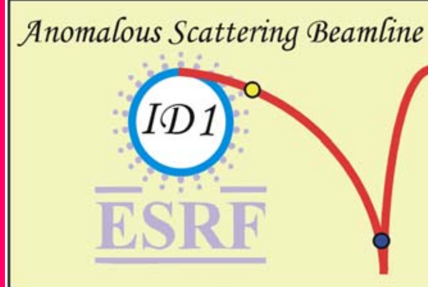
Self-Ordered Si Nanodots Fabricated by Ion Beam Sputtering

O. Plantevin[1], T. H. Metzger[1],
R. Gago[2], L. Vázquez[3], J. M. Albella[3]
[1]ESRF, [2]Research Center Rossendorf, Dresden,
[3]Instituto de Ciencia de Materiales de Madrid (CSIC)

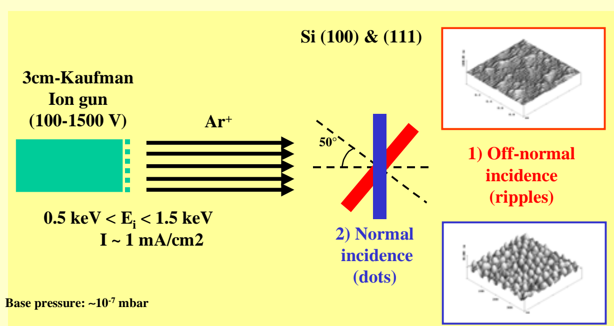


Introduction

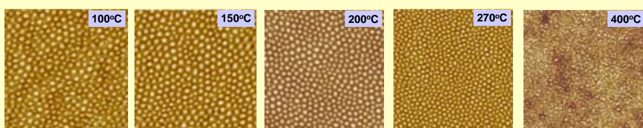
During the erosion of semiconductor surfaces by ion sputtering, a new self-organization process has recently been discovered for the generation of nanostructures [1]. Under normal incident low energy ion bombardment, a regular dot pattern appears on initially flat GaSb (100) and InSb (100) surfaces. These nanostructures have also been obtained on Si [2].The formation of the dots results from a surface instability induced by the curvature dependence of the sputtering yield. We investigate shape, strain and correlation of Si dots, and their evolution with sputtering time and temperature, with surface sensitive grazing incidence x-ray scattering techniques.

[1] S. Facsko *et al.*, Science 285 (1999) 1551.
[2] R. Gago *et al.*, APL 78 (2001) 3316.

Nanostructures fabrication by Ion Beam Sputtering

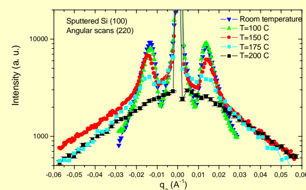


Effect of substrate temperature



AFM images (1 µm*1 µm), Si(100) 1.2 keV Ar^+ sputtering, 10 min (R. Gago)
Dots disappear at ~300 C

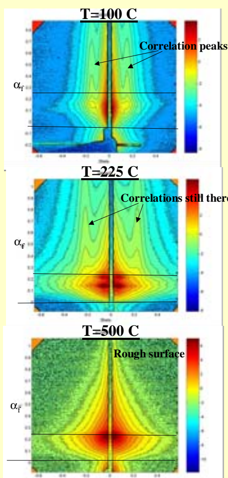
Grazing Incidence Diffraction



Crystalline part of the dots

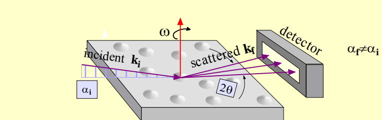
Inter-dot distance D~44 nm is **constant.**
Result in contradiction with Bradley-Harper model for dots' formation (1988).
At T=200 C : Loss of correlation,
Form factor of small crystalline inclusions (~5 nm)

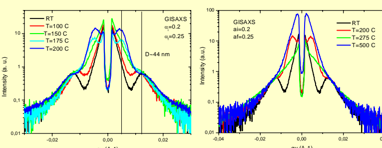
GISAXS Surface morphology independently of crystallinity



$\alpha_f \neq \alpha_i$

Cuts in the 2D images at α_f=0.25°



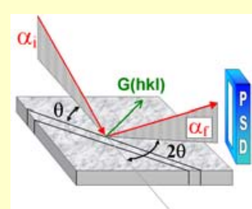


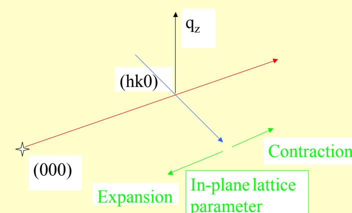
Loss of correlations at T=275 C
Evolution towards a rough surface
At T=200 C, there is an amorphization of the dots
No change of the characteristic inter-dot distance with temperature

Scattered intensity recorded in a CCD camera at ID01Beamline.
Incidence angle α_i=0.2°

Grazing Incidence Diffraction

ID01, E=9 keV
Critical angle α_c=0.3° (GaSb), α_c=0.2° (Si)





Angular (θ) Scans → Correlation and Shape sensitivity

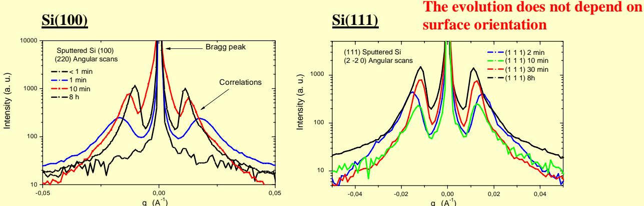
Radial (θ,2θ) Scan → Correlation, Shape and Strain sensitivity

Scans around (400), (220) and (2-20) Bragg peaks.

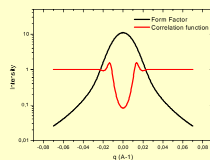
Sputtering time evolution

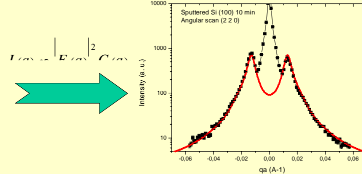
E(sputtering)=1200 eV

The evolution does not depend on surface orientation

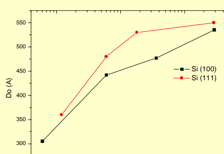


Data analysis





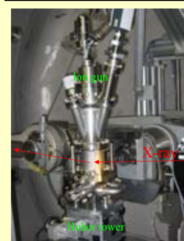
Inter-dot distance



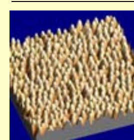
Increase and saturation of the inter-dot distance
Better ordering with time : domain sizes go from 100 to 400 nm for longer tines

This time evolution is not accounted for by current theoretical descriptions of sputtering process : there is a need for a better understanding of the mechanisms that lead to these nanostructures formation.

In-house development : Sputtering chamber for *in-situ studies*

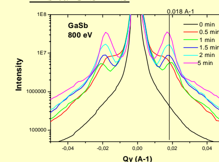


First Result 29/01/2004



AFM 1µm*1 µm, GaSb surface
10 min sputtering
Diameter~60 nm
Height~40 nm

In-situ GISAXS



Time evolution of GaSb nanostructuring
Stabilization of the pattern within the first 3 minutes of the process