Investigation of the Morphology of Surface Nanostructures by Means of the Synchrotron Radiation Based High-Resolution GEXRF Technique

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Motivation

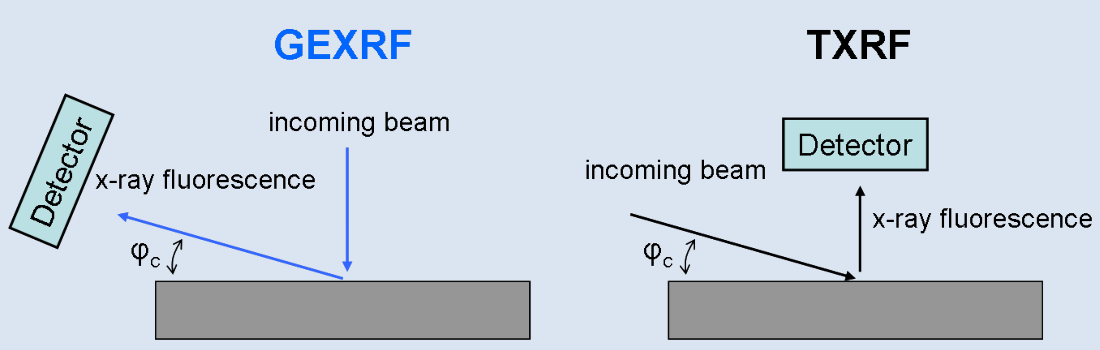
- Search for a multipurpose method of investigation of the surface structures
  - composition
  - 3D distribution
  - chemical state
  - morphology
- Test the utility of the GEXRF method applied to the investigation of the morphology of surface nanostructures

Advantages of High-Resolution GEXRF

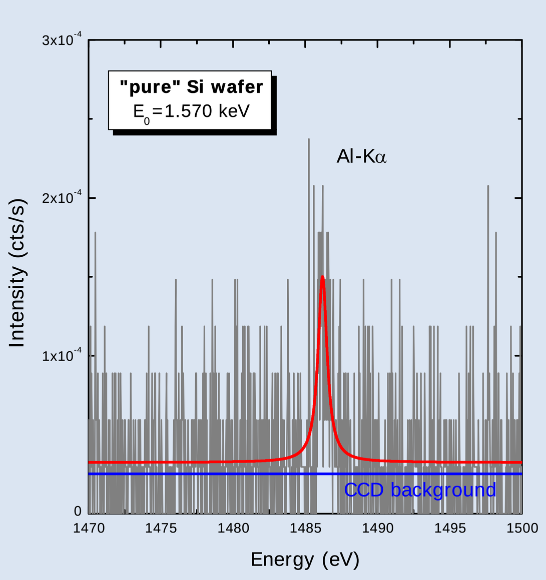
- Sample characterization (bulk, layer, islands)
- 2D-mapping with μm spatial resolution
- No overlapping of the fluorescence peaks — possibility of a better chemical specification
- Very good peak to background ratios (increased detection limits)

Grazing Emission X-Ray Fluorescence (GEXRF)

- GEXRF — "Inversed" Total Reflection X-Ray Fluorescence (TXRF) [2]



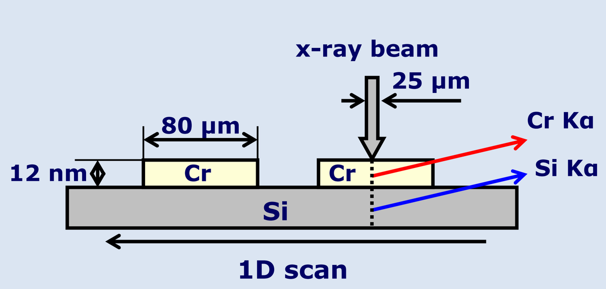
- Detection of low-level surface impurities [3, 4]

