Defects in ultra-low energy As implanted Si: Characterisation by combined x-ray scattering methods.

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This work is financed by the ***European FP5 project*** ***<u>IMPULSE 2001</u>****-32061*

Introduction: The next generation of device fabrication has to challenge the production of ultra-shallow junctions with a depth of less than some tens of nm (see International Technology Roadmap for Semiconductors 2001 updated). One possible approach to meet this goal is to make thin conducting layers in Si by ion-implantation at ultra-low energies (1 keV for B and some keV for As). The unavoidable defects present after implantation and annealing need to be characterised both with respect to their nature and depth distribution. Specular reflectivity, XRD and grazing incidence diffuse x-ray scattering combined together are very well suited to study the defects evolution with different thermal budgets in a non destructive manner.

X-RAY DIFFRACTION

(004) Bragg reflection

(crystalline quality contrast!) :

Sensitive to the strain of the lattice parameter perpendicular to the surface

➡ solid phase epitaxial (SPE) regrowth of the layer amorphised by the As implantation!

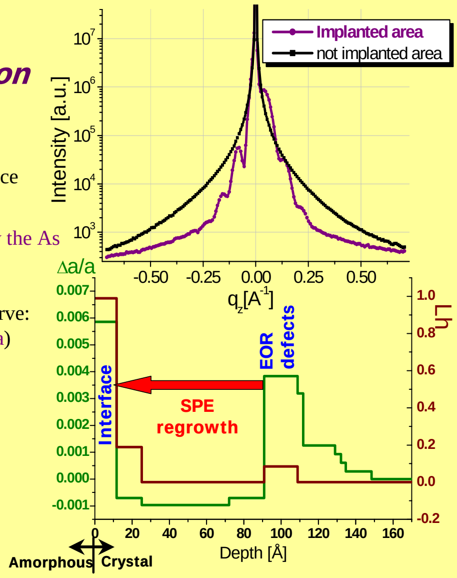
From the simulation of the XRD curve: depth distribution of the strain ($\Delta a/a$) and static disorder (Lh)

Three regions:

✓c/a interface

✓SPE regrown layer

✓EOR defects



THE SAMPLE

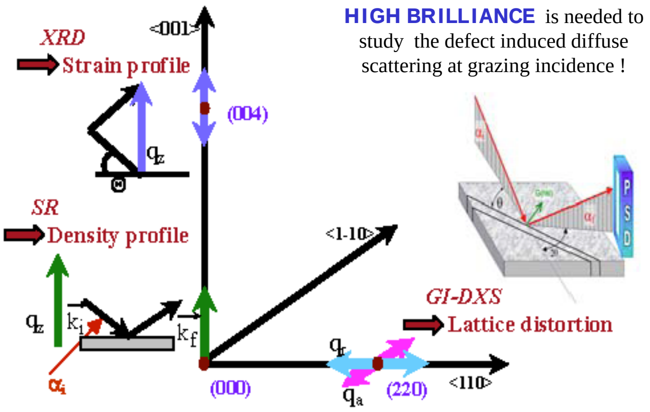
Support: *Cz-Si (100) single crystal*;

NO preamorphisation implant (non-PAI);

Implanted species: As; Energy: *3 keV*; Dose: *2*10 ^{15} cm^{-2};*

Annealing treatment: furnace annealing 600^{0}C; 20 min.

THE EXPERIMENTAL TECHNIQUES :

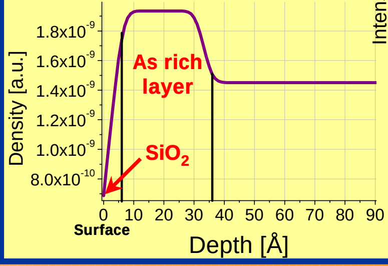


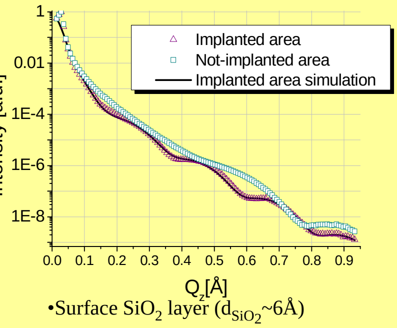
HIGH BRILLIANCE is needed to study the defect induced diffuse scattering at grazing incidence !

