

# **Applications of Automated High Resolution Strain Mapping in** TEM on the Study of Strain Distribution in MOSFETs

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## Introduction

- Strain measurement is critical to monitor designed and unintended strain distributions
  - Desired: Strain introduced in Si to enhance electron mobility in the channel
  - Unintended: Stress concentration in devices leads to failure



Industry Requirements **Desired spatial resolution** ~ 1-3 nm Strain sensitivity << 0.1%

- **Highly automated**

Thompson et al., IEEE Trans. On Electron Devices, VOL. 51, NO. 11, 2004

### **Conventional Nano-Beam Diffraction**

- Acquire spot diffraction patterns from strained and unstrained regions using a quasi-parallel nanoprobe
- Use measured shift in spot positions to calculate strain
- Experiment is relatively straightforward
- High spatial resolution (better than 5 nm)

### Disadvantage

- Strong dynamical effects lead to rapid changes in spot intensities with small thickness and orientation changes
- Strong dependence of spot intensities on changes in local thickness and orientation makes automated analysis challenging

-Requires manual intervention in identifying spot positions

• Inadequate sampling of higher order reflections limits the accuracy

# **Precession Electron Diffraction (PED)**



: Standard setting



R. Vincent, P.A. Midgley, Ultramicroscopy 53 (1994) 271)

- Can compare to kinematical pattern Not very sensitive to thickness
  - Can automate analysis
- Get more diffraction spots
  - Higher precision measurements



- Diffraction patterns with and without precession from single crystal Si
- FIB prepared sample

### Experiment

- Microscopy was performed on a JEOL ARM 200F operating at 200kV
- Automated acquisition of PED patterns and their analysis for strain mapping was performed using **Topspin**.
- Precession angle: 0.7°
- Diffraction pattern acquisition time: 0.02 s



Y: Full precession

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## **Topspin Strain Measurement Analysis**

a reference pattern



### nMOS Strain Mapping with Topspin





Step size: 3 nm Scan size: 200x82 steps Acquisition time~ 4 mins





• Diffraction patterns from strained region are matched against

### • All pixels utilized, not just selected spot centers



Precession angle: 0.7°

200 Position (nm)

 $-\varepsilon_{xx}$  (022) line profile

(200) line profile

 $-\epsilon_{xx}$  (022) line profile

 $- \epsilon_{vv}$  (200) line profile

200 300 Position (nm)

No precession