Submicron-Resolved Strain Analysis for Semiconductor Materials Using Fresnel-Zone-Plate X-ray Image Magnification

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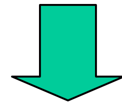
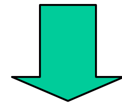
Background and Objective

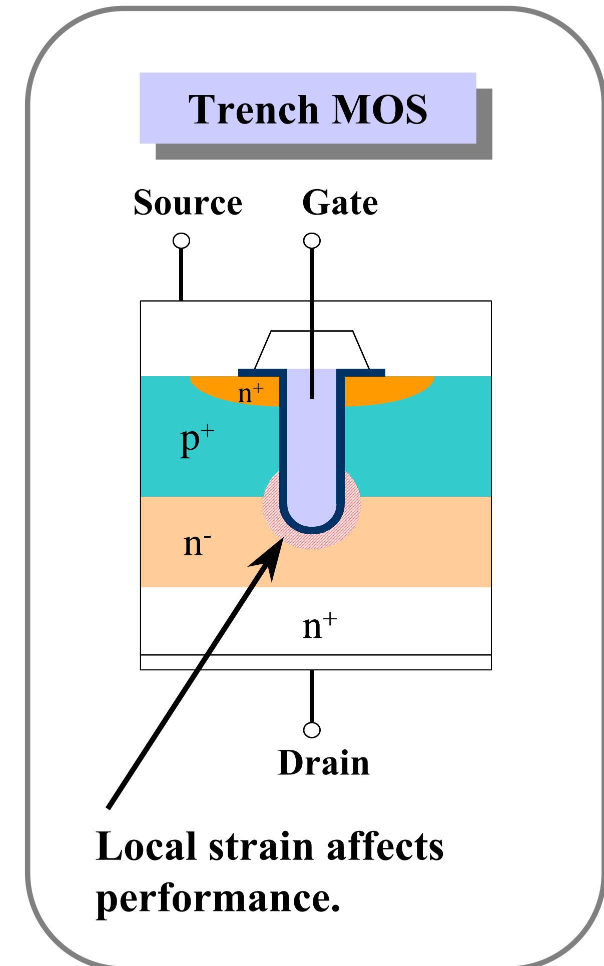
■ **Downscaling of semiconductor devices**



