Time of Flight Backscattering and Secondary Ion Mass Spectrometry in a Helium Ion Microscope

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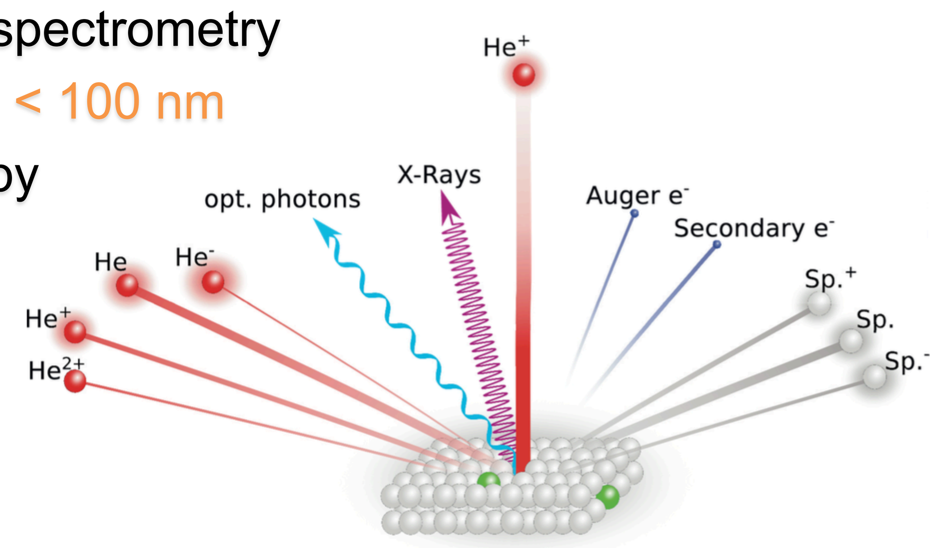
Helium Ion Microscope (HIM)

- 5-35 keV He/Ne ion beam with sub-nm spot size
- Contrast generation by number of secondary electrons
- Modifications on the nm-scale
- So far: **Limited analytical information!**

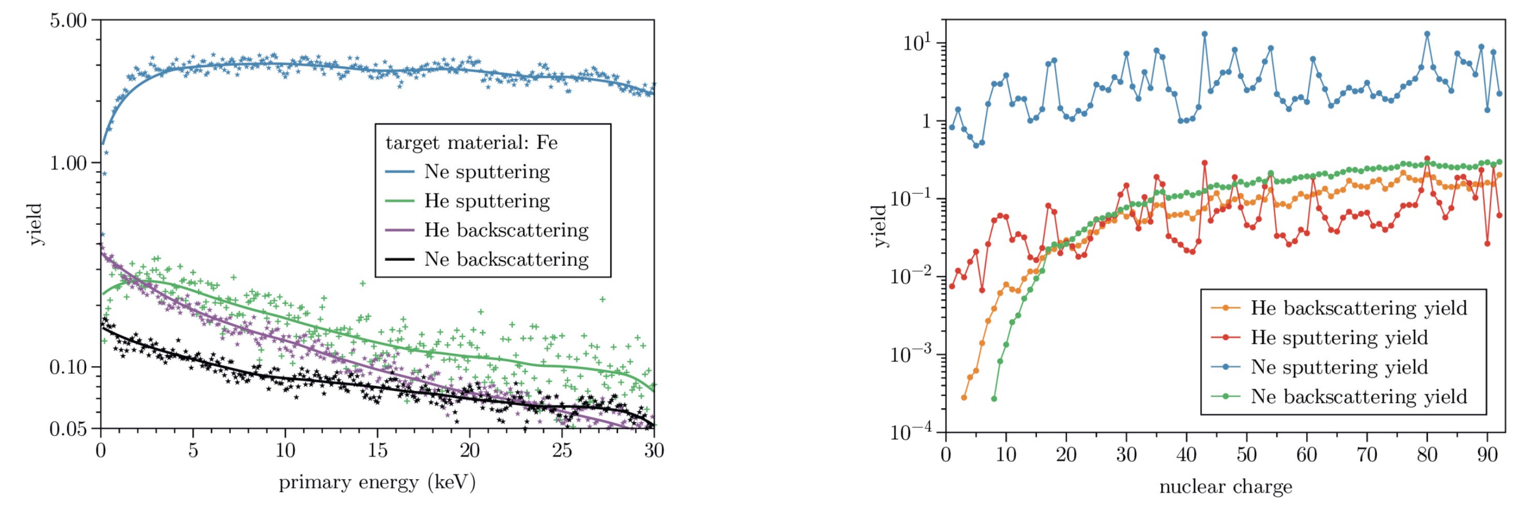
Motivation and Challenges

- Motivation
  - Elemental analysis by backscattering spectrometry and secondary ion mass spectrometry with lateral resolution < 100 nm
  - Correlative microscopy

