Optical Imaging meets MS Imaging: Integrating a Dual-Beam Scanning Electron Microscope and a SIMS into one Device for Simultaneous Imaging

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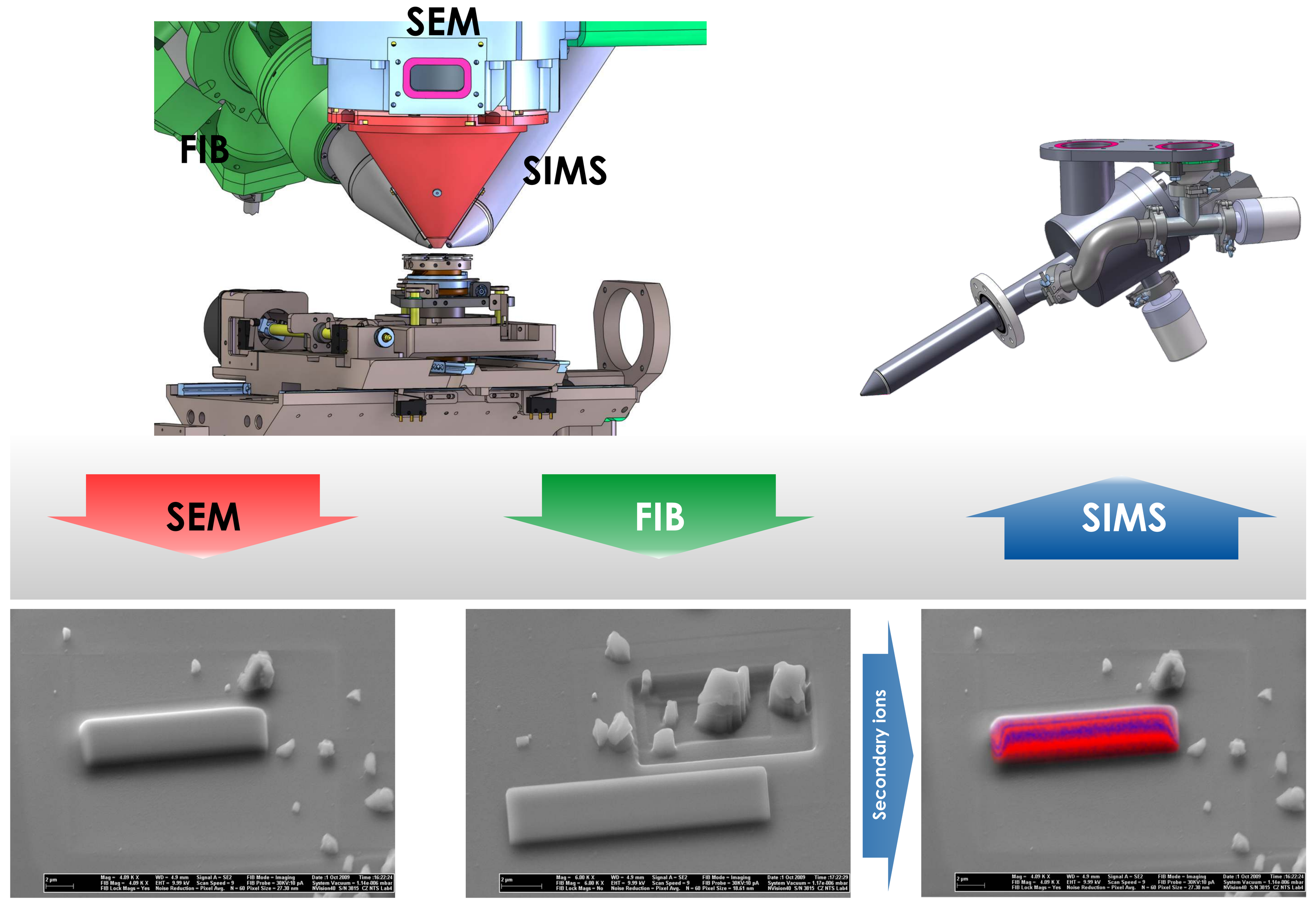
Introduction

Overview:

Optical imaging using a Scanning Electron Microscope (SEM) is a well-known tool in the nanotechnology, semiconductor industry and material science which allows for nanometer resolution.

For advanced imaging capabilities, sample preparation and surface processing a Focused Ion Beam (FIB) is used. The FIB produces a small amount of secondary ions which can be used for high laterally and spartially resolved mass spectrometry imaging.



