UNIVERSITÄT DUISBURG ESSEN

Creation of nanodots with swift heavy ions

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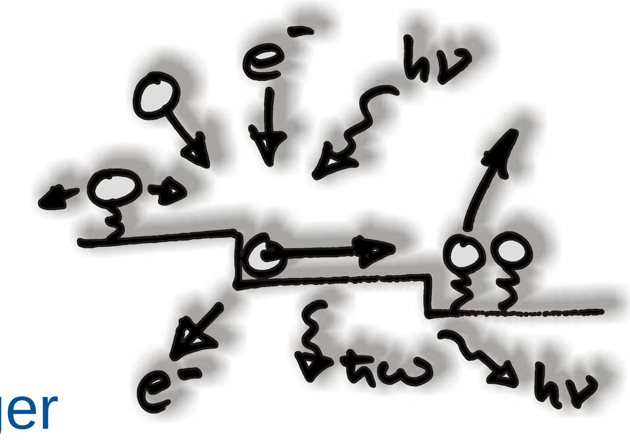
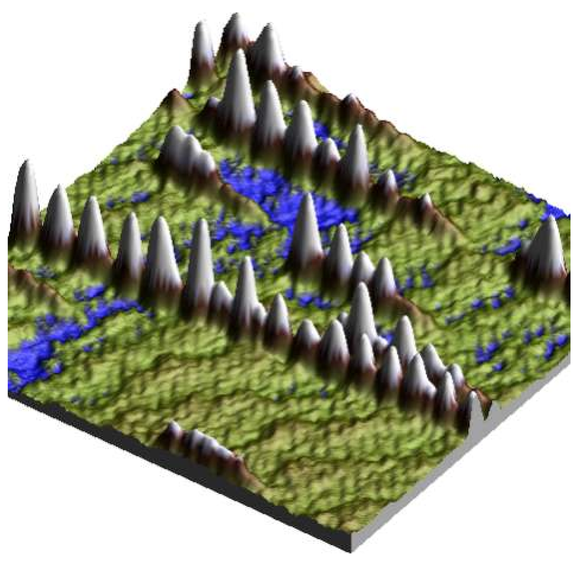


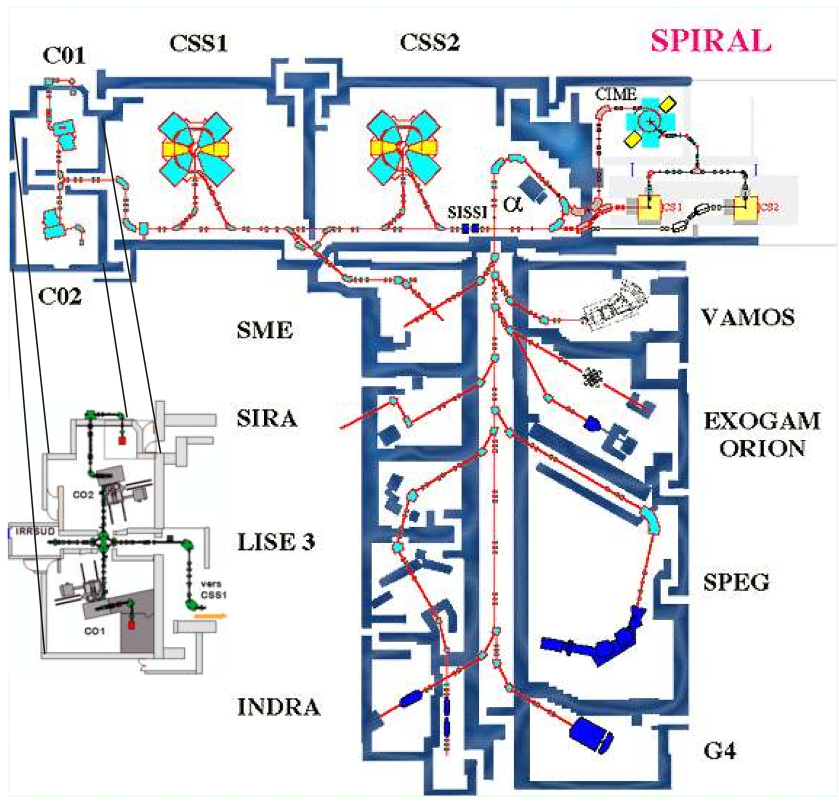
Goals

- Investigation of electronic excitations in the surface region of non-conducting solids
- Characterization of ion induced defects with scanning probe microscopy under UHV conditions
- Controlled modifications of oxide surfaces and thin film systems on the nanometer scale

