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Magnetostatic Micro-Structures for Secondary Electron Yield Reduction

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Introduction / Research Interests

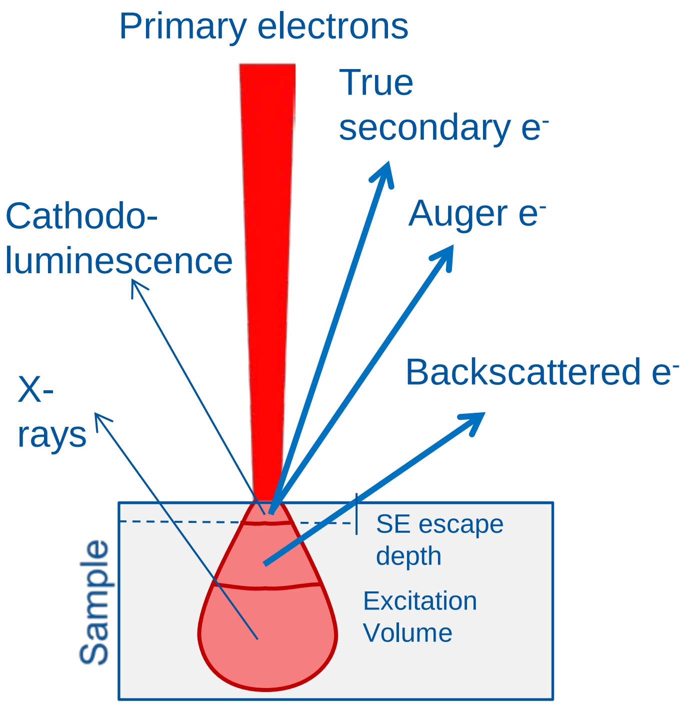
- Secondary Electron Yield (SEY) is the physical quantity governing:
  - multipacting in radiofrequency devices
  - charging in space applications
  - electron-cloud in particle accelerators

- Lowering the (effective) SEY enables the mitigation or eradication of the later effects. This could be achieved with:
  - specific coatings (sensitive to air exposure)
  - microscopic tuned roughness / grooves (RF power losses)
  - **magnetostatic (micro)-structures (insensitive to air exposure)**

- **Magnetic roughness** possible applications (where it is possible to implant a pattern of permanent magnets):
  - waveguide filters
  - devices in satellites
  - insulators (very high SEY)
  - particle accelerators

Secondary Electron Emission (SEE)

Secondary Electron Emission



Secondary e⁻ escape depth: typ. 1-5nm

SEE Energy Spectrum

Energy spectrum of the secondary electrons at a constant primary electron's energy

A large part of the SE have an energy < 50eV

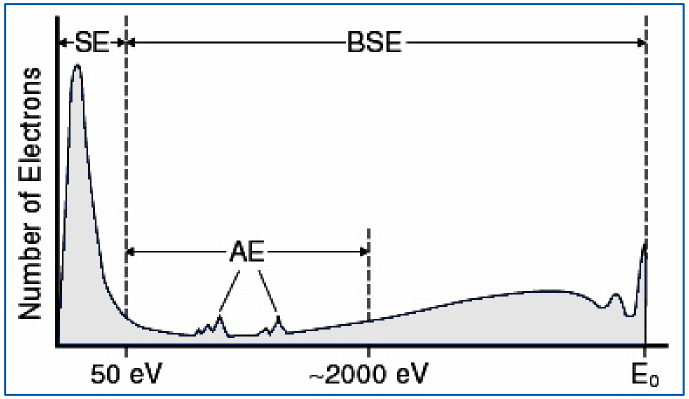
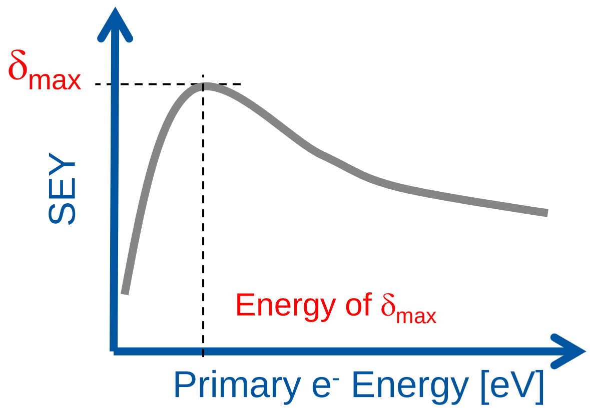


Figure after Goldstein et al. 1981

Secondary Electron Yield (SEY)

Secondary Electron Yield (SEY)