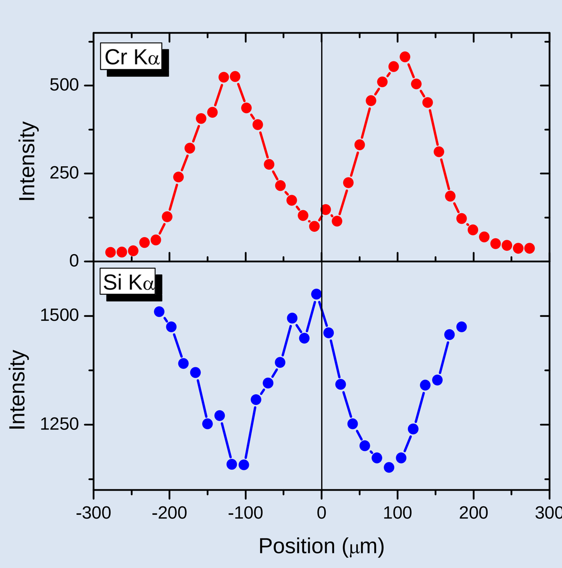


- $C_{dl}(1000s) = \frac{3\sqrt{N_{bcg}}}{N_{peak}} \frac{\sqrt{t}}{\sqrt{1000s}} C$
- Detection limit measured for Al impurities in Si substrate:

$$C_{dl} \approx 10^{12} \frac{atom}{cm^2}$$

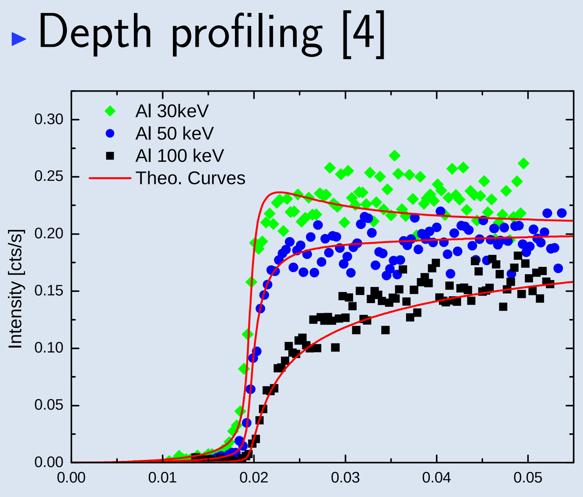
- Lateral 2D-mapping [3]





Results of 1D scans across a pattern of Cr-strips deposited on a Si sample [3]

- Depth profiling [4]



- Al ions implanted in the Si substrate with different ion energies
- Gaussian distribution of the implanted ions for the considered implantation energies
- Implantation dose of the Al ions: $10^{16} \frac{atom}{cm^2}$

	Theo.	Exp.	Theo.	Exp.	Theo.	Exp.
Ion En. [keV]	30	35.47	50	48.73	100	97.21
Center [nm]	50.25	59.70	83.67	81.95	172.8	167.2
Width [nm]	23.38	26.30	35.56	34.64	61.93	60.77