■ **Strain analysis with submicron resolution is required.**

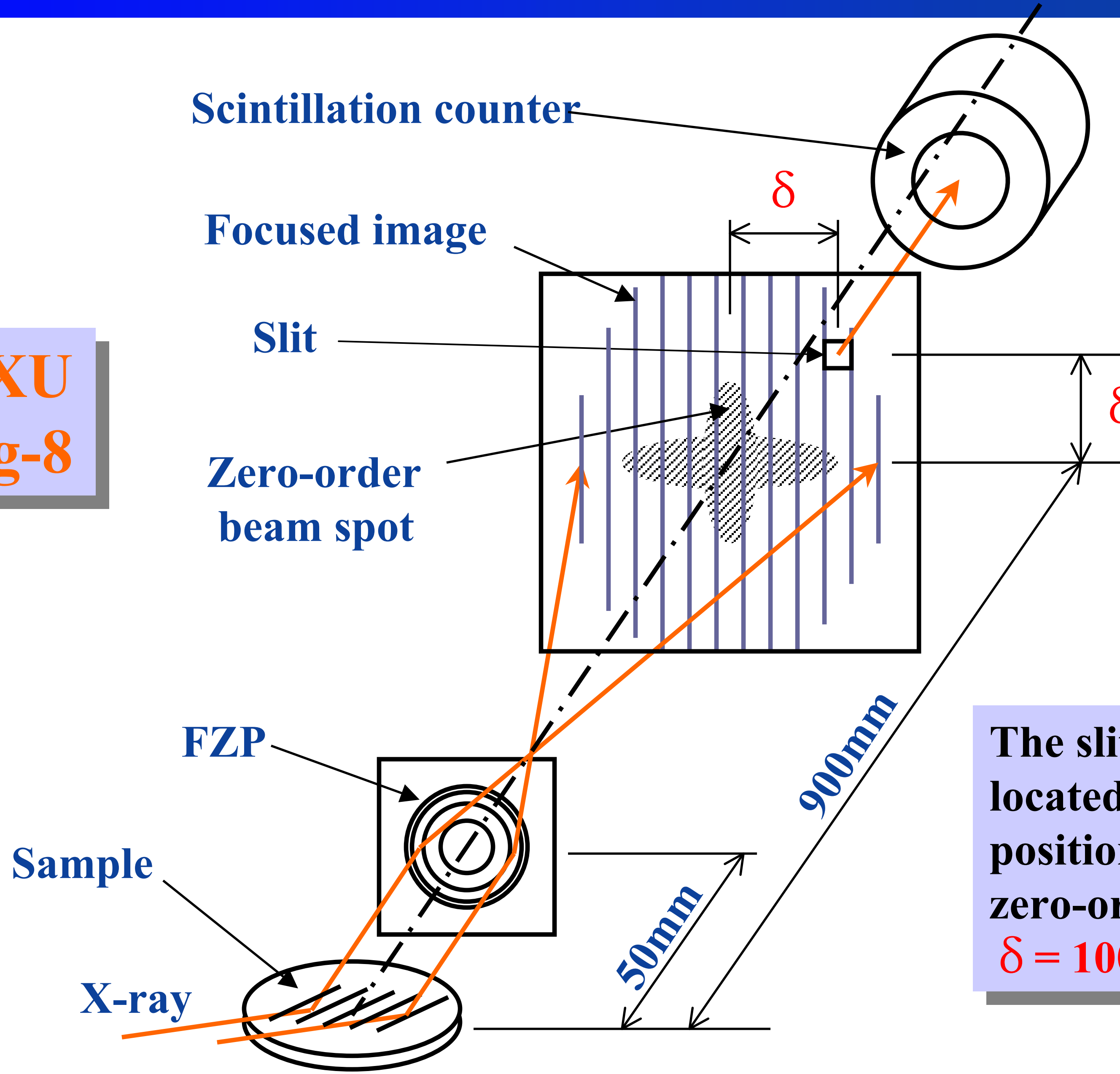


■ **Objectives: in local strain analysis,**
— **spatial resolution below 1 μm**
— **strain sensitivity below 10^{-5}.**