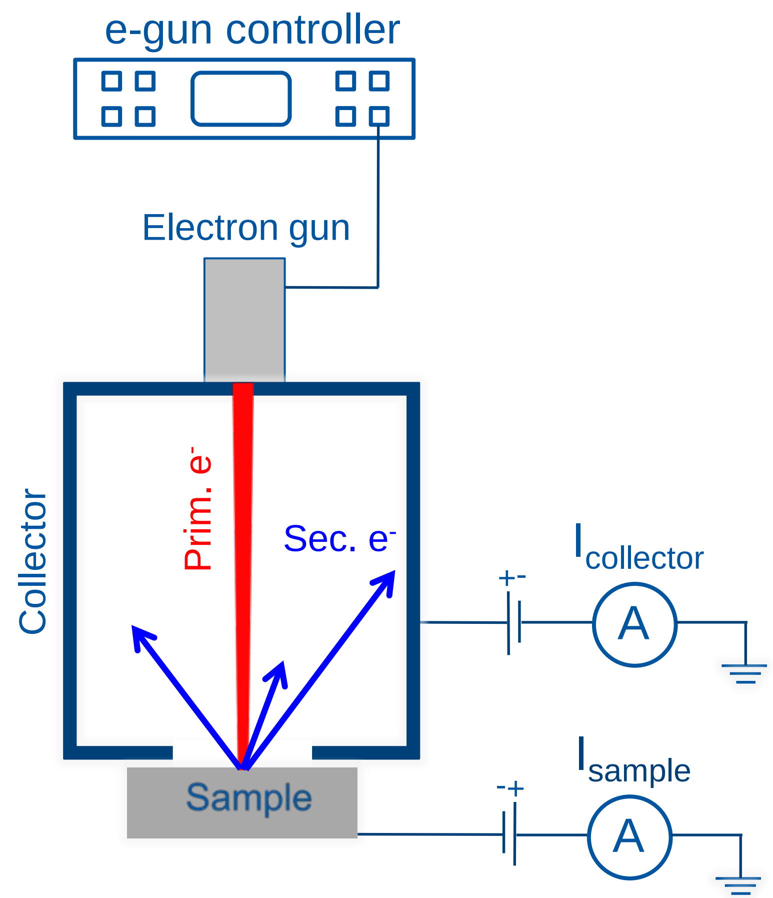
$$SEY = \frac{\text{Secondary e-}}{\text{Primary e-}}$$



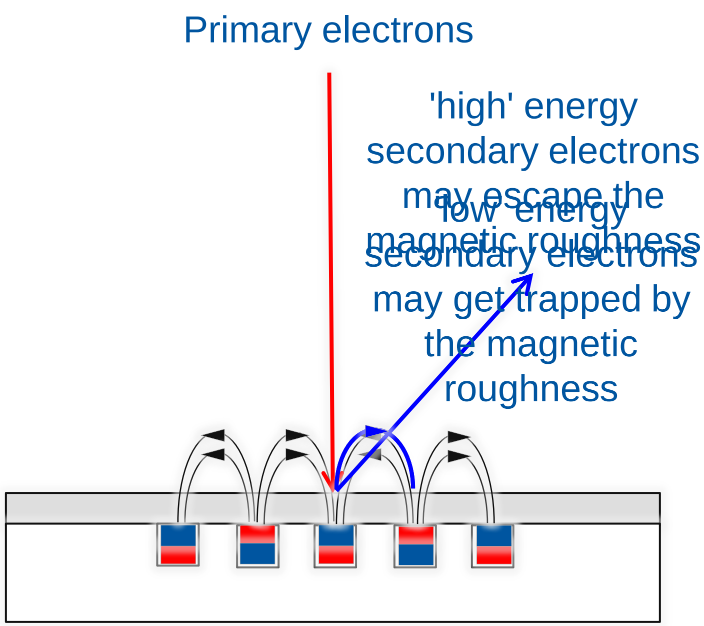
$$SEY = \frac{I_{coll}}{I_{coll}+I_{sample}}$$

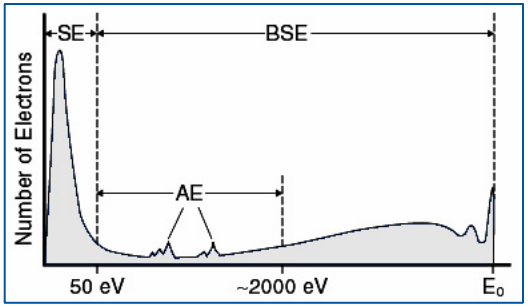
Cum. primary electron dose per SEY curve $< 10^{-7}$ C/mm^2

Experimental Setup



Reduction of Secondary Electron Yield on Smooth Metallic Surface by Means of Magnetic Roughness