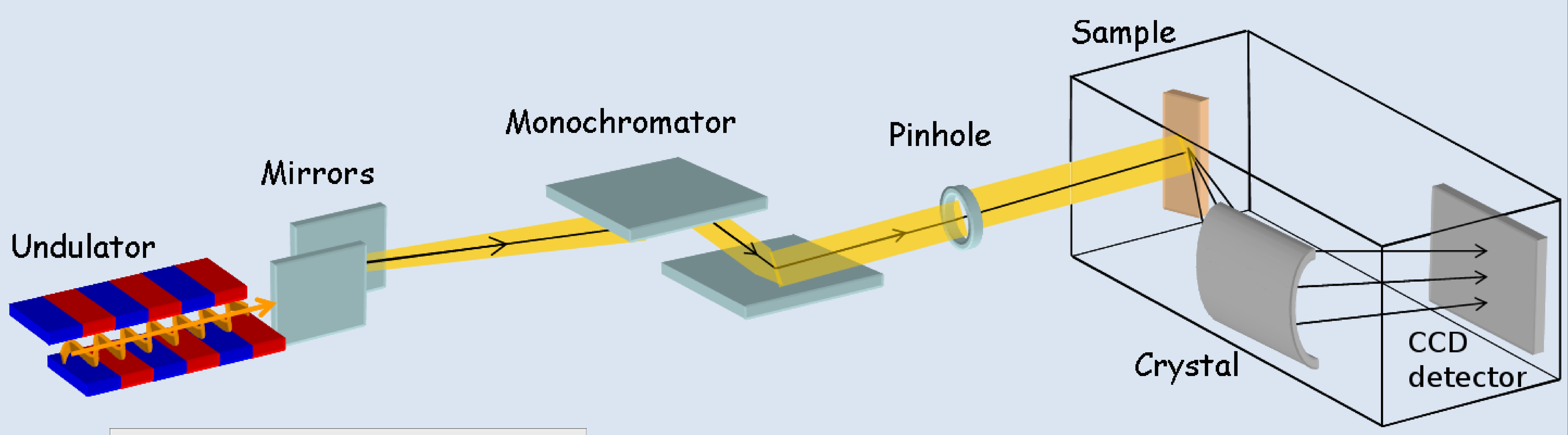
Experimental setup

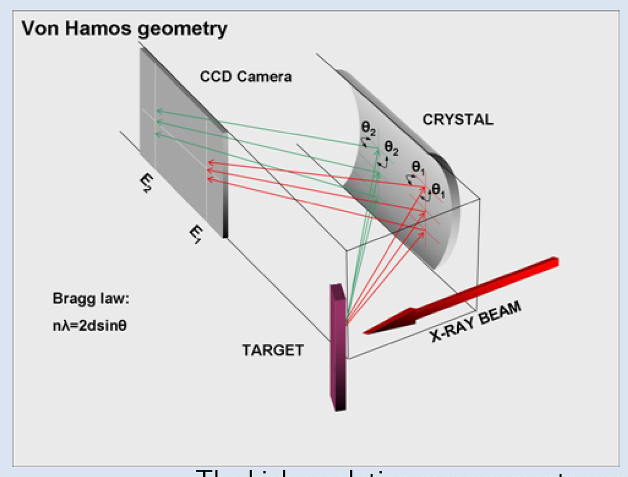
Photon beam:

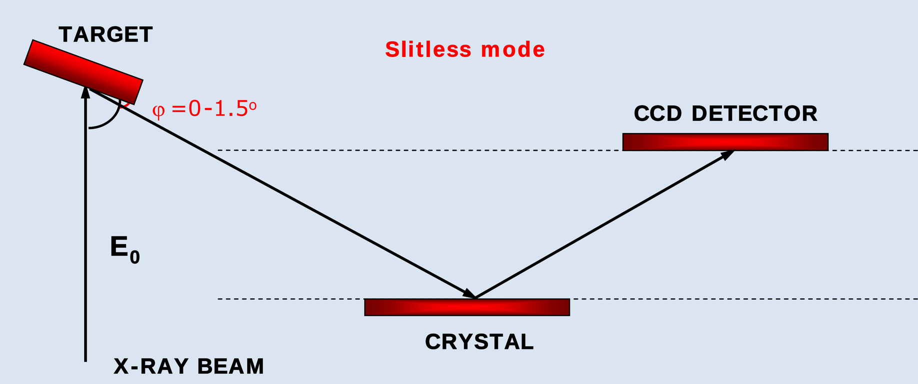
- ~2 mm^2 beam size
- ~10^{13} photons per second
- Energy range: 3.5 keV – 7.2 keV
- Few eV resolution (Ni/B_4C multilayer monochromator)
- Horizontal polarization

Von Hamos spectrometer [1]

- Energy resolution: ~1 eV
- Back illuminated CCD camera
- Slitless operation mode
- Crystals: Ge(220), ADP(101)



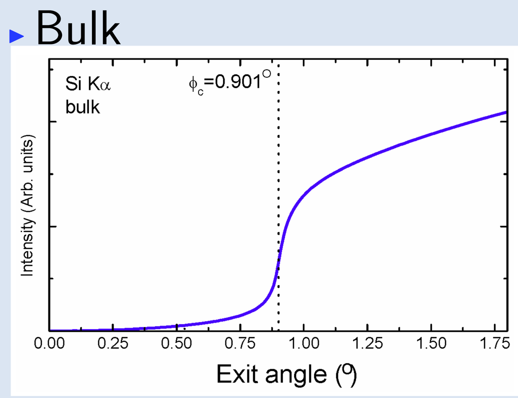


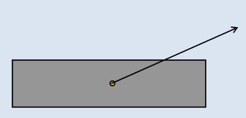


The high-resolution measurements were performed at the beamline ID21 of the European Synchrotron Radiation Facility (ESRF) in Grenoble, France.