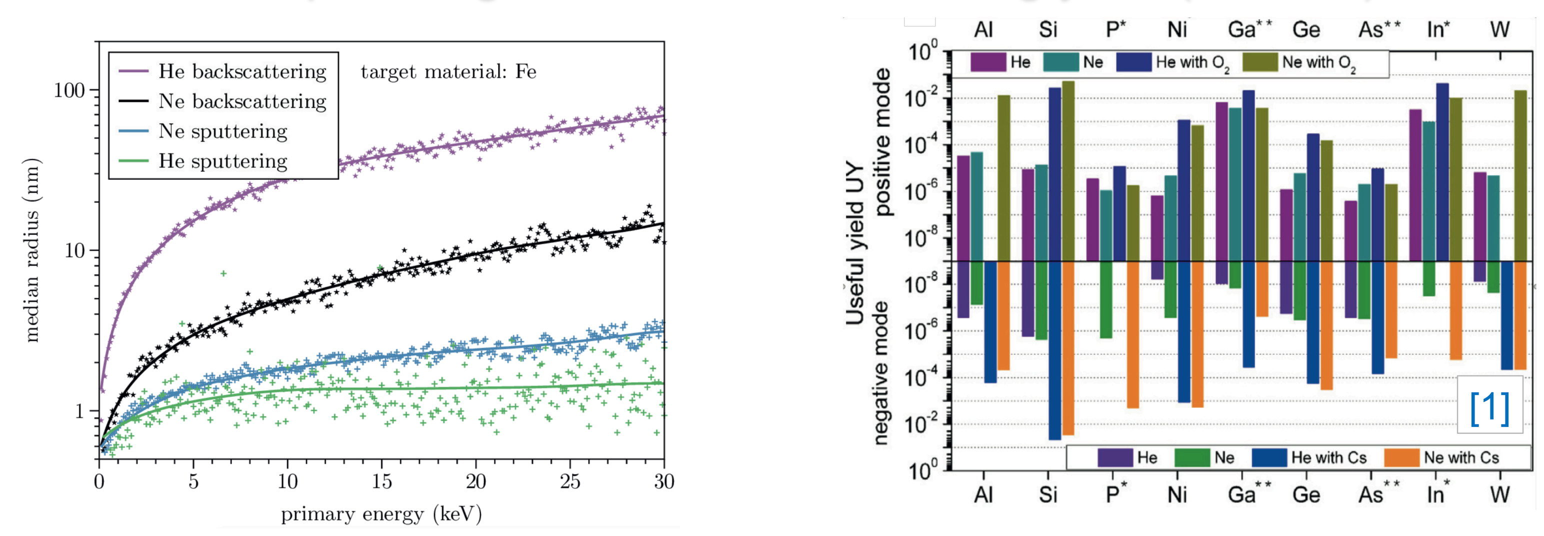


- Challenges
  - Small interaction volume → high local fluences (damage)
  - Small fraction of charged BS particles
  - Limited available space
  - Minimum reduction of imaging capabilities

Theory and Simulation



- Backscattering yields and sputter yields for He and Ne according to TRIM
- For neon sputtering exceeds backscattering yield (for all Z)

