Analysis of local stress distribution in a metal gate MOSFET with a new Raman simulation method

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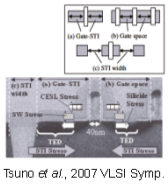
Background

Development of Leading Edge Devices

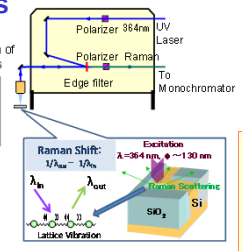
Improvement of device performance using strain technology

Si mechanical strain → Mobility(on-current), Band gap(threshold voltage), Dopant diffusion(threshold voltage)

Layout-dependent-variation of the device characteristics



H. Tsuno *et al.*, 2007 VLSI Symp.

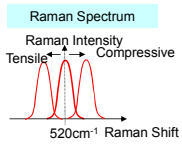


Characterize the stress in the device!!

- to improve transistor performance
- to clarify the origin of the transistor characteristics fluctuation
- to predict the transistor characteristics variation (improve simulation accuracy)

Raman spectroscopy is a promising technique for stress analysis in Si devices

Non-destructive, non-contact
Bulk sample c.f. TEM → sliced sample

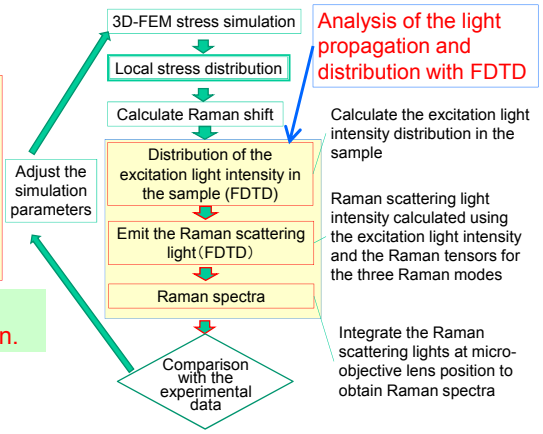


Problems

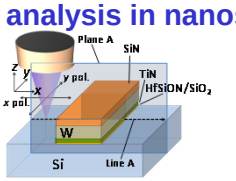
Spatial resolution・・・optical diffraction-limited 150-500nm
Stress・・・tensor quantity (6 components)
It is difficult to estimate the stress quantitatively only from Raman shift values.

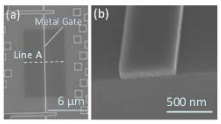
→ Quantitative stress analysis is possible only in the case where the type of applied stress is already known or supposed.

Raman simulation combined with FEM and FDTD simulation



Stress analysis in nanoscale regions





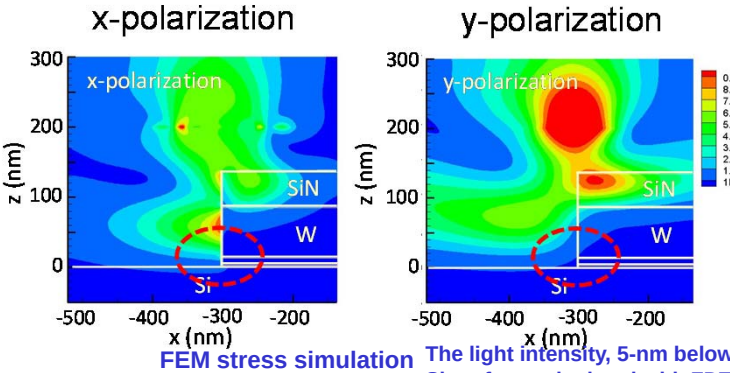
Analysis using simulation technology is needed for quantitative stress evaluation.

Excitation light intensity distribution modified by sample structure → Significant impact on Raman spectra

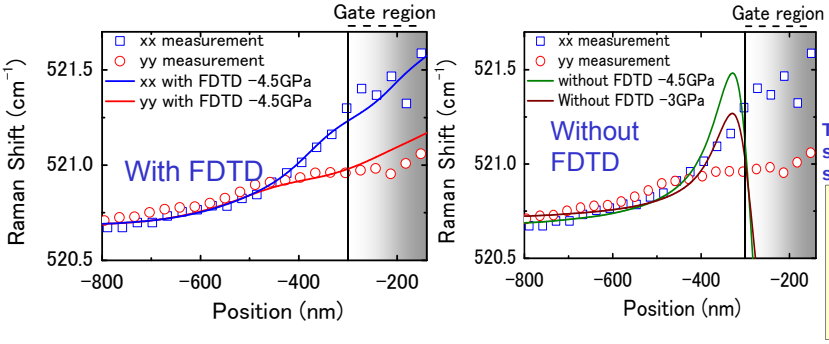
Modification of the excitation light intensity distribution near the metal gate edge, caused by the sample structure.

The stress changes intensively near the gate edge, suggesting "significant impact on the Raman spectra".

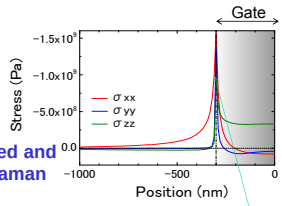
FDTD simulation



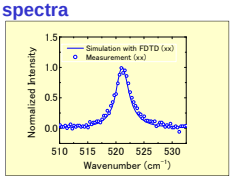
Comparison between the Raman simulations with and without the FDTD



FEM stress simulation

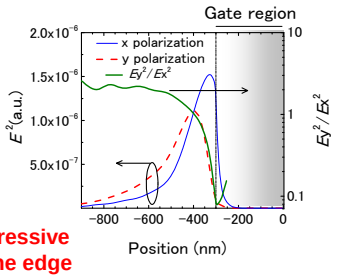


The measured and simulated Raman spectra



Strong compressive stress near the edge

The light intensity, 5-nm below the Si surface calculated with FDTD



The simulation with FDTD →internal stress of the gate -4.5GPa
The simulation without the FDTD → internal stress of the gate

Internal stress of the tungsten measured with wafer bending → -4.3GPa

The new simulation gives correct stress values!!

Summary

We have developed Raman simulation method combined with FEM and FDTD simulation.

→ Simulate the micro-Raman measurement process

The simple calculation of Raman shifts without using light propagation simulation **does not give a correct stress distribution** near an opaque structure
- the sample structures cause the nanoscale modification of light distribution and propagation.

The developed Raman simulation method **gives the correct stress distribution in nanoscale region**.

T.Tada et.al., Appl. Phys. Lett. **101**, 243511 (2012)