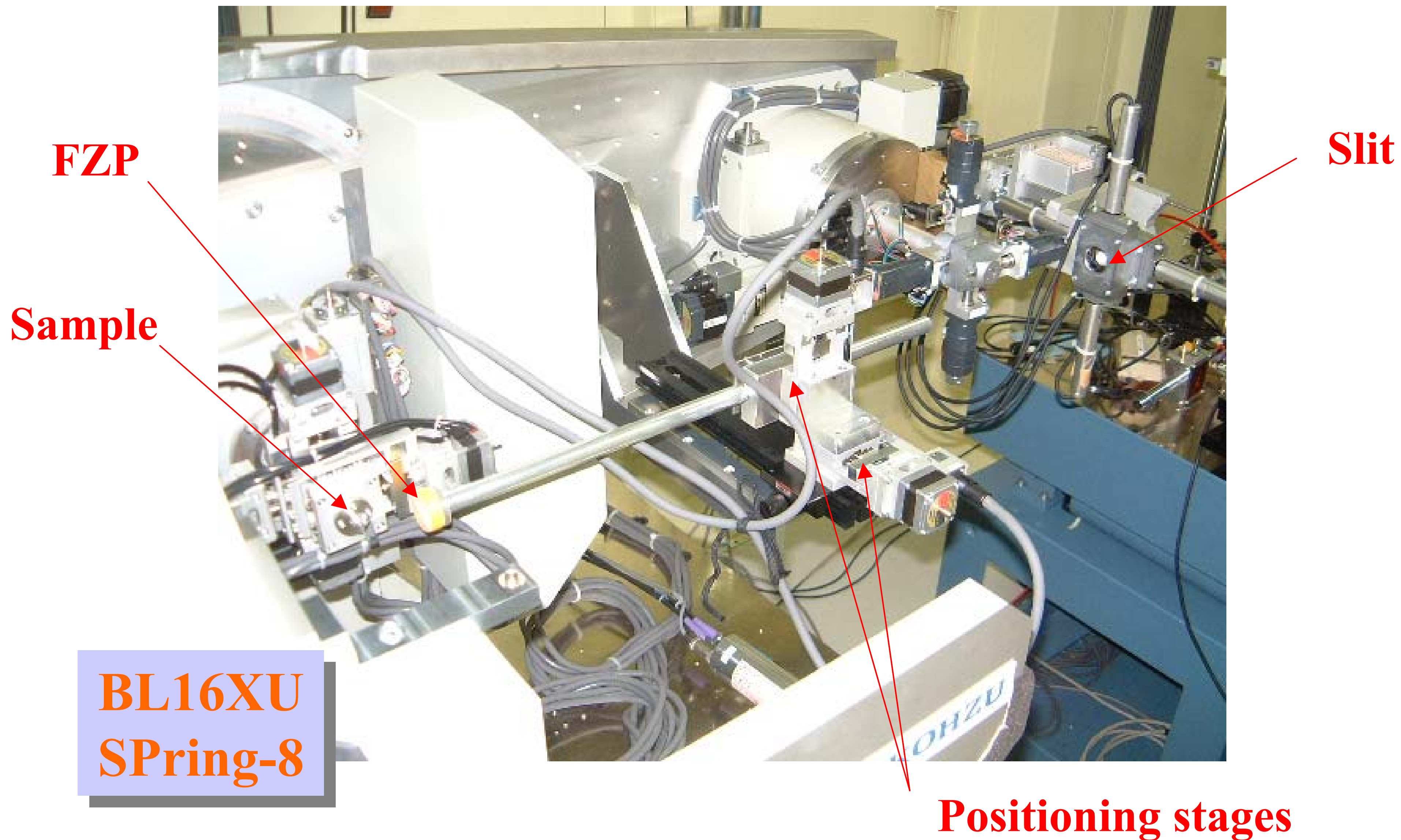
Set-up of the FZP method

BL16XU
SPring-8



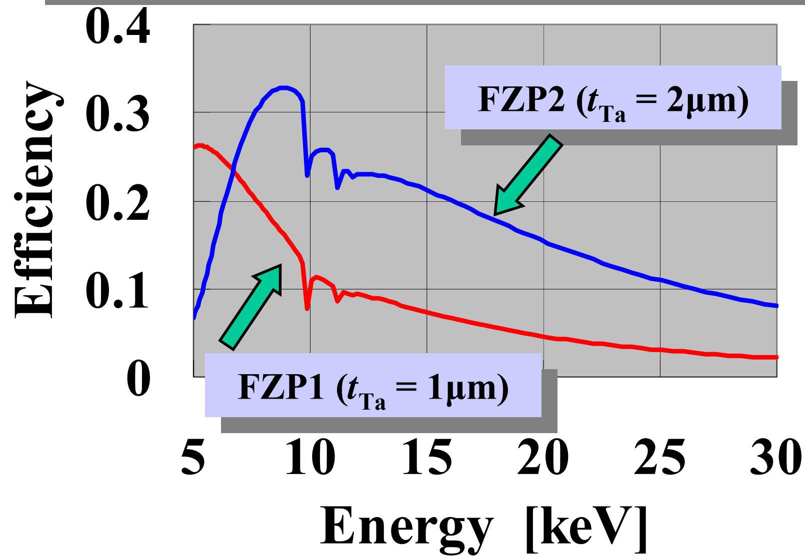
The slit window is located at an off-axis position to avoid the zero-order beam.
δ = 100 - 400 μ m