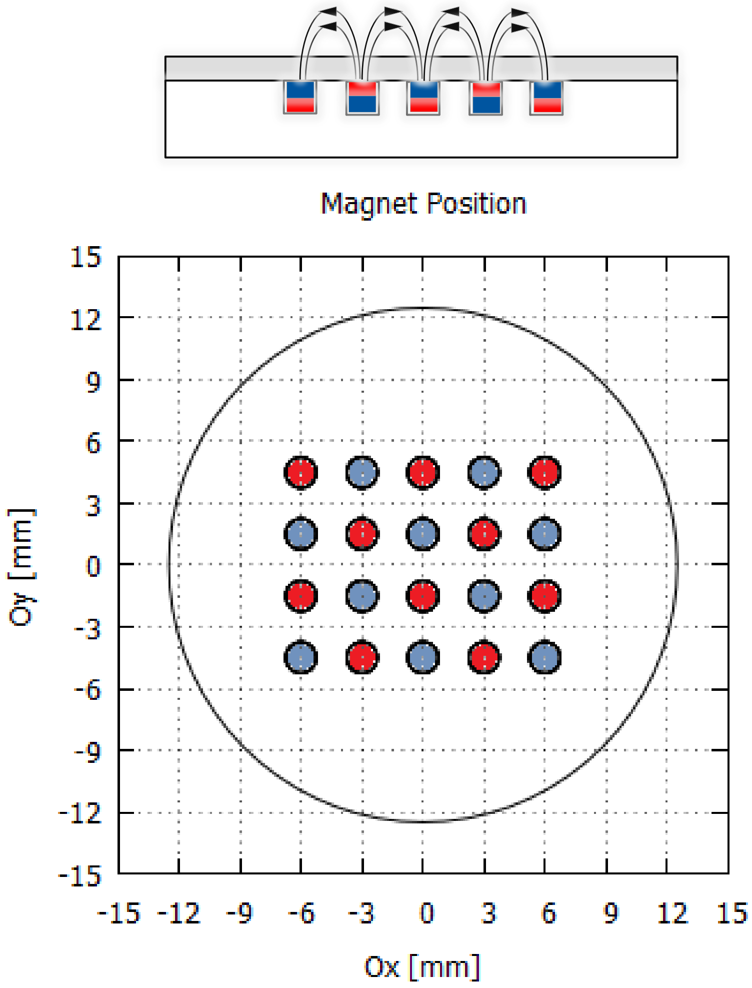




General Idea

- High energy (fast) secondary electrons such as backscattered e^- may escape the magnetic roughness
- Low energy (slow) secondary electrons such as true secondary e^- may get trapped by the magnetic roughness and reduce the effective SEY of the surface
- **The reduction of the secondary electron yield is achieved through the bending of the secondary electrons trajectories by the magnetic field above the surface due to Lorentz forces**

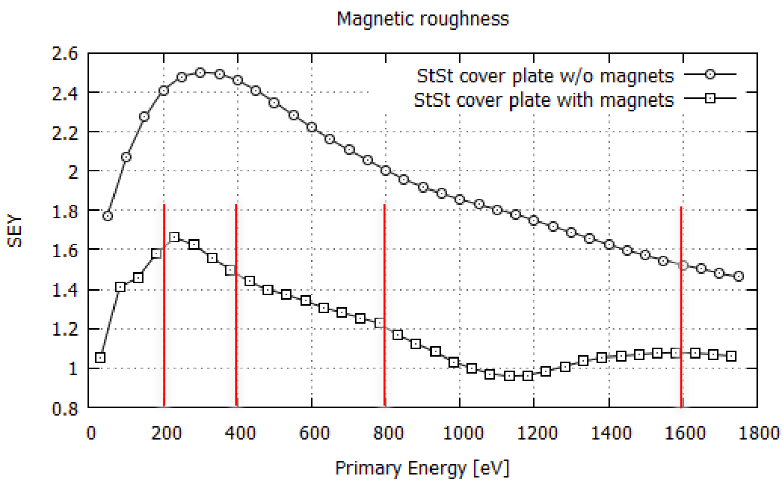
Macroscopic Magnetic Roughness Test Sample

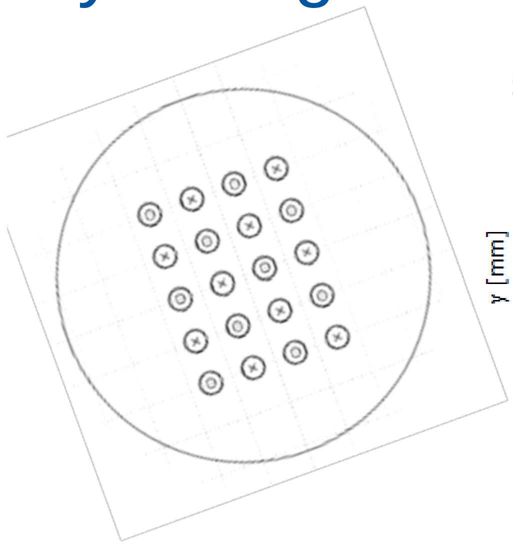


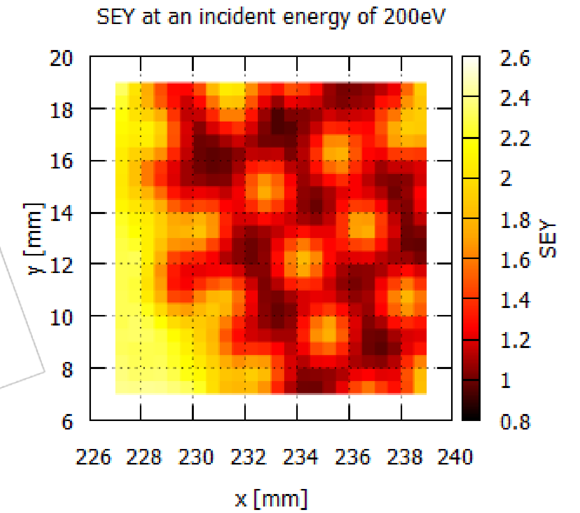
- **General Idea**
  - A smooth conducting surface with low microwave losses covers a large number of tiny permanent magnets building a magnetically rough equipotential structure.