Optical Imaging
- SEM
- FIB

Material processing
- sputter
- deposit

MS Imaging
- SIMS

Transfer efficiency of the SIMS Device

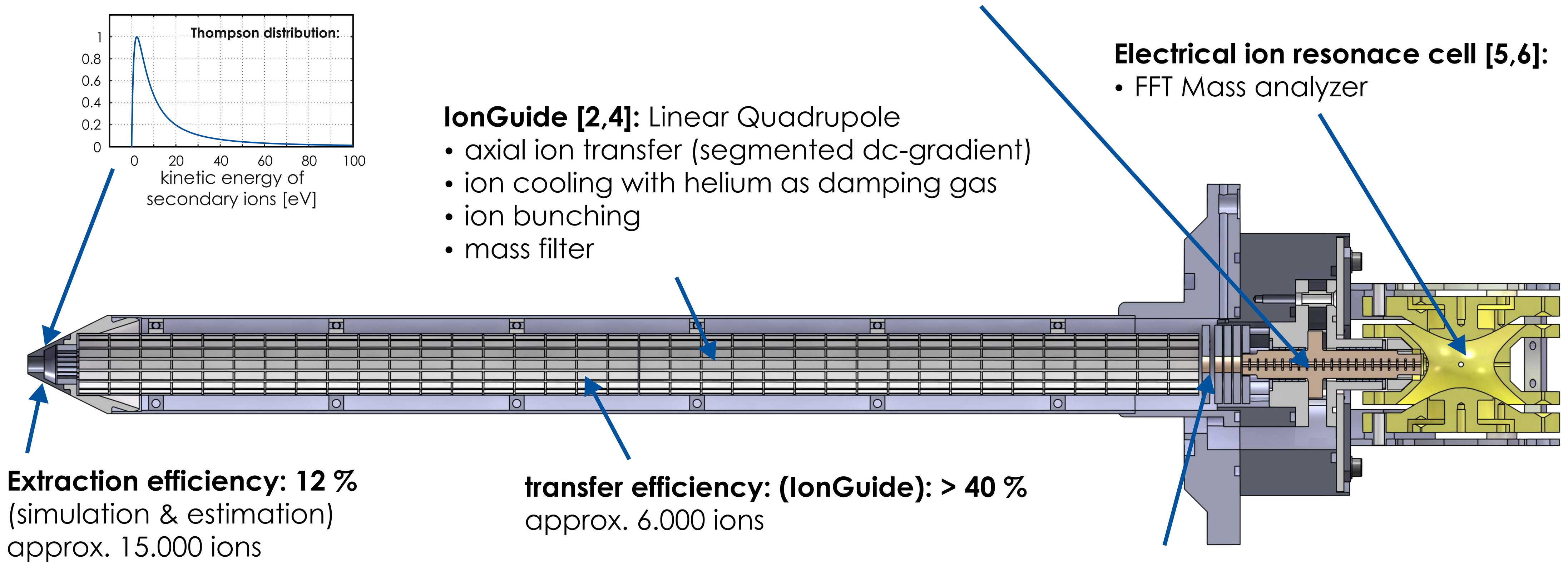
Primary ion beam current:	100 pA
Secondary ion beam current:	approx. 200 fA ⇨ 125.000 ions in 100 ms

Electrostatic extraction lens [1]:
- broad kinetic energy distribution (Thompson)

WaveGuide[3,4]: Miniature Quadrupole
- accumulating secondary ions
- sequential ion transfer
- pressure stage

Electrical ion resonace cell [5,6]:
- FFT Mass analyzer

IonGuide [2,4]: Linear Quadrupole
- axial ion transfer (segmented dc-gradient)
- ion cooling with helium as damping gas
- ion bunching
- mass filter



Extraction efficiency: 12 %
(simulation & estimation)
approx. 15.000 ions

transfer efficiency: (IonGuide): > 40 %
approx. 6.000 ions

transfer efficiency: (WaveGuide): > 70 %
approx. 4.200 ions
kinetic energy of ion: < 0,5 eV FWHM

Overall transfer efficiency inside the SIMS: 28 %

Conclusions

- The combination of SIMS, FIB and SEM opens doors to new applications and methods which are impossible with seperate devices
- A full functional SIMS for Scanning Electron Microscopes has been built and evaluated
- The SIMS has been tested with different anorganic and structured samples
- High transfer and cooling efficiencies of sputtered secondary ions have been shown
- High sensitivity of the mass analysis has been shown at FIB currents down to 10 pA
- To avoid surface defects low FIB currents and low sputter rates must be used
- The FFT mass analyzer allows for multiple measurements of the same ion population with higher sensitivity
- Scanning speeds up to 10 Hz have been demonstrated