Diffractometer Equipped with the FZP System

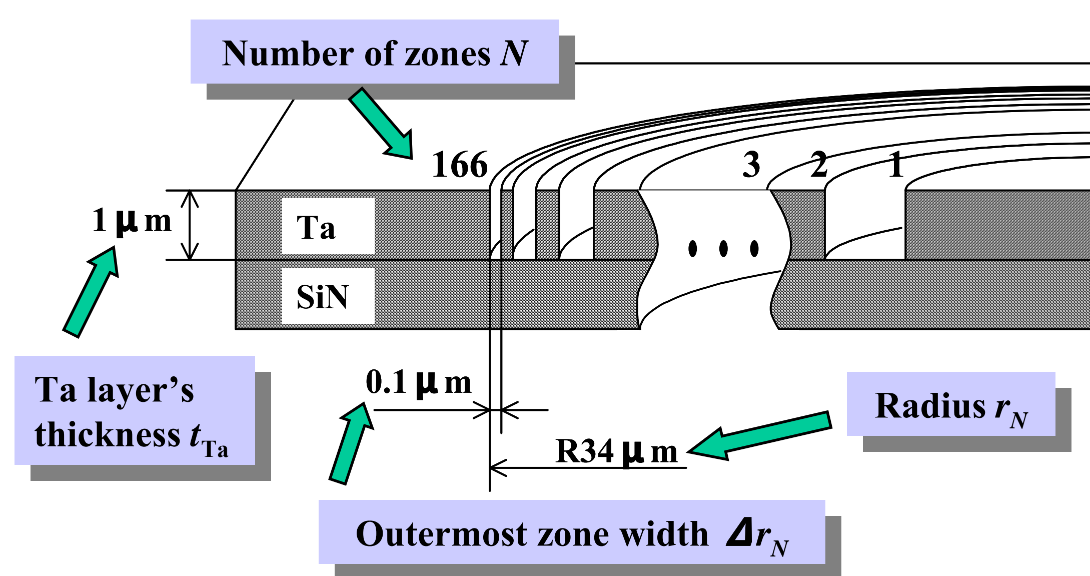


Design Parameters of FZPs

+1st order diffraction efficiencies



Design parameters of FZP1



Parameter values

	r_N	N	t_{Ta}	Δr_N (~spatial resolution)	Magnification m* 8.5keV	Magnification m* 20keV
FZP1	34 µm	166	1 µm	0.1 µm	20	7
FZP2	11 µm	27	2 µm	0.2 µm	27	10