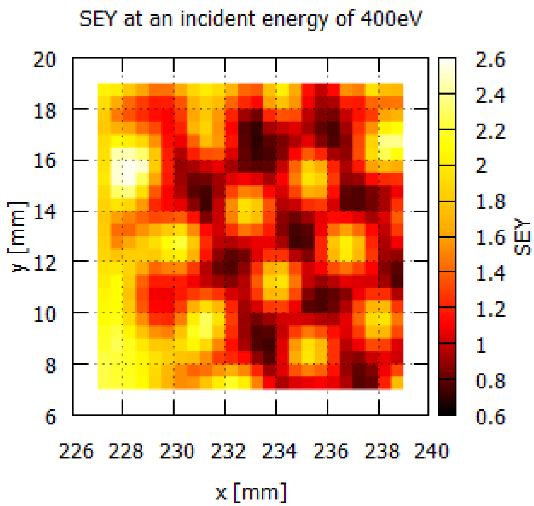
- **Experimental Setup**
  - 4 x 5 array of NdFeB magnets
  - Antiparrallel orientation
  - 316LN non-magnetic stainless steel cover plate

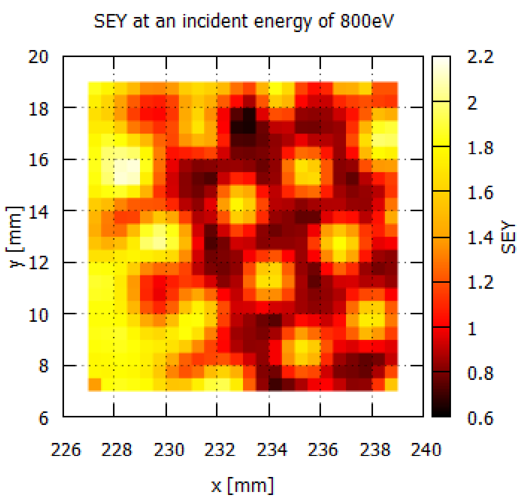
SEY Maps on Magnetic Roughness at Different Primary Energies

