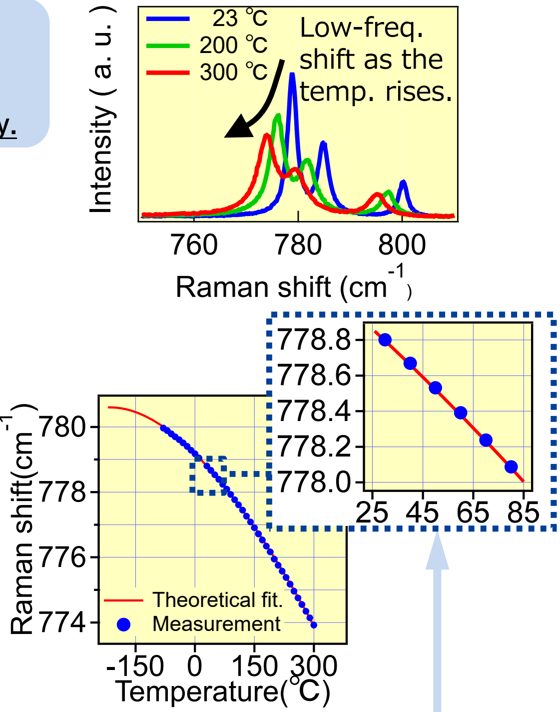

Fig. 3 Temperature dependence of E_2 peak frequency in 4H-SiC.

Δ(Theory−Experiment) is within ±0.01 cm^{-1}

$$\text{Frequency Shift}(T)=C\left[1+2n(T,\omega_0/2)\right]+D\left[1+3n(T,\omega_0/3)+3n^2(T,\omega_0/3)\right]$$

4. Temperature dependence of stress components in packaged SiC MOSFETs

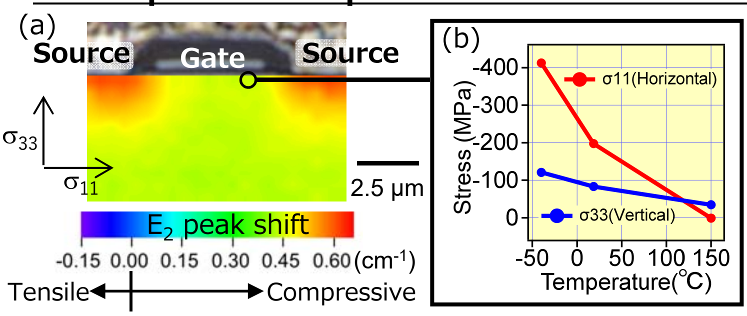

Fig. 4 (a) Mapping of E_2 peak shift in SiC MOSFET at 23℃ and (b) temperature dependence of σ_{11} and σ_{33} at channel region.

Fig. 4(a) shows stress mapping of a packaged SiC MOSFET obtained by Raman scattering measurements at 23℃. The compressive stress is observed near source region.
Fig. 4(b) shows the stress components at -40, 23, and 150 ℃ derived from the peak shifts of E_2 and A_1(TO) bands using the theoretical equations. The horizontal stress component (σ_{11}) shows larger temperature dependence than the vertical one (σ_{33}).

5. Toray Research Center's activities

Materials	Si, SiC, GaN, Ga_2O_3, ZnO, GaAs, ceramics, etc.
Devices	Local stress evaluation (MOSFET, IGBT, HEMT, MMIC, LED) Stress by packaging (solder joint, molding resin, wire bonding, TSV) Process optimization, failure analysis (FA), etc.
Pre-treatments	Cross-section cutting, decapping, film removal, etc.

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