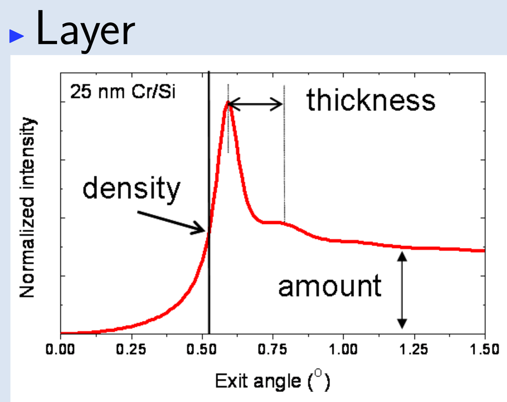
Different surface morphology measured by means of GEXRF [6]

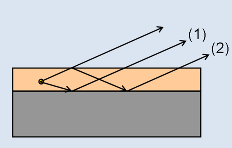
- Bulk



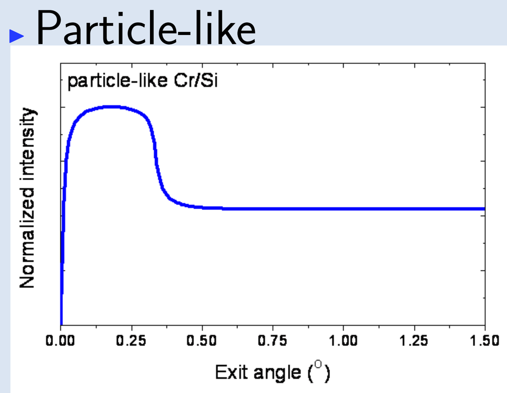


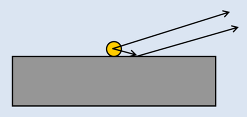
- Layer





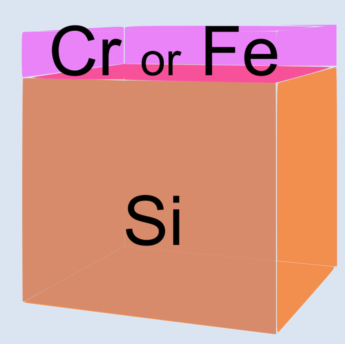
- Particle-like



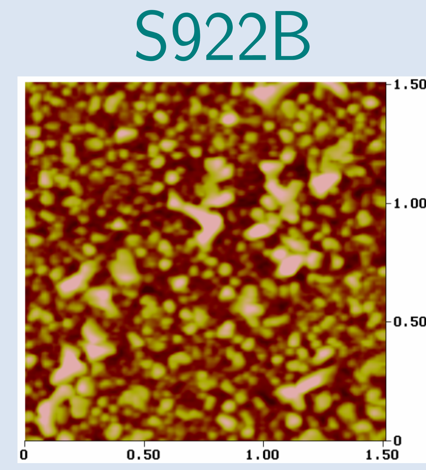


Samples (AFM images)

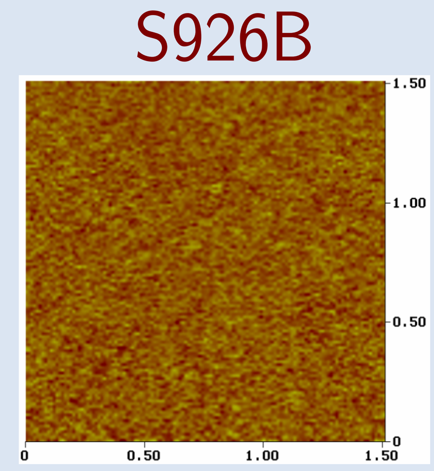
- Si substrate
- Cr or Fe cap layer
- The same cap layer nominal thickness (for samples S922B, S926B and S922C, S923C, S926C)
- Big differences in the surface morphology — different growth conditions