Applications & Requirements

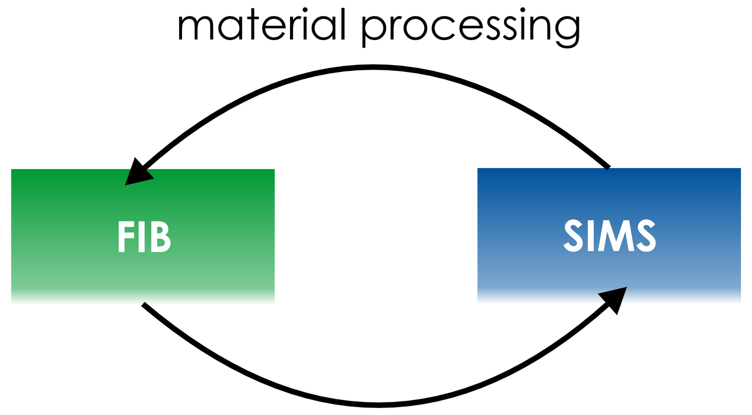
Mass spectrometry controlled material processing:

- Material dependent sputtering (e.g. end-point detection) - only remove those parts of a target which consist of a specific material
- Advanced layer thickness analysis - detect different layers whose material contrasts are too low for optical detection

Requirements:

- Real-time mass spectra generation
- Short measurement time per spectrum

MS controlled material processing



Generate secondary ions during sputter process

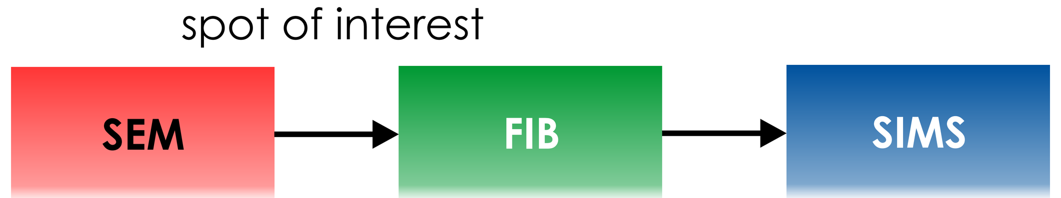
Optical controlled mass spectrometry:

- Optical feedback of sputtered spot (simultaneous imaging)
- Find and identify spots of interest without surface defect (SEM) and create selective MS spectra with minimal surface defect (FIB+SIMS)
- Analyze optically identified spots of interested (fractional mapping)

Requirements for MS imaging:

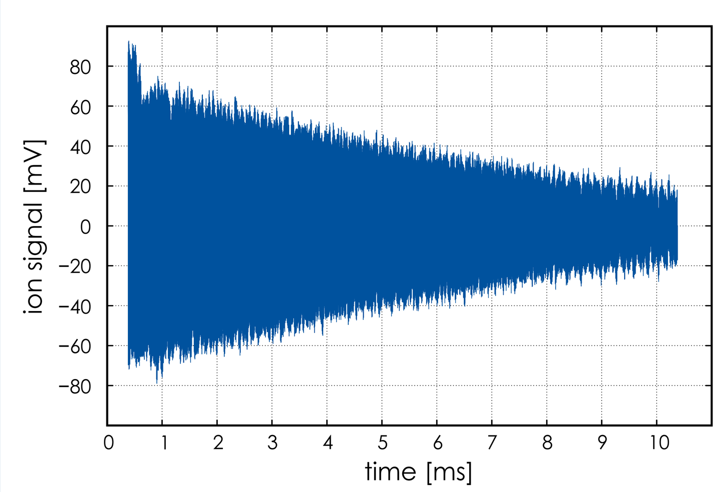
- Fast sampling rate per MS-Pixel: 100 ms
- High lateral and axial resolution
- Low target defect ⇨ high sensitivity