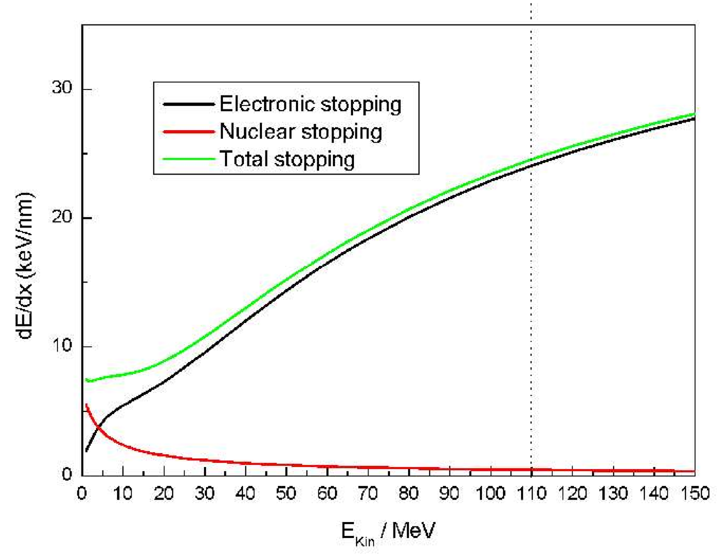


IRRSUD at GANIL

- **ECR4-CO2:** ECR-source for the production of swift heavy highly charged ions. Acceleration in the cyclotron CO2.

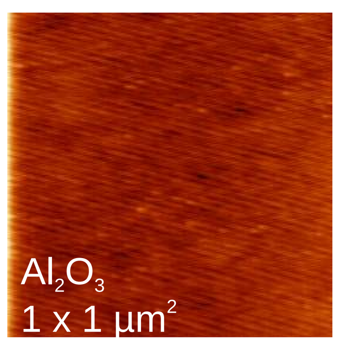


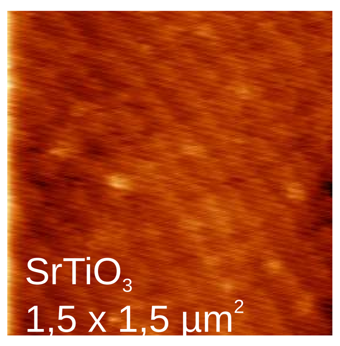
- **Ions:** The energy loss can be varied by chosing the energy and the charge state. Depending on these parameters structural defects are produced that can be investigated by scanning probe methods.
- **0,521 MeV/u 208 Pb^{28+}:** The energy loss according to SRIM calculations is about 24 keV/nm for the oxide surfaces Al_2O_3, $SrTO_3$ and TiO_2. The ions penetrate ca. 8 µm into the solid.

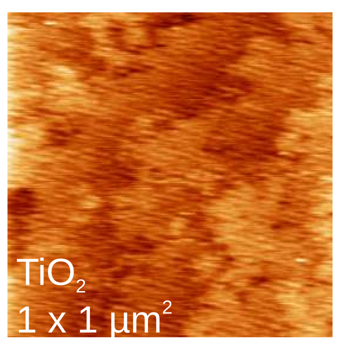


Analysis of defects

- **Preparation:** Oxide surfaces are easily prepared ex-situ (aceton) and are extremely flat (rms < 0.2 nm). After introducing the samples into UHV terracses and steps can be easily resolved.