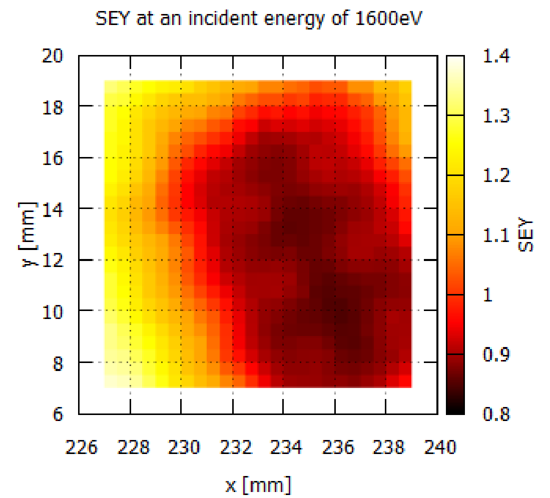




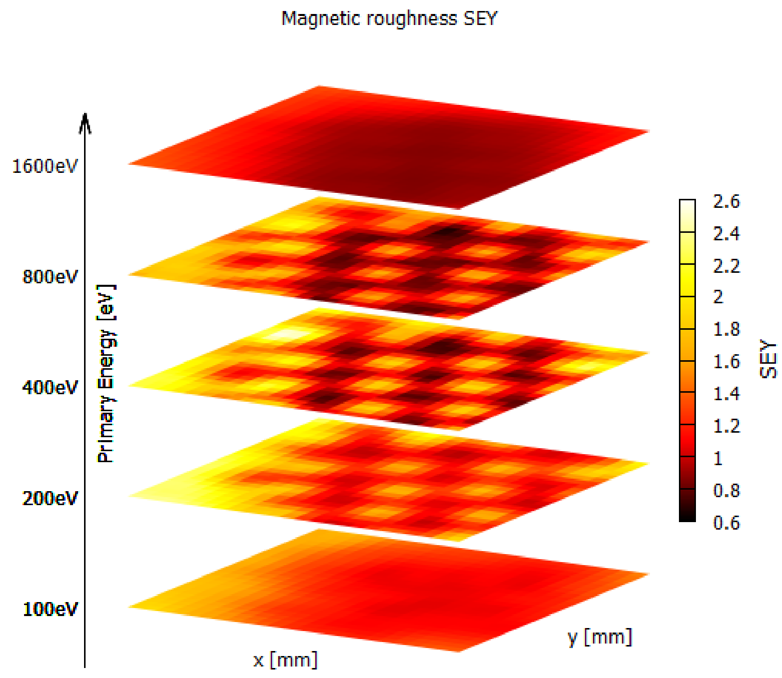


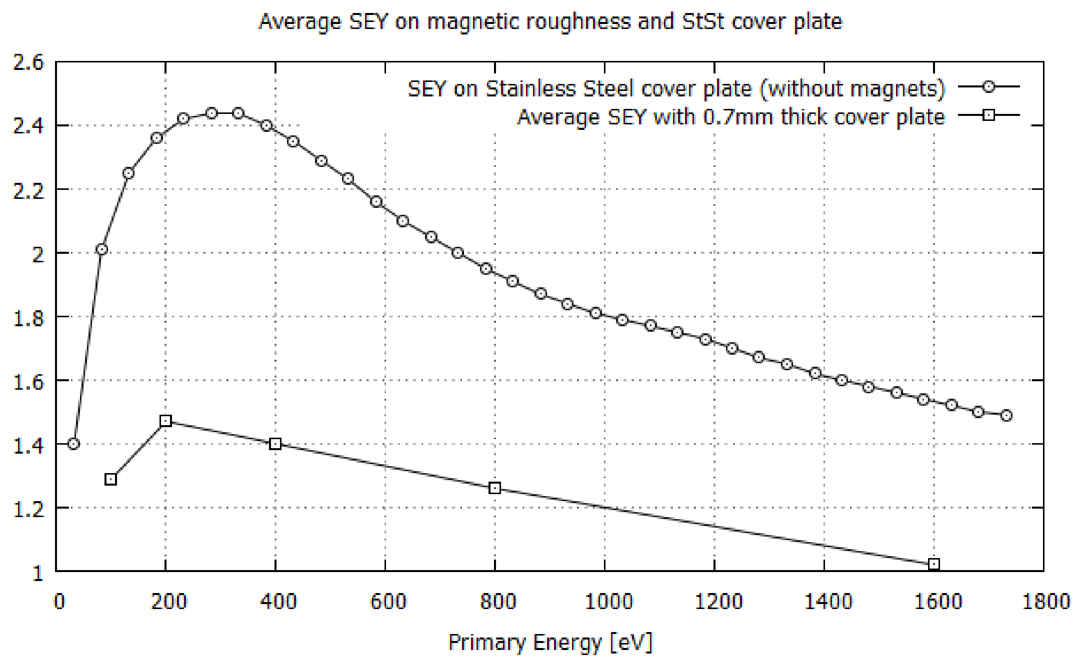






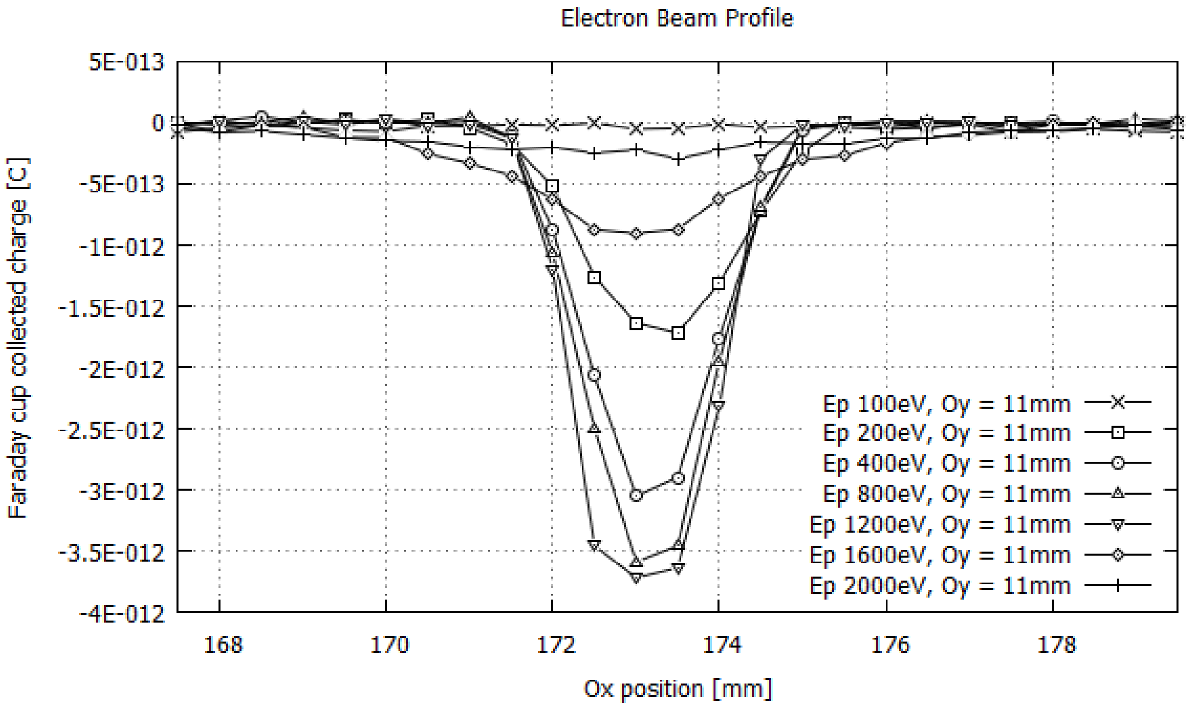
Effect of the Primary Electron's Energy on the Average SEY