SPECULAR REFLECTIVITY

(density contrast!)

From the simulation of the SR curve: density depth distribution



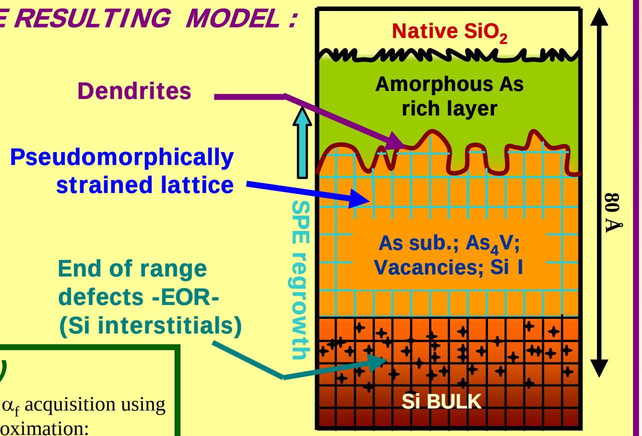


•Surface SiO_2 layer (d_{SiO_2}~6Å)

•As rich layer~ 28.5 Å

➡ As segregation below the surface!

THE RESULTING MODEL :



Dendrites

Pseudomorphically strained lattice

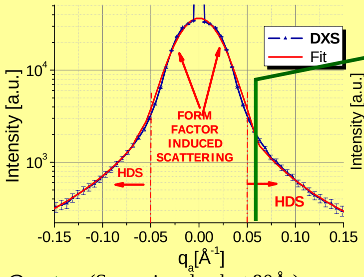
End of range defects -EOR- (Si interstitials)

DEFECT INDUCED DIFFUSE SCATTERING (Huang scattering –HDS-)

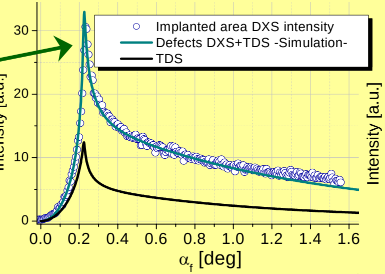
near (220) surface Bragg reflection

(distortion in the Si lattice + depth resolution)

Angular scan:
form factor and defects induced DXS @ $a_i<a_c$

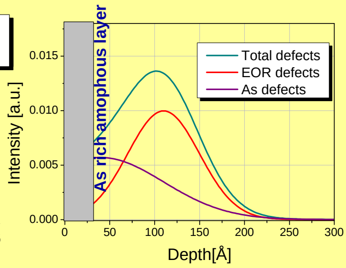


Defect induced DXS as a function of α_f at q_a=0.06 Å^{-1} @ $\alpha_i<\alpha_c$



From the simulation of the α_f acquisition using Distorted Wave Born Approximation:

Defects distribution=
near surface As defects +
EOR defects (Si interstitials)



@ $\alpha_i<\alpha_c$ (Scattering depth < 80Å) **:**
Dendritic growth (R=60±30Å) in the amorphous region & expanding point defects in the near surface crystalline lattice

@ $\alpha_i>\alpha_c$ (Scattering depth >> 80Å) **:**
point defects expanding the lattice (EOR defects)

CONCLUSIONS:

Combination of XRD, SR, GID and GI-DXS allows to determine the implantation induced structural changes and to characterise the defects nature and depth distribution;

OUTLOOK :

- ➢ Systematic annealing study of As implanted Si;
- ➢Comparison between (PAI) and no-PAI samples;
- ➢Comparison with MEIS and SIMS data;
- ➢Simulation of all the relevant experimental curves.