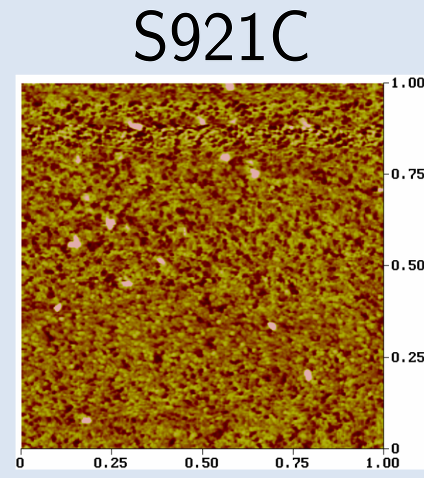
S922B



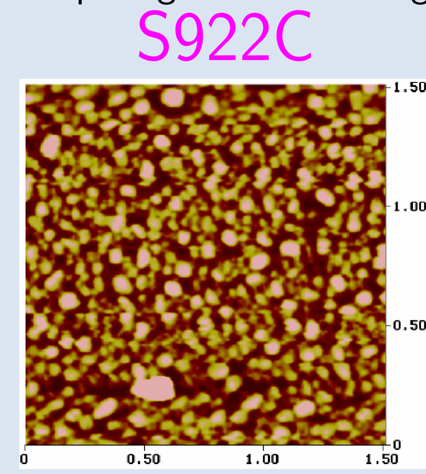
S926B



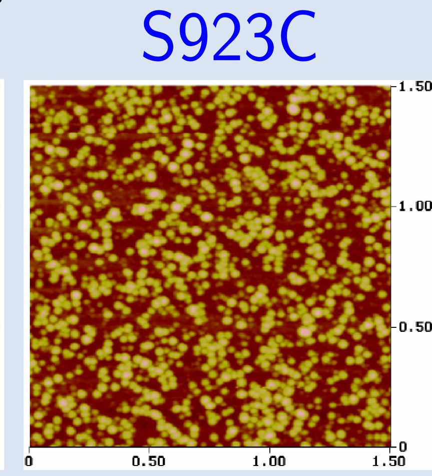
S921C



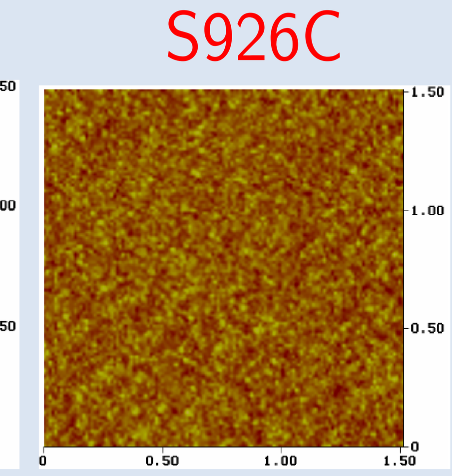
S922C



S923C



S926C

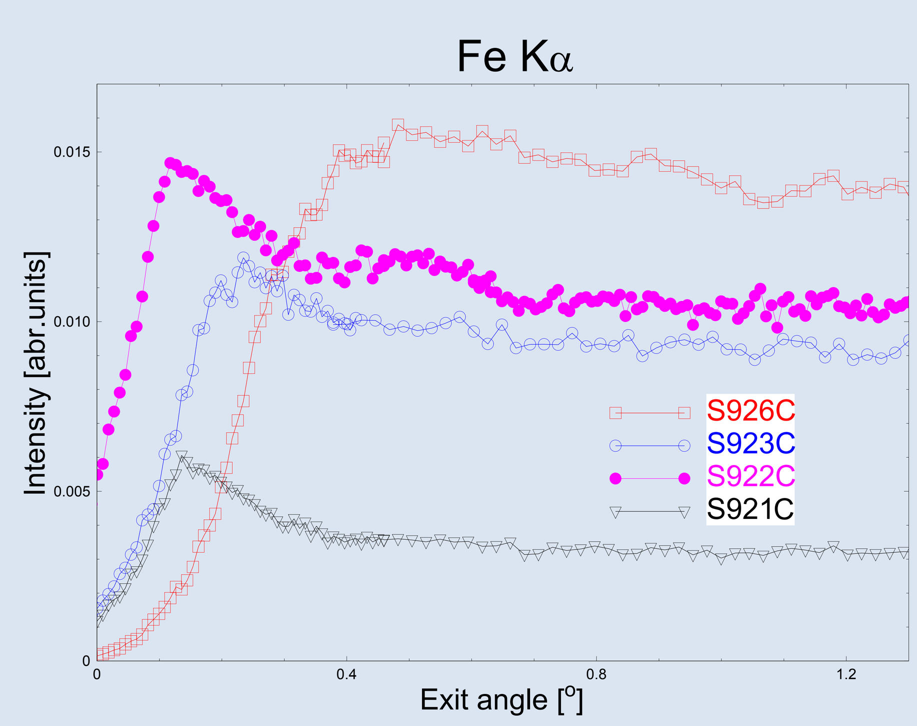


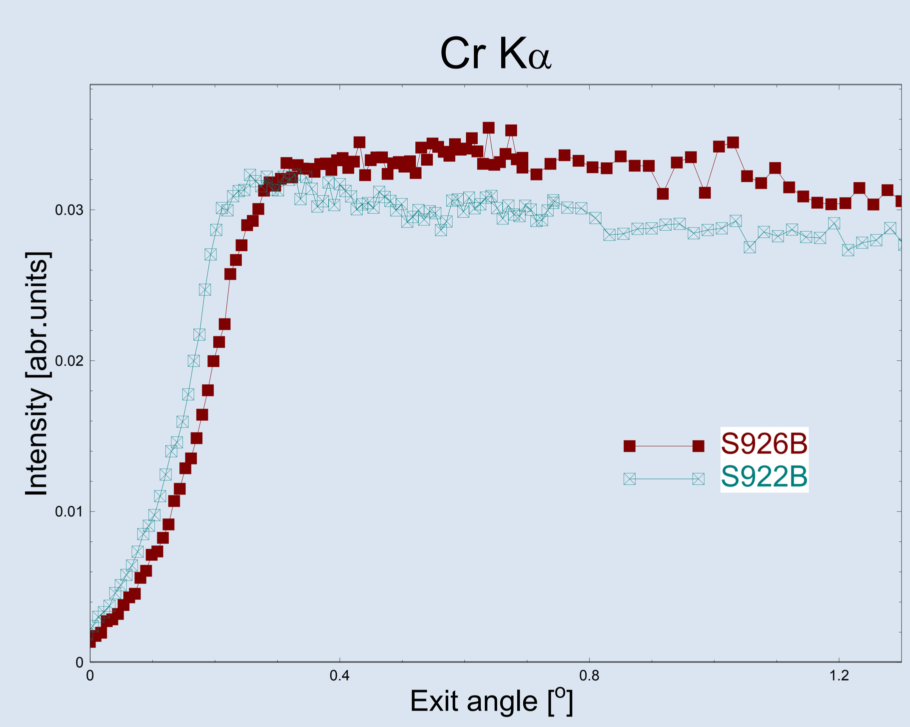
	S922B	S926B	S921C	S922C	S923C	S926C
Cap layer	Cr	Cr	Fe	Fe	Fe	Fe
Cap thickness:	0.5 nm	0.5 nm	0.1 nm	0.5 nm	0.5 nm	0.5 nm
surface roughness:	4.07 nm	0.26 nm	0.82 nm	5.91 nm	3.42 nm	0.31 nm
growth temp.:	300°C	300°C	300°C	300°C	800°C	300°C
post growth annealing:	800°C	—	800°C	800°C	—	—

Samples were grown and imaged at the Institute of Physics, Polish Academy of Sciences, 02-668 Warszawa, Poland.

Results

- High sensitivity to changes of the surface morphology
- Layer-like angular dependences for large islands (sample S922B)
- Particle-like angular dependences for samples S921C and S922C
- Transition from particle-like to layer-like angular dependences (samples S922C, S923C and S926C)





Conclusions

- Promising qualitative results
- Algorithm and its implementation for quantitative interpretation (height, width, separation of islands) is in development

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