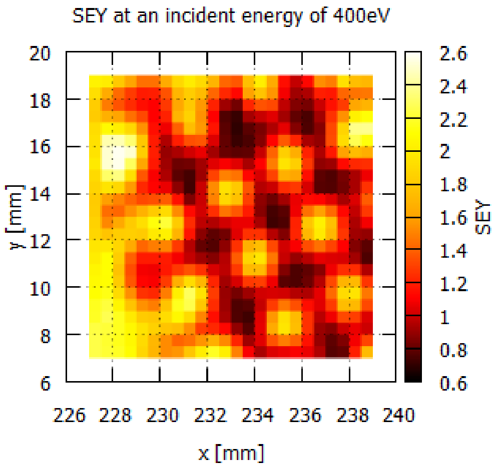


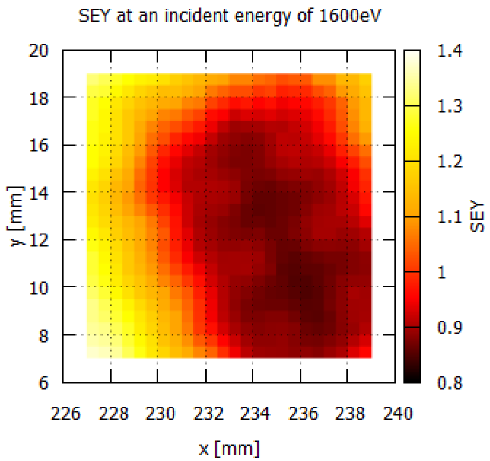


The average SEY values (right plot) are computed by averaging the local SEY values from the SEY maps (left plot). It shows a sharp reduction of the effective SEY compared to that of the 316LN stainless steel cover plate without the magnets.

Electron Beam Profile

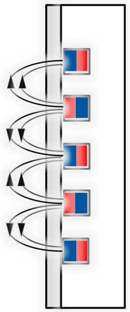


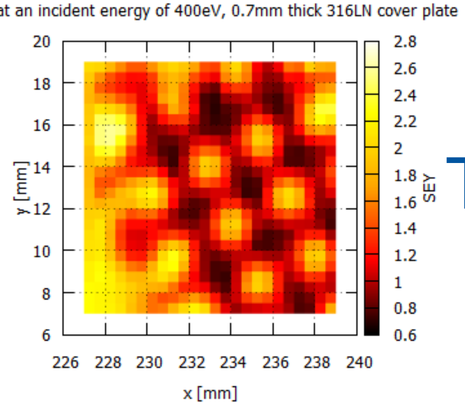


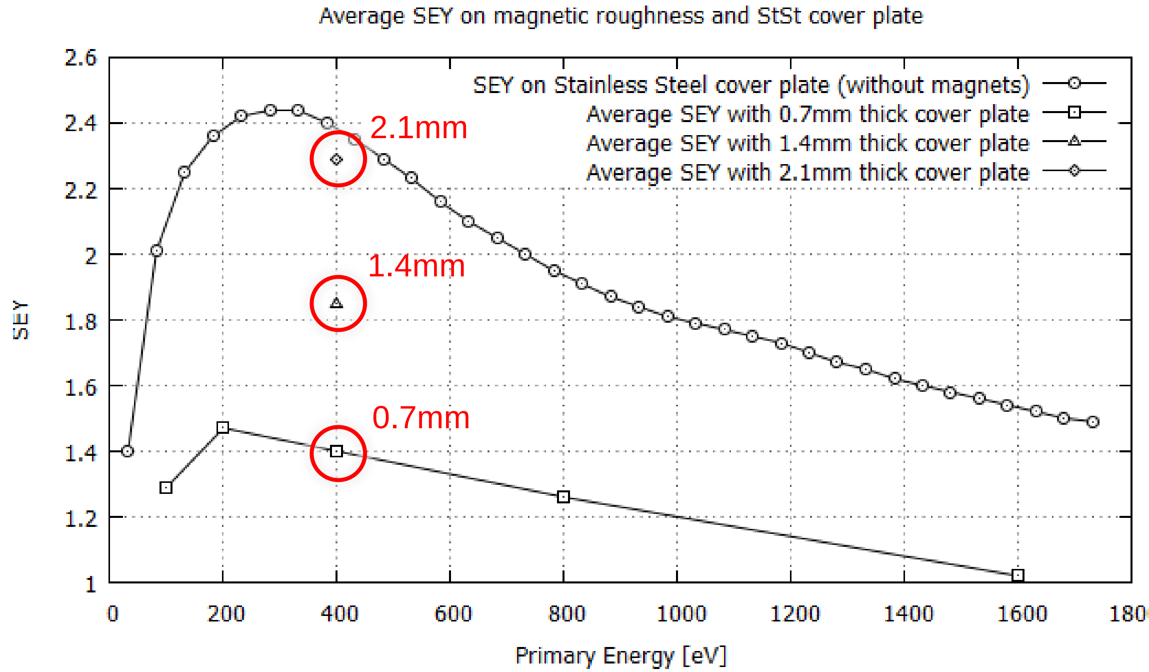


The electron beam longitudinal current distribution – measured with a Faraday cup – shows a strong dependency with the primary electron energy which partly explains the 'blurring' of the mapping at a primary energy of 1600eV (bottom right)

