Towards X-Ray Diffraction On Single Islands

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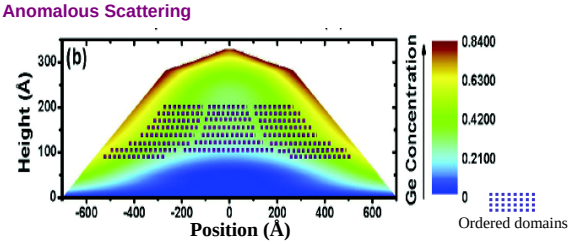
Objectives: Structural Characterisation

- Determination of composition and strain profiles in nanostructures (uncapped islands)
- Determination of shape, size, distribution, and ordering of nanostructures in 3D

Methods used so far

- **Reciprocal Space Maps (RSMs)**
- **Grazing Incidence Diffraction (GID)**
- **Grazing Incidence Small Angle X-ray Scattering (GISAXS)**
- **Anomalous Scattering**



3D composition map *Malachias et al., PRL 91, 176101 (2003)*

Aim

High spatial resolution (in real space) using the same methods (RSMs, GID, GISAXS, Anomalous Scattering)

i.e : measure and compare individual islands properties

Actual approach

Beam size used ~ (100 x 100) μm^2

Consequence : $10^5 - 10^6$ islands are analysed at a time

Conclusion : statistically averaged sample properties are obtained

Idea

- **Use of focussed beams**

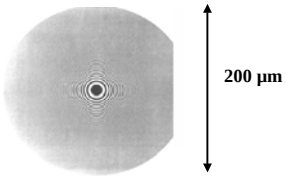
Beam size targeted ~ 100 nm in diameter

Consequence : Single islands could be mesured

Gain in flux ~ 10^6

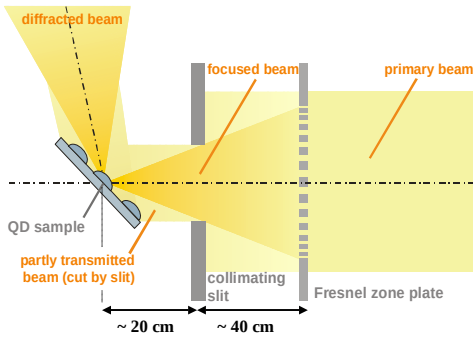
Microfocussing techniques

- **Kirkpatrick-Baez Mirrors (KB)**
- **Capillaries**
- **Waveguides**
- **Compound Refractive Lenses (CRL)**
- **Fresnel Zone Plates (FZPs)**



FZP

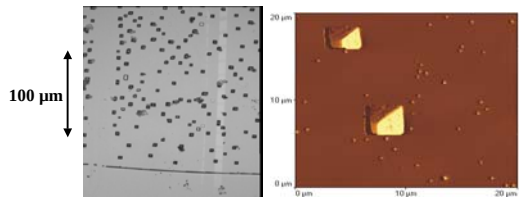
Microdiffraction Setup with FZP



Setup Characteristics

+ Alignment of FZP relatively easy
+ Focus spot of 3*6 µm (V*H) at 10 keV
+ Good stability of setup (no beam and sample drifts)
+ A particular island can be identified and aligned
- "Halo" of transmitted beam and higher order focus (about 10% intensity)
- Mechanical vibrations limits the focus size

Sample: Ge islands on Si (001)



Ge islands grown by Liquid Phase Epitaxy (LPE)

(M. Schmidbauer, IKZ Berlin)

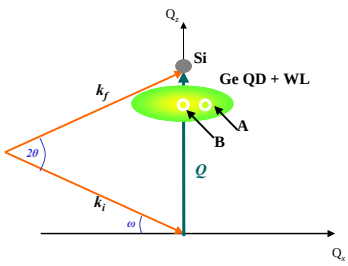
Island size ~ 3.2 µm and 1.8 µm on Ge WL

➡ Big enough to be seen under an optical microscope

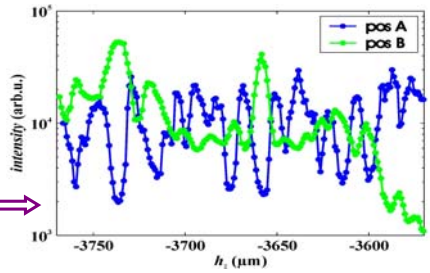
Average distance between islands: ~ 20 µm in studied regions

➡ Enough to measure single islands

Alignment at (004) and Results



Scattering geometry at (004)



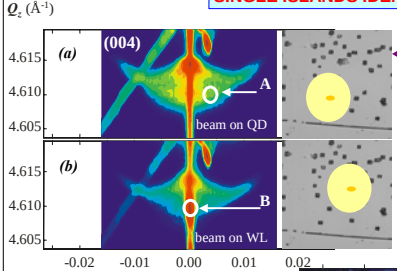
Line scans at positions A and B

Q at pos. A: Scattered intensity comes mainly from the QD.

Q at pos. B: Scattering intensity comes mainly from the pseudomorphic WL.

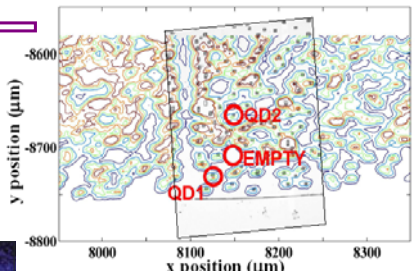
Reverse contrast observed between scattering from the coherent truncation rod and diffuse scattering.

SINGLE ISLANDS IDENTIFIED

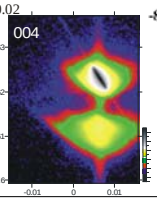


RSMs at (004) on (a) QD and (b) WL

In fig. (a), strong contribution from the island is observed, while in fig. (b), only a weak contribution is seen.



Overlay of the optical microscope image on the area scan of the islands at fixed Q and pos. A



RSM obtained with lab X-ray tube

average intensity is obtained over a large number of islands and WL.

Summary

For the first time, x-ray diffraction has been performed on single islands.

Individual island properties are obtained rather than average properties.

Comparisons can be made from one island to another. Discrimination of the island and the wetting layer properties.

BUT: Setup needs **Improvements** :

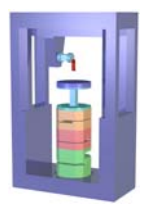
- **Smaller focus size**
- Reduce vibrations
- Other focussing devices e.g. Crossed zone plates
- **Non optical alignment for sub-micron sized structures.**

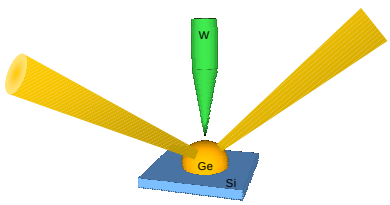
Outlook

Combination of microdiffraction and local probing systems (e.g. AFM) in collaboration within the EU *X-Tip project*

Aim: Use x-rays to characterise mechanical interactions between the tip and the islands.

Advantage: Good means to identify nano-sized islands





Collaboration with: *Fabio Comin, Olivier Dhez, Mario Rodrigues*