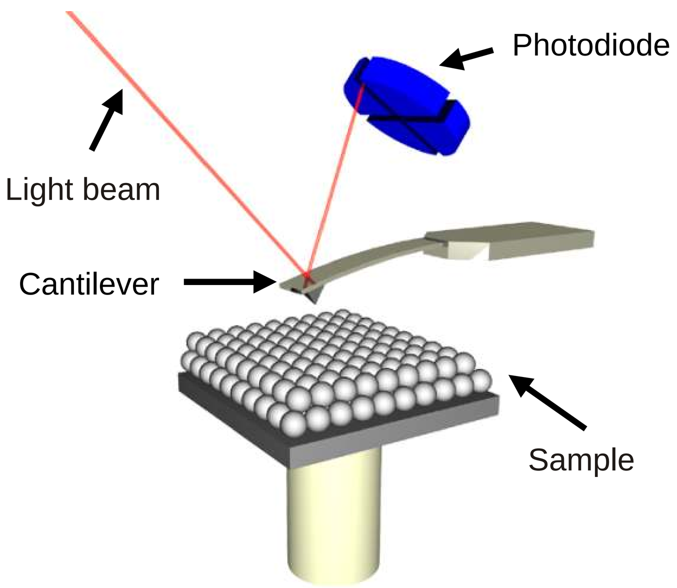




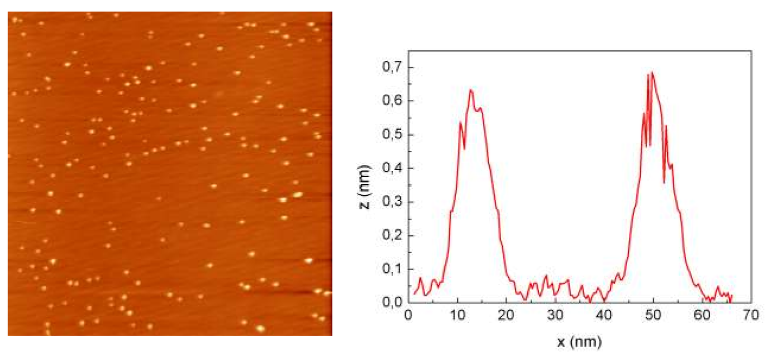


- The surfaces are irradiated and are transferred into the AFM without breaking the vacuum (base pressure AFM: 4 x 10^{-10} mbar, base pressure beamline: 6 x 10^{-7} mbar). In this way the defects can unambigiously attributed to the irradiation.

- **Contact and non-contact mode:** Number, shape and type of defects are recorded with different measurement techniques. The non-contact mode allows a non-destructive measurement also of soft structures



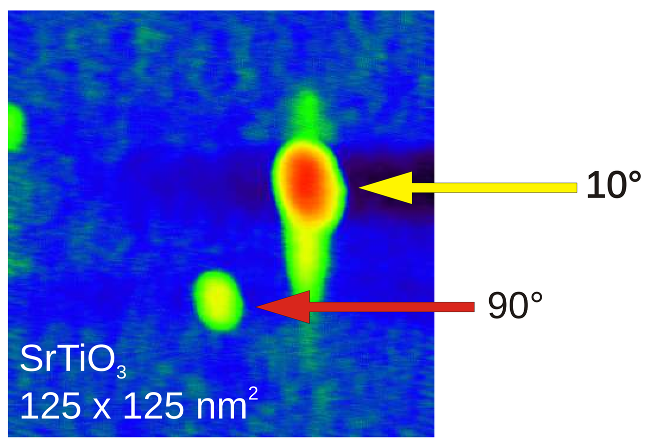
- Topography after irradiation with 4 x 10^9 Ions/(cm^2 s). The fluence is low enough so that the impacts do not overlap.



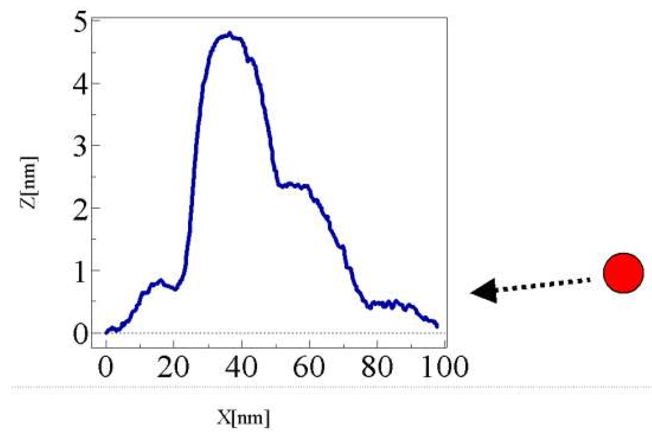
- Hillocks are created - no craters
- One defect per ion
- Height ranging from 1 to 5 nm
- Diameter (FWHM) ca. 15 nm (limited by tip radius)
- Mechanically hard
- Stable in time

$SrTiO_3$:

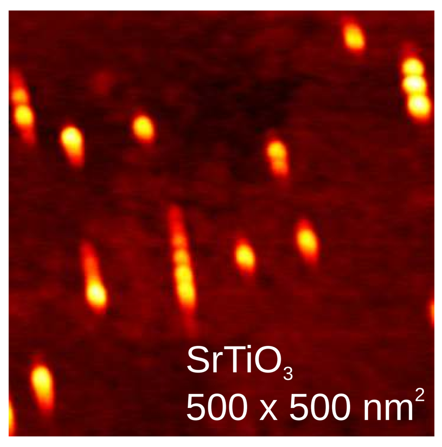
- Irradiation under 90° and 10°



- Round defects at vertical impact
- Elongated defects at glancing angle

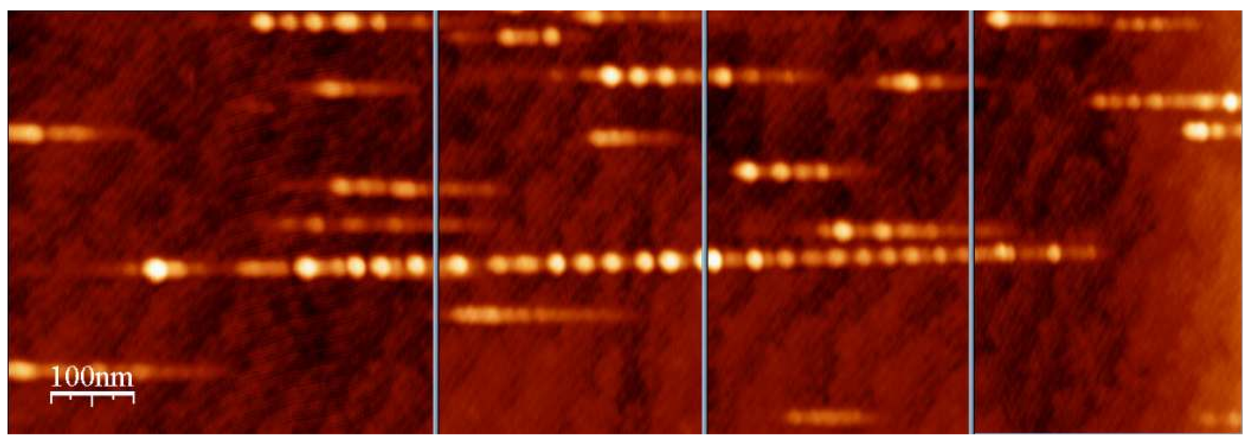


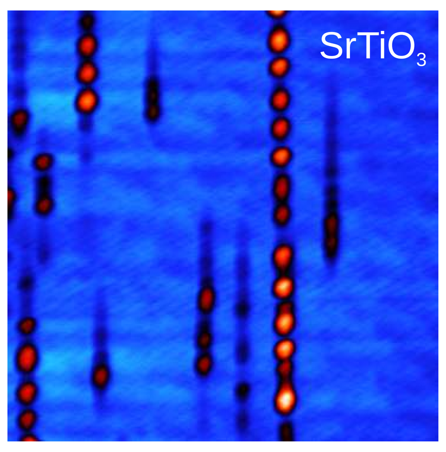
- Irradiation under 3° and 6°



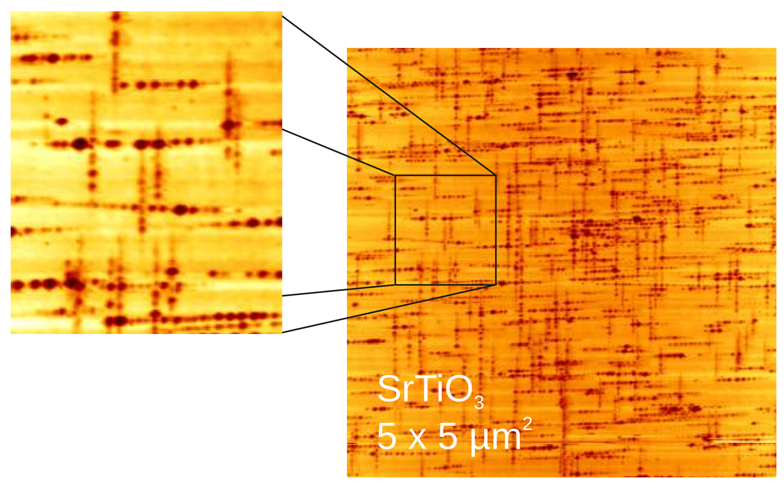
- The distance between hillocks increases with angle of incidence
- Critical angle ~ 5°
- Track length of more than a micron can be produced
- Hillocks within the chain are of equal height
- Hillocks appear on terraces as well as at step edges