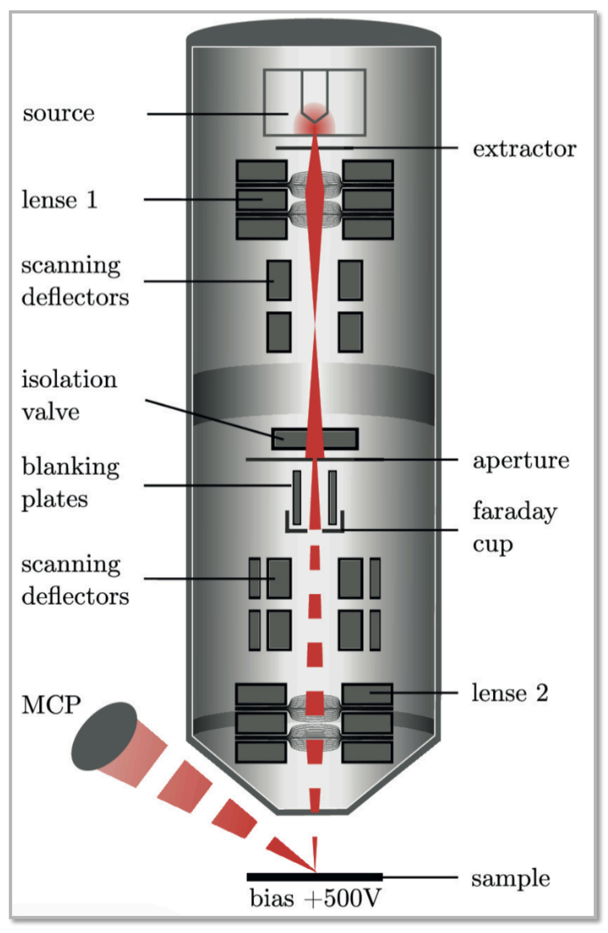


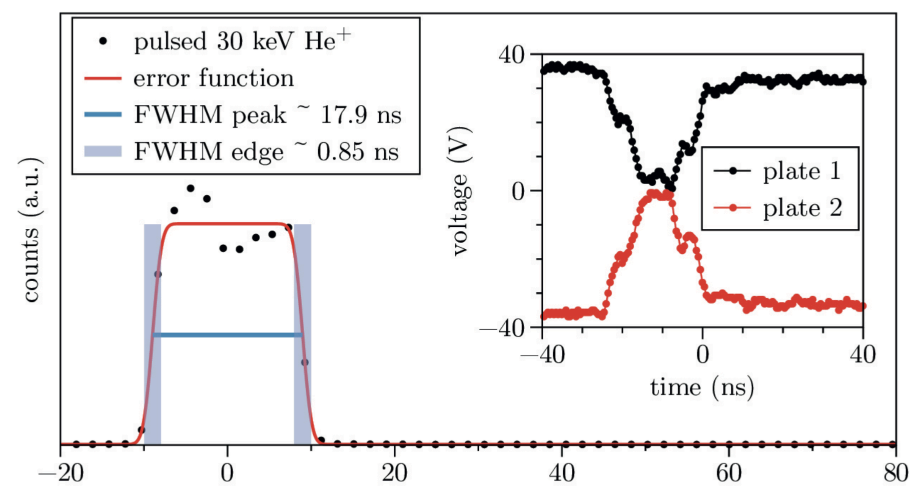
- Size of collision cascade defines minimal spatial resolution
- Smaller cascade at low energies but worse microscope performance
- Fraction of sputtered ions can be enhanced by oxygen flooding

[1] Pillatsch, L. *et al.*, Applied Surface Science, **282** (2013)
[2] N. Klingner, R. Heller, *et al.* Ultramicroscopy **162** (2016) 91-97

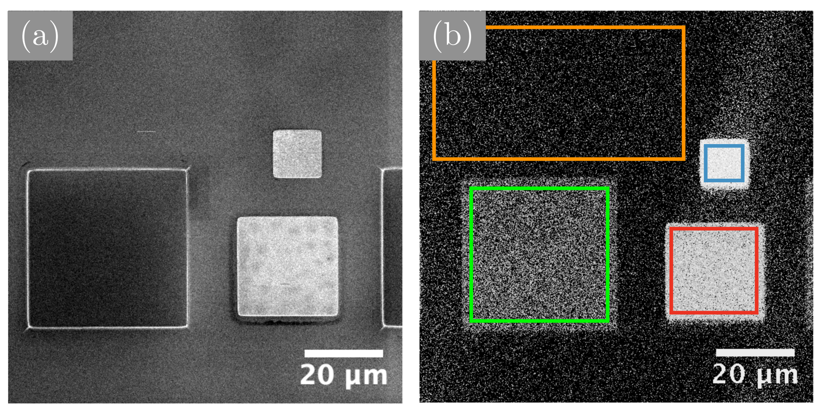
ToF Backscattering Spectrometry

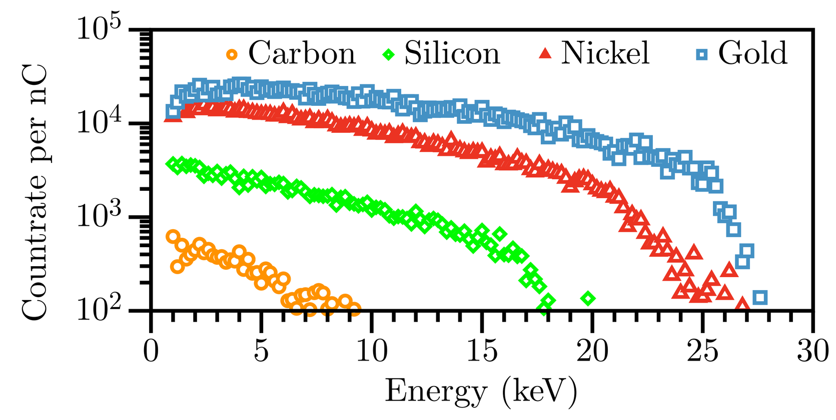
- Start signal: chopping primary beam
- Pulse width: 17-250 ns (@max 500 kHz)
- Stop signal: multi channel plate @ d=36 cm