Aspect ratio $t_{Ta}/\Delta r_N \leqq 10$

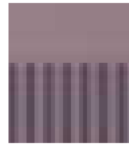
* Sample-slit distance = 900mm

Strain Analysis of Oxide-Patterned Si Wafers

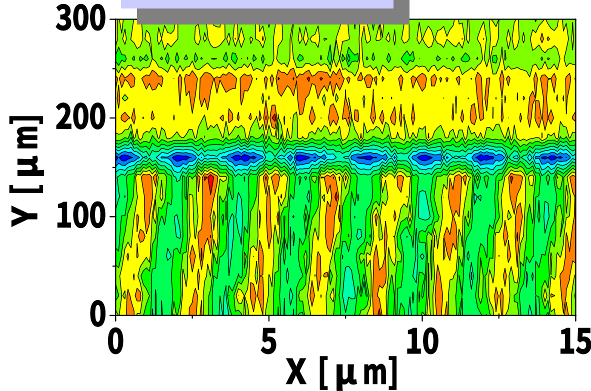
e-Front runners

W = 0.5μm

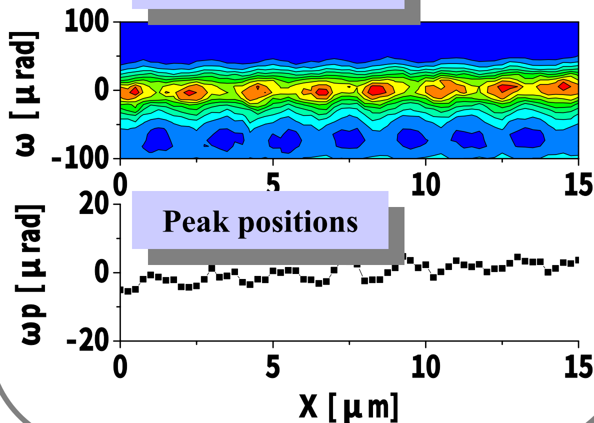
Photograph



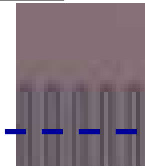
Topograph

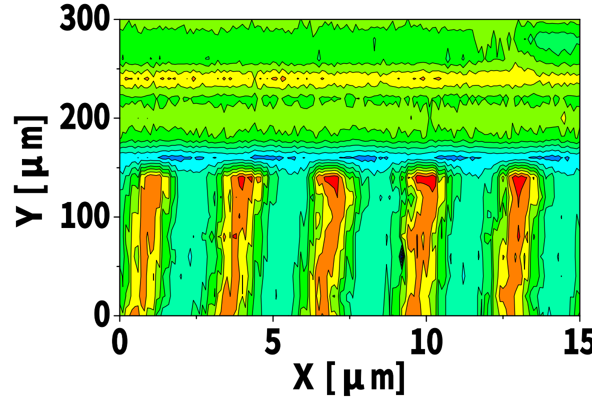


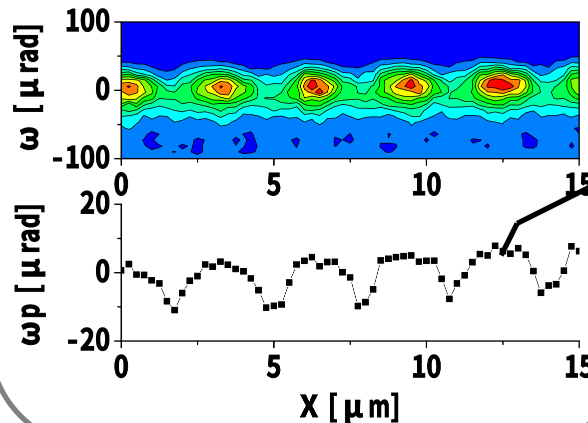
ω-scan map



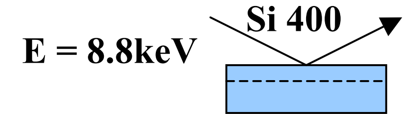
W = 1μm

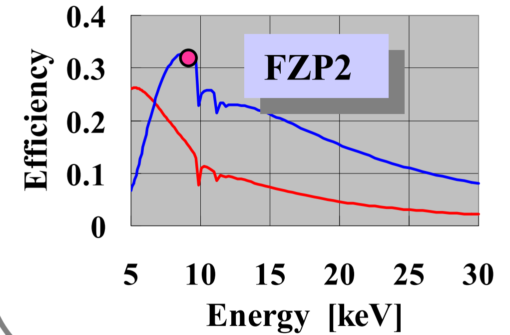


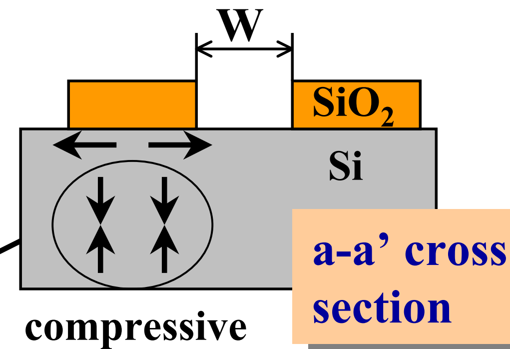




Exp. conditions