Effect of the Cover Plate's Thickness at 400eV Primary Energy


0.7mm





When decreasing the distance between the surface and the location of the magnets, the reduction of SEY is more and more effective

Conclusion

- Magnetically rough surfaces build of regular arrays of permanent magnets produce a sharp decrease in the effective SEY as compared to that of flat metallic surfaces. The main effect is due to the bending of the low energy secondary electrons' trajectories by the magnetic field above the surface.
- The reduction of the effective SEY was shown to be sharp for primary energies ranging from 100eV to 1600eV
- When decreasing the distance between the surface and the location of the magnets, the reduction of SEY is more and more effective

Results confirmed by independent measurements by

I. Montero, Instituto de Ciencia de Materiales, CSIC, Madrid, Spain

Many thanks to Holger Neupert (TE-VSC) for fruitfull discussion about magnetic roughness measurements

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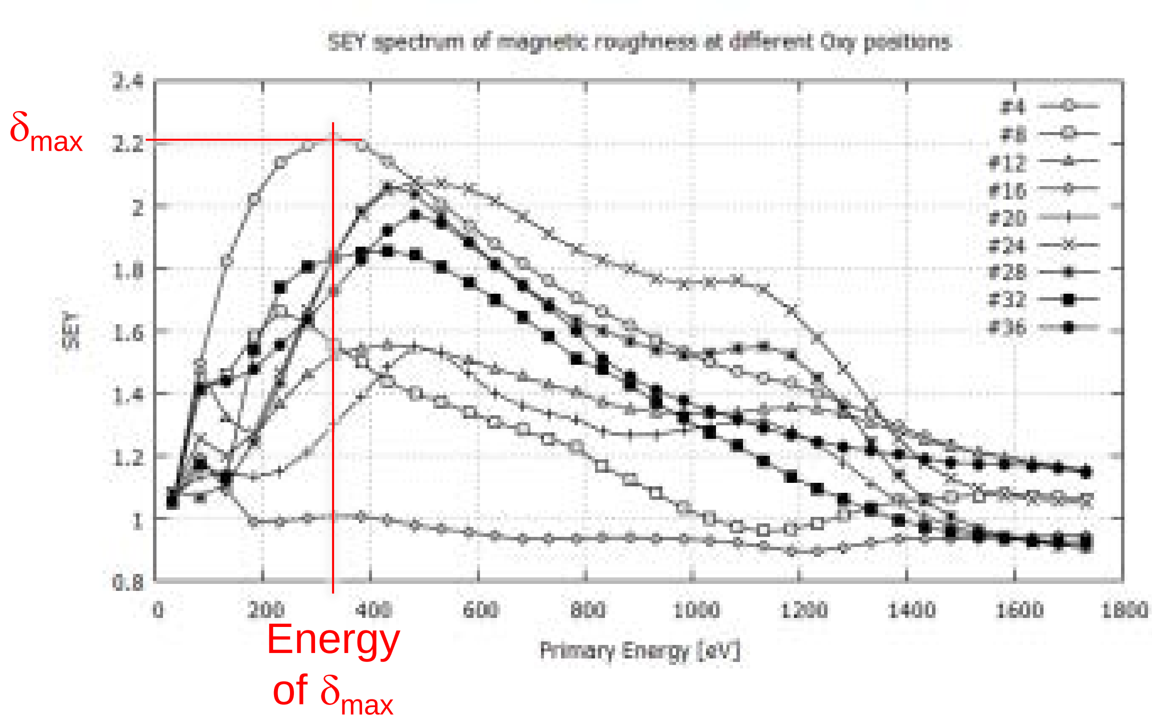
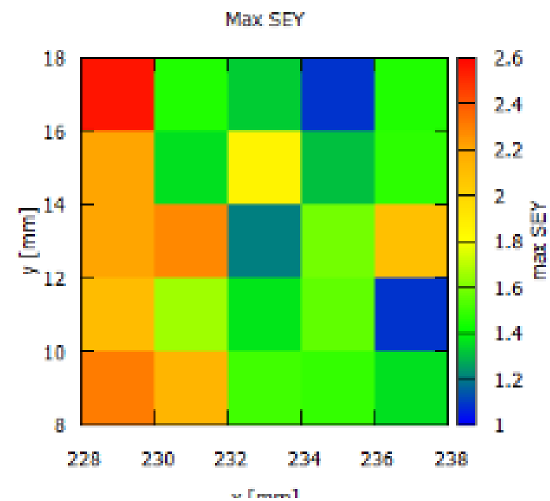
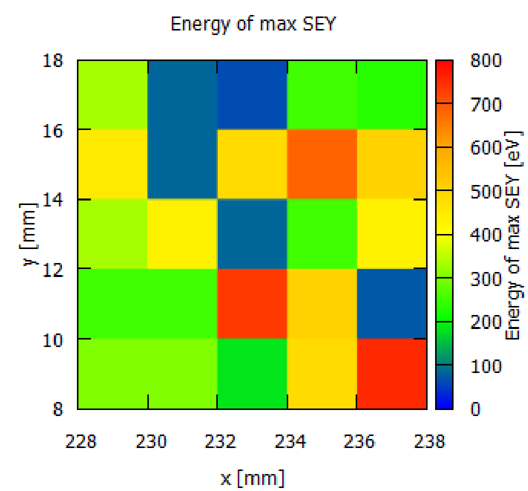
SEY δ_{max} and Energy of δ_{max} at Different Positions