- Irradiation under 1°



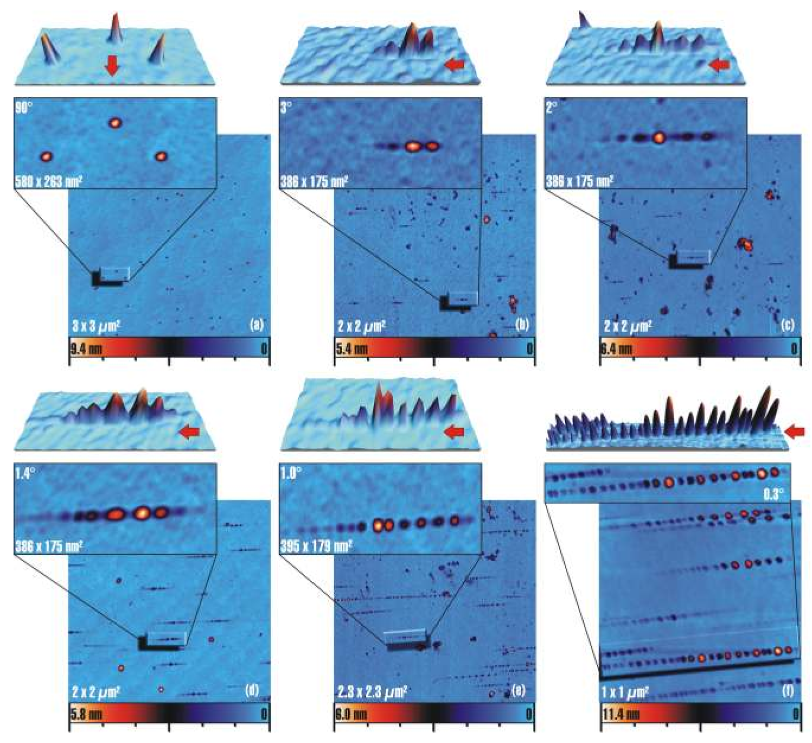


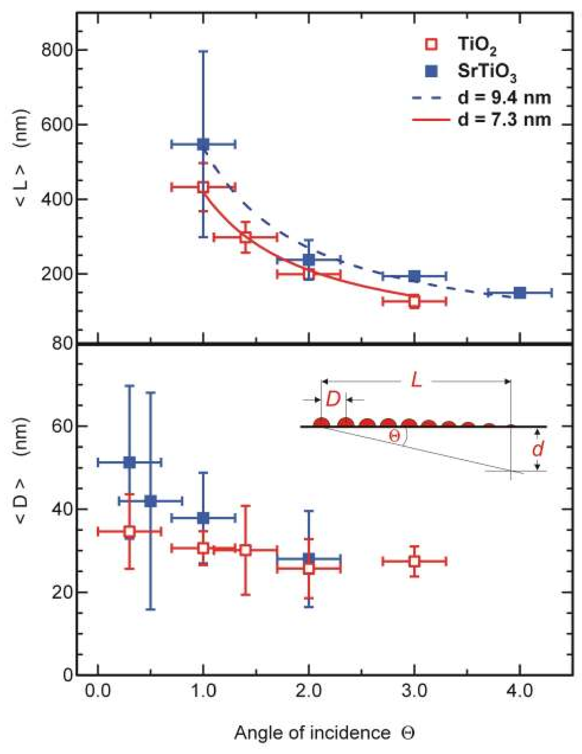
- A striking periodicity of hillocks is observed
- Criss-cross pattern of chains can be written



TiO_2:

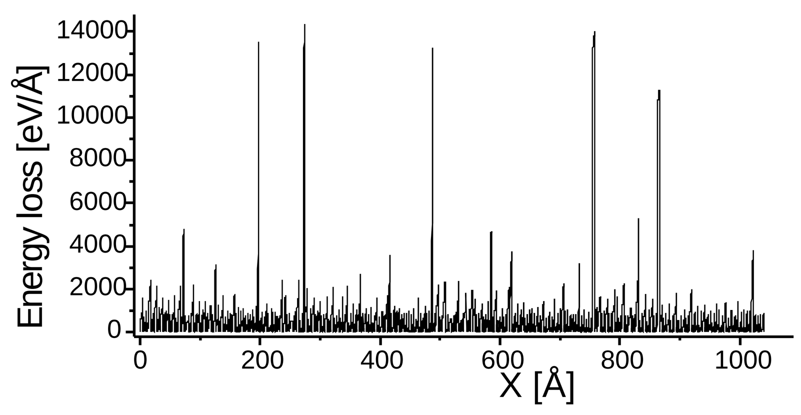
- Same effect on TiO_2
- Track length different compared to $SrTiO_3$, depending on geometry with the same relationship to the angle of incidence: L=d/tan(θ)
- To explain the distance between hillocks the electron density must be taken into account





Track length L and hillock distance D

Calculated energy loss of Xe^{23+} with 93 MeV kinetic energy in TiO_2 under 1°, polar angle 10°



References/Acknowledgement

- Fission Fragment Tracks in Semiconducting Layer Structures, L.T. Chadderton (1968)
- Electron density calculations by R. Meier, AG Entel, Uni Duisburg-Essen
- SRIM, J.F. Ziegler, J.P. Biersack, 1984-2003

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