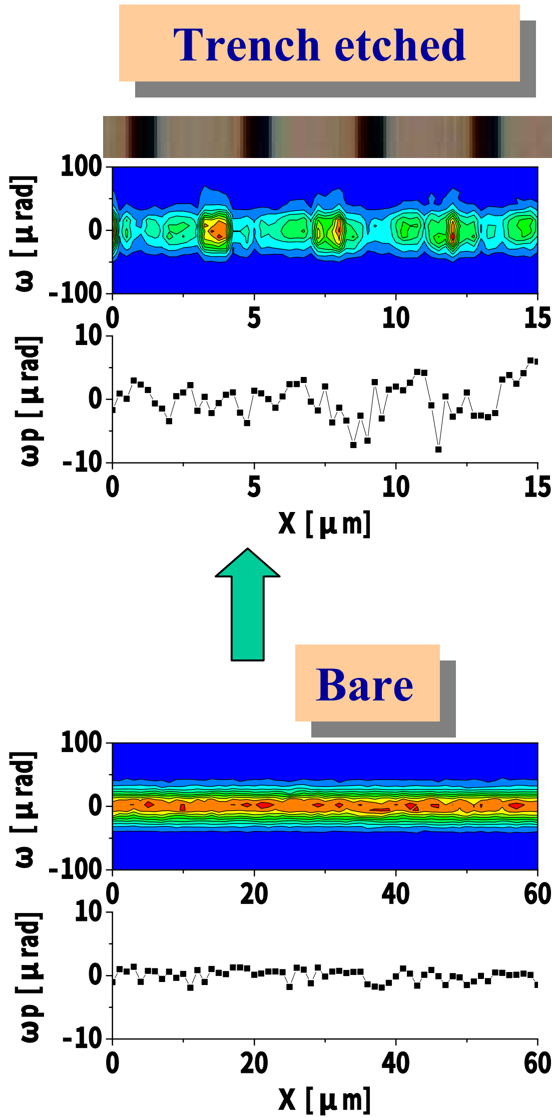


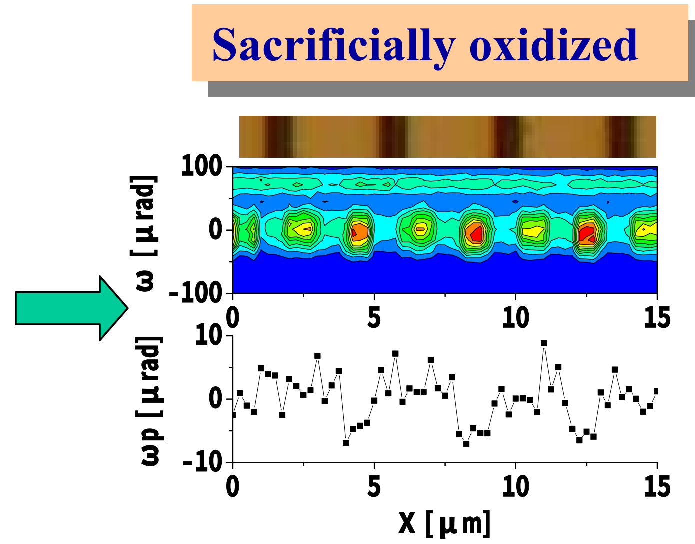


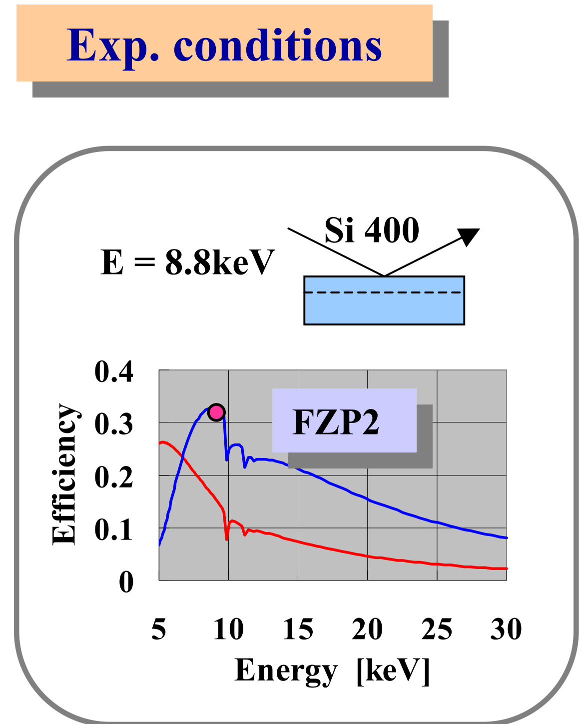
$\Delta d/d \sim \pm 10^{-5}$

Strain Analysis of Trenched Si Wafers

e-Front runners



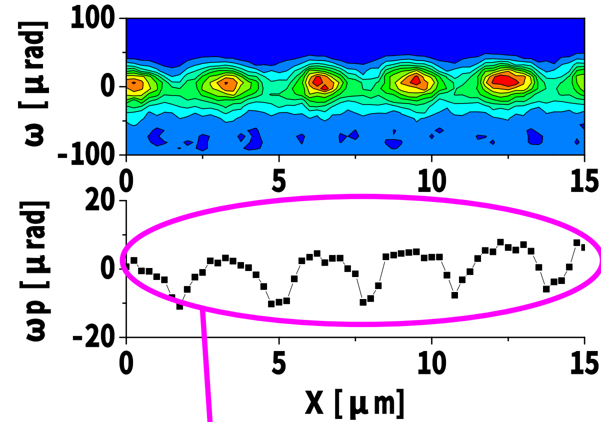


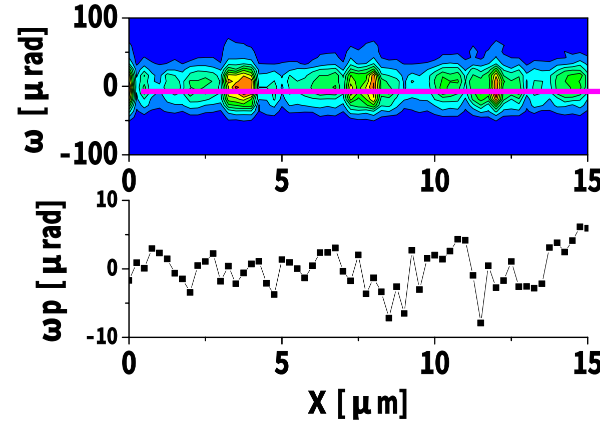


■ **Strains were not reduced by sacrificial oxidation.**

Estimating Spatial Resolution

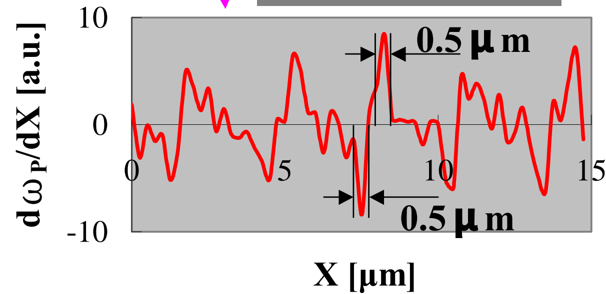
e-Front runners

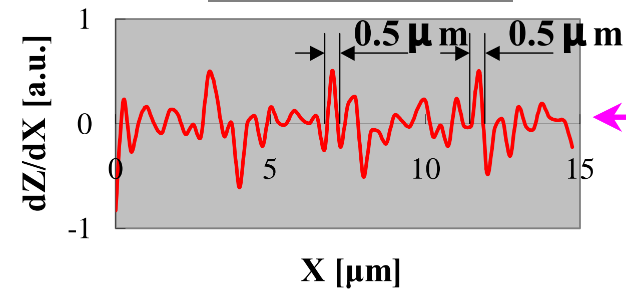




Differential

Differential





■ Less than 0.5-μm-wide patterns were reproduced in the ω-scan maps.