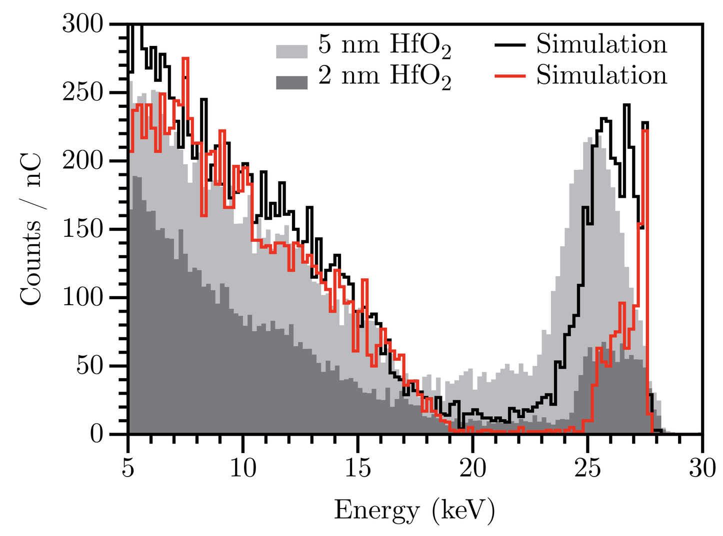


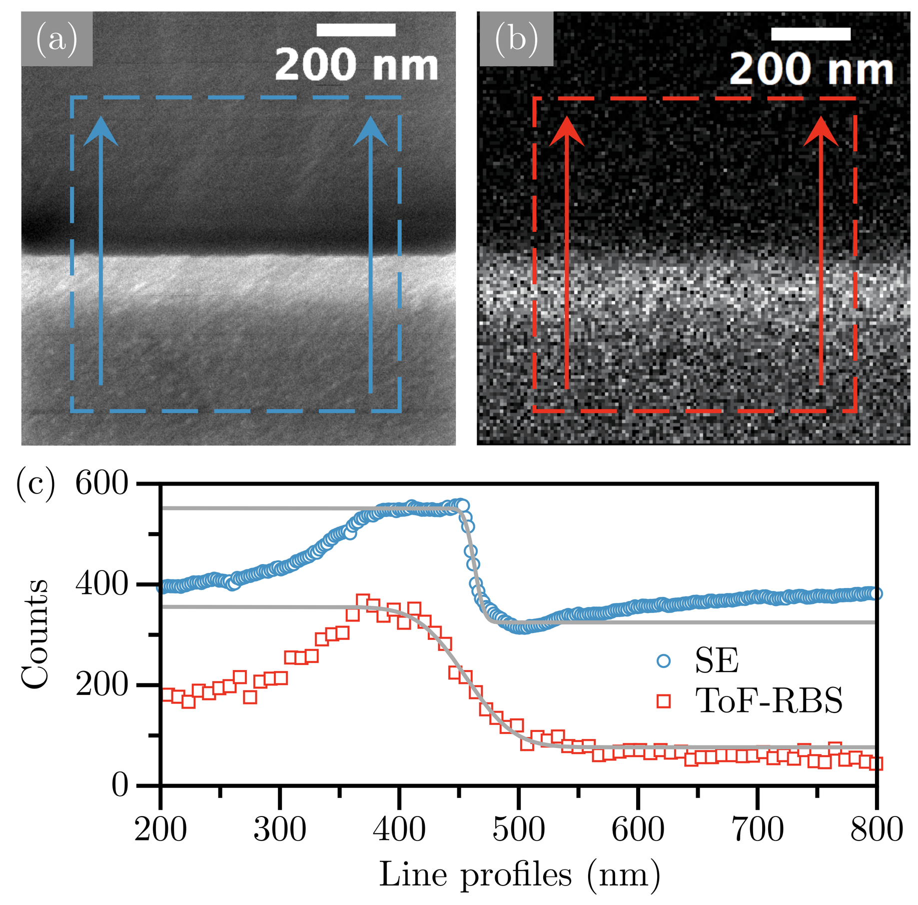
- Sensitive to charged & neutral particles
- Standard-free quantification
- Ions energy loss → depth information on elemental concentrations





