# Strain Analysis at nano-meter region using ASTAR

Information about crystal strain can be extracted from the spatial distribution of precession electron diffraction (PED) patterns. 2-dimensional strain maps with nano-meter spatial resolution using ASTAR in TEM are shown below.

## Strain analysis based on ASTAR

Diffraction spots even in higher scattering angle.

The difference between strained and ref. patterns including high index is analyzed.

Second order strain tensor can be stably estimated using ASTAR.

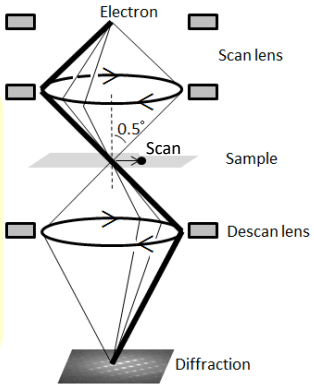


Fig. 1. Electron path in PED

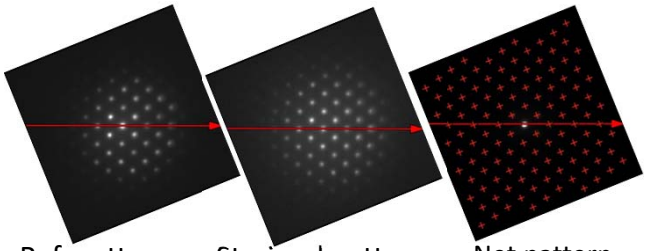


Fig.2. PED pattern ( Si Beam = [110 ])

## Comparison of strain analysis methods

An advantage of ASTAR-strain analysis is high spatial resolution. Nano-meter order single crystal region, which creates clear 2D-diffraction patterns, is just necessary.

Table 1. Comparison of strain maps

| Method | Strain sensitivity | Spatial resolution |
|---|---|---|
| HR-TEM FFT analysis | Trade-off between strain sensitivity and spatial resolution [1 ~ 3)] | 1 nm |
| **ASTAR** | **0.1 % [1 ~ 4)]** | **2 nm** |
| EBSD | 0.1 % [2, 4)] | 50 nm |
| Raman | more than 2 digits precision | 500 nm |

cautionary note

1) Strain in thin specimen, different from bulk state.
2) Relative strain to reference point in the same sample.
3) Strain map in single crystal region along zone axis.
4) The limited number of pixels in a strain map because of calculating time.

## Cross-sectional analysis around Si/SiGe (PMOS region)

Cross-sectional STEM image using thin specimen prepared by FIB. Strain map is analyzed in red outline area using ASTAR.

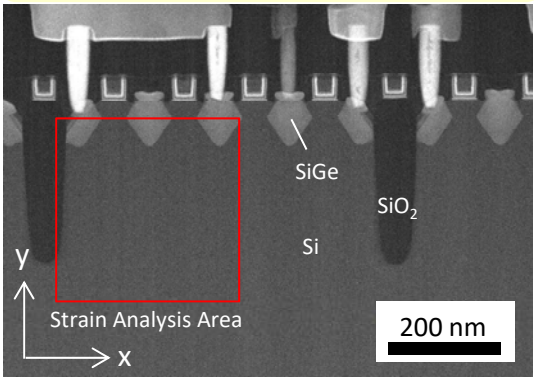


Fig.3 : HAADF-STEM image of SiGe (PMOS)

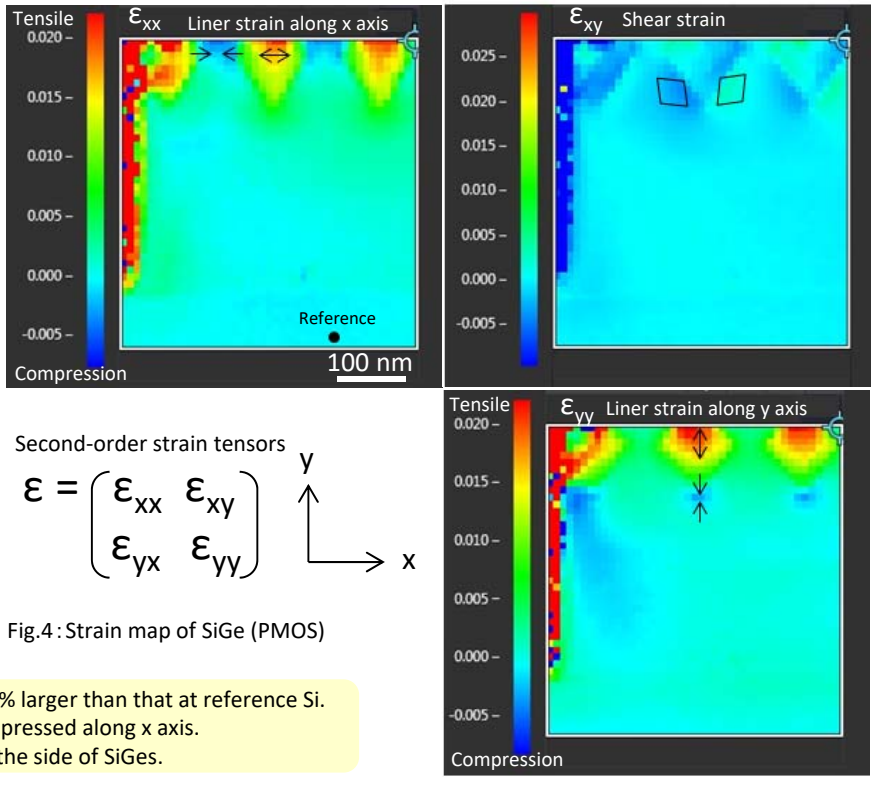


Fig.4 : Strain map of SiGe (PMOS)

The lattice constant at the center of SiGes is 2% larger than that at reference Si.
The Si/SiGes intermediate region is 0.5% compressed along x axis.
Shear strain is also detected in Si region near the side of SiGes.