■ Spatial resolution is less than 0.5 μm.

Section Topography at 20keV

Topograph

Resolution window (0.8×1.7 μm²)

Blur caused by the beam thickness

~4 μm

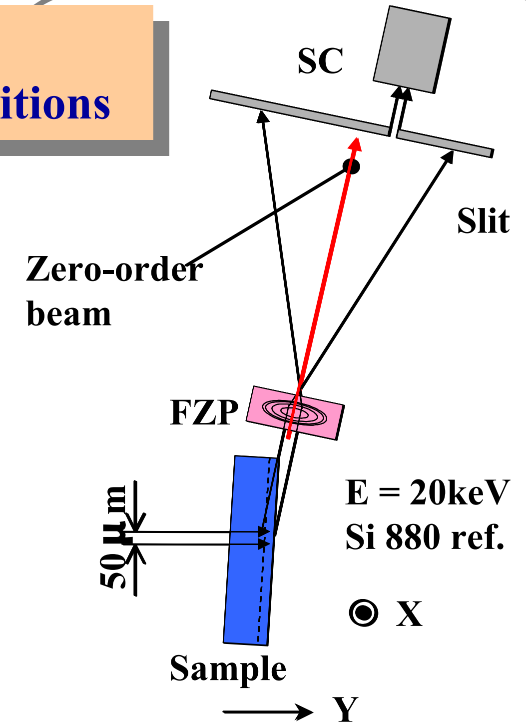
Trench (W0.8 μm× D3 μm)

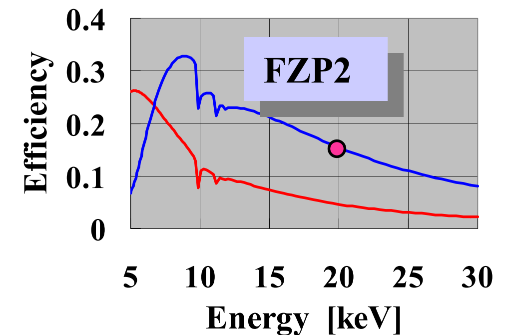
Y [μ m]

X [μ m]