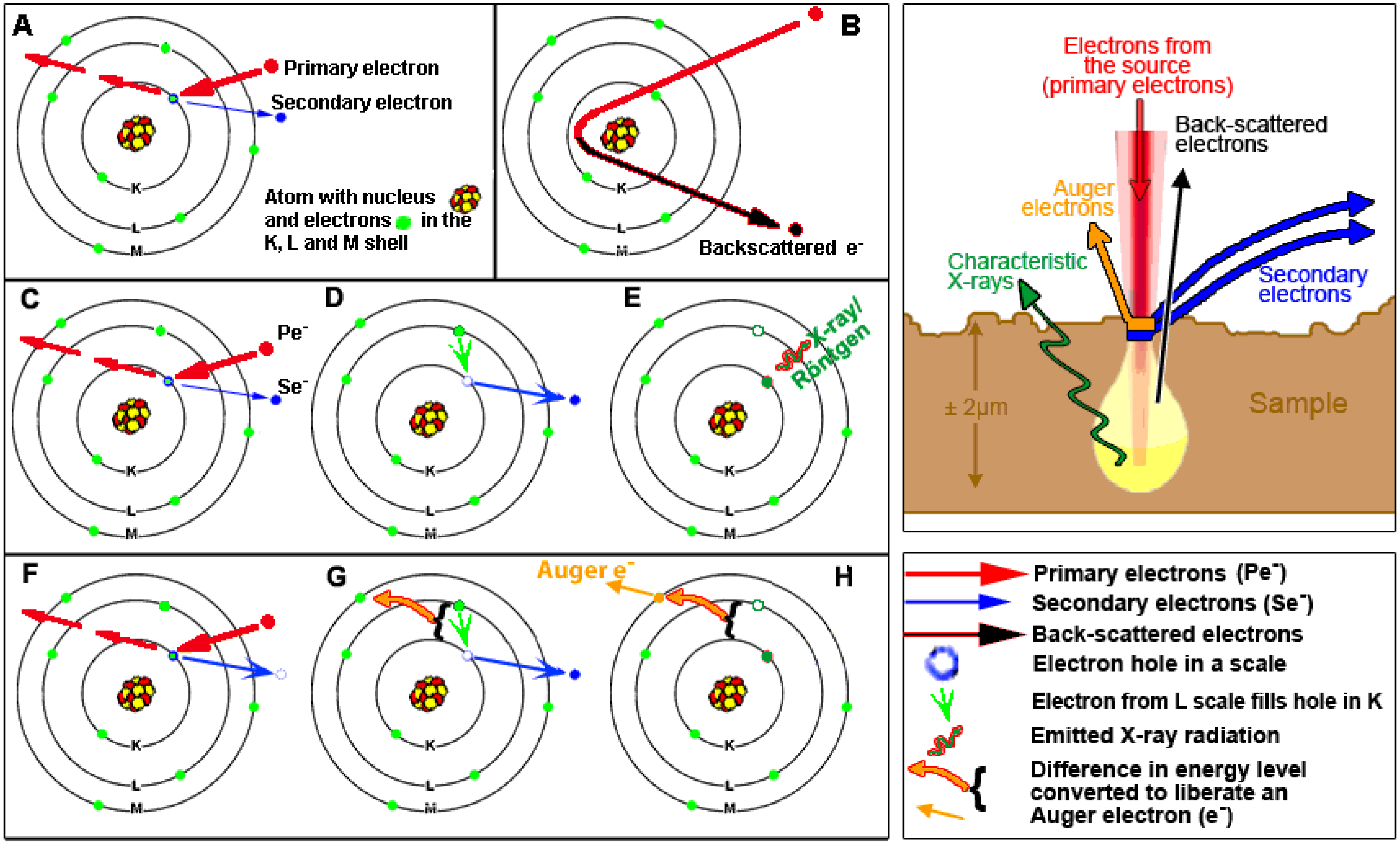






The magnetic roughness influences the secondary electron emission spectrum as secondary electron may or may not – depending on their energy – escape the smooth metallic surface

Origins of the SEE



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