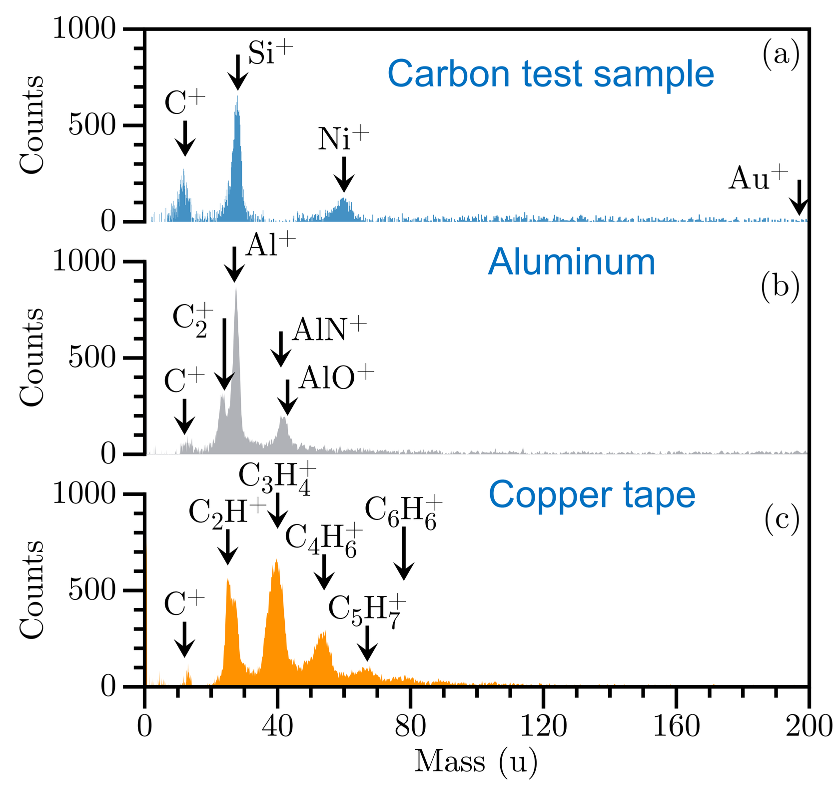
- ToF-BS images and spectra of a carbon sample covered with squared patches of Si, Ni and Au
- ToF-BS reveals **enhanced elemental contrast compared to SE mode**
- **Lateral resolution <55 nm** [2]
- Data acquisition in list mode allows post-processing (post-analysis) of ToF-BS images

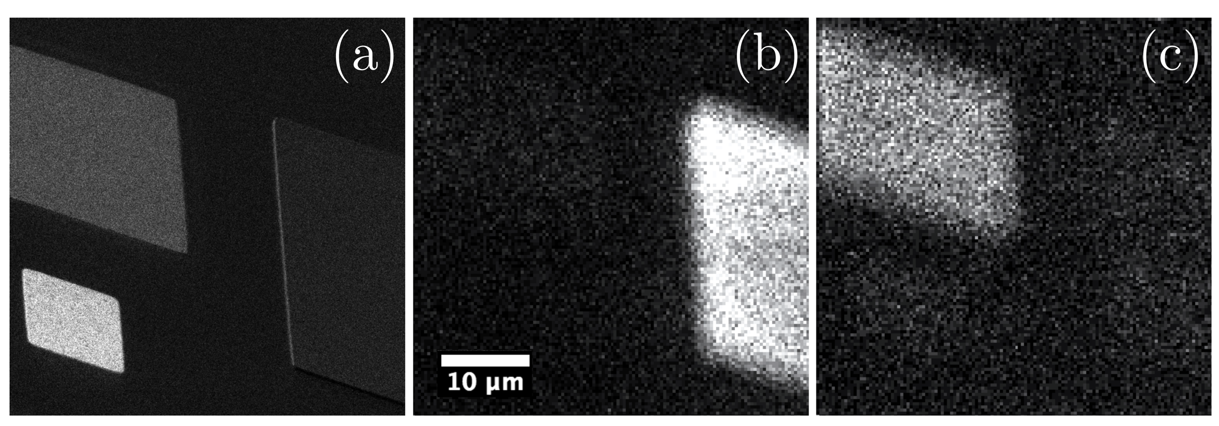




ToF SIMS

- Biasing the sample (500 V) enables ToF-SIMS
- 250 ns pulse width transfers to a mass resolution of 1/64
- Mass filtered imaging allows direct element mapping on the nm scale [2]
- Intended improvements:
  - Add an extraction system
  - Use oxygen flooding
  - Increase mass resolution





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IBC.

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