0 2 4 6 8 10 12 14

Exp. conditions





■ **Spatial resolution seems 1 μm or less in the X direction.**

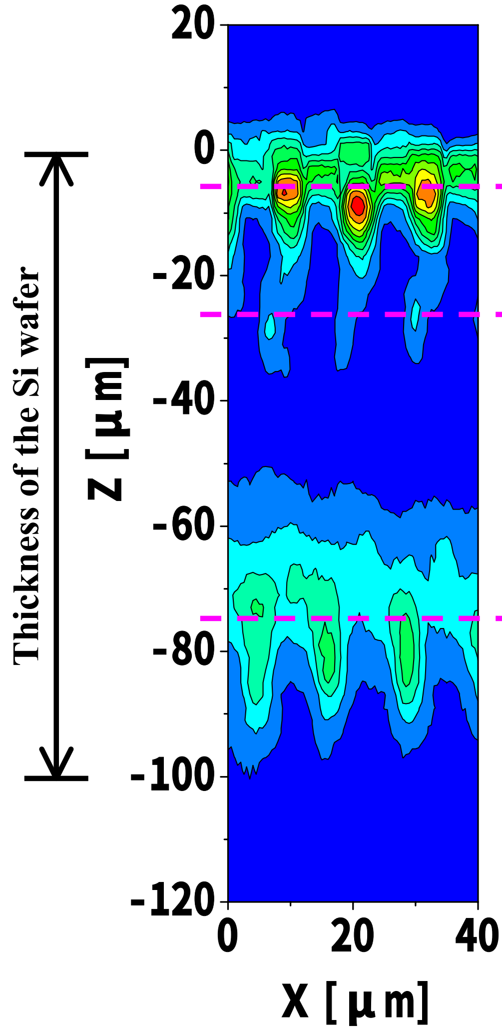
Section Topography at 8.5keV

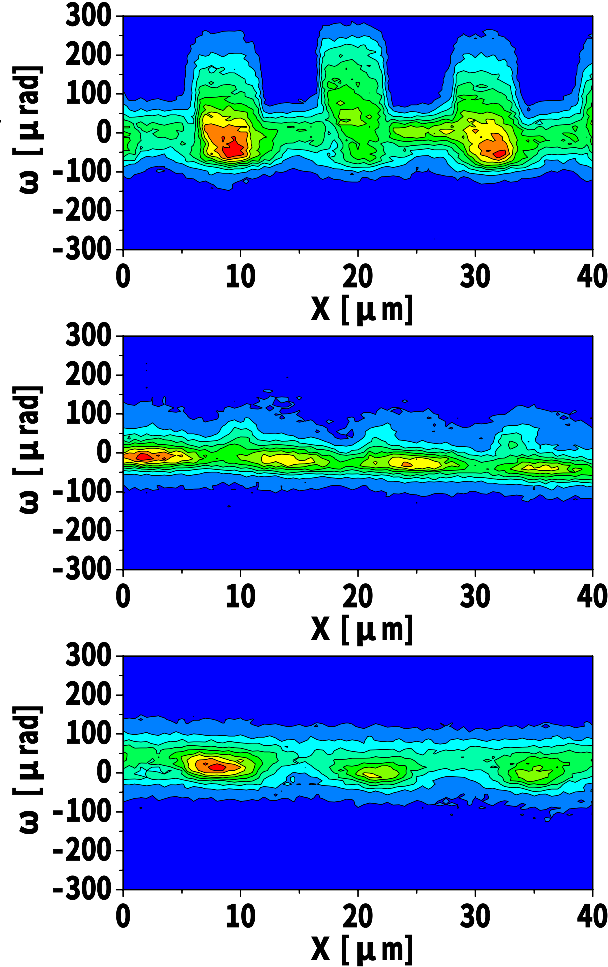
e-Front runners

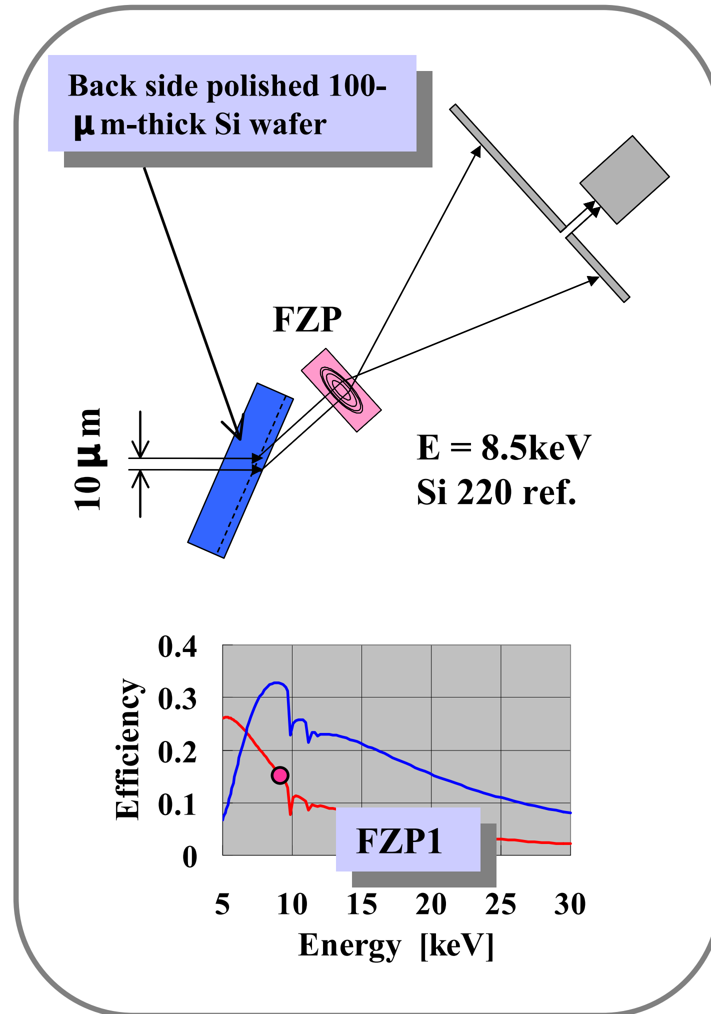
Topograph

ω-scan maps

Exp. conditions







Summary

- The 4 applications of FZPs in the strain analyses were reported (figure).
- Spatial resolution below 0.5 μ m and strain sensitivity below 10^{-5} were achieved.
- Avoiding zero-order beam is a key technique.
- Energy range below 10keV is recommended because of high efficiencies and high magnifications.