Find and identify spot of interest

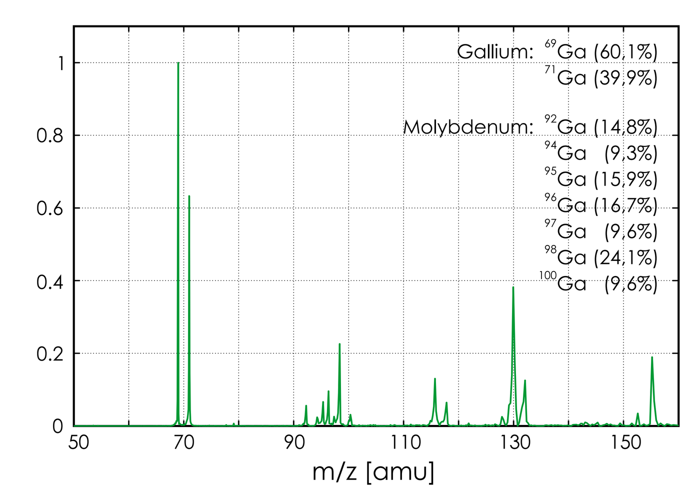


Analyze with minimal target defect

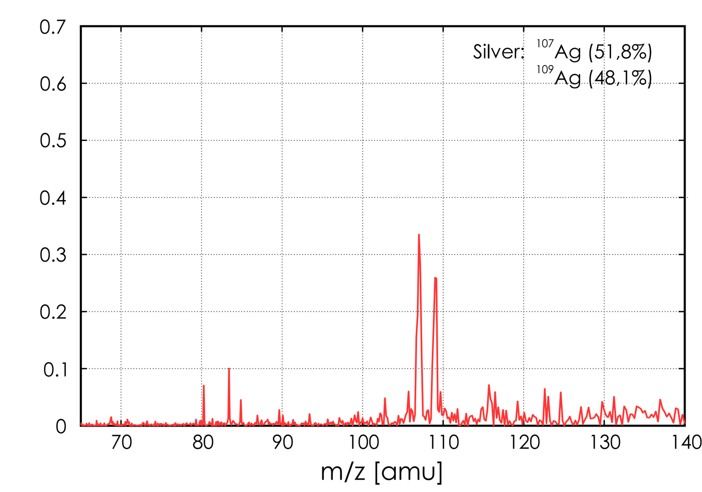
Measurement Results



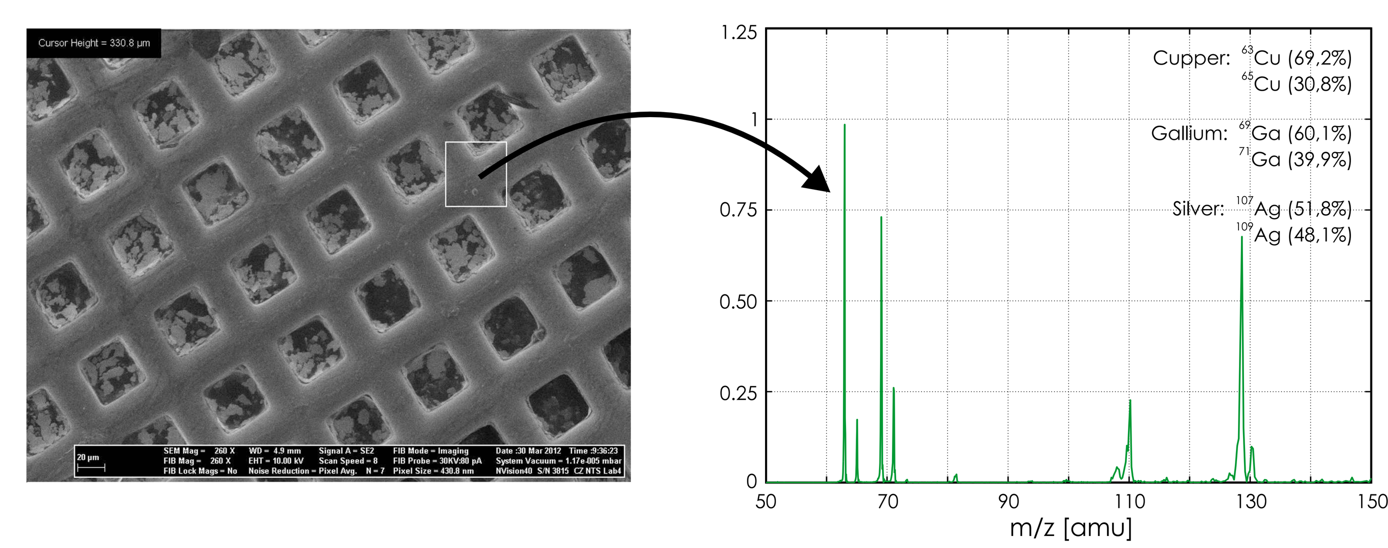
Ion transient:
gallium and molybdenum ion signal



Spectrum of Molybdenum:
300 pA FIB current (Gallium) @ 30 keV,
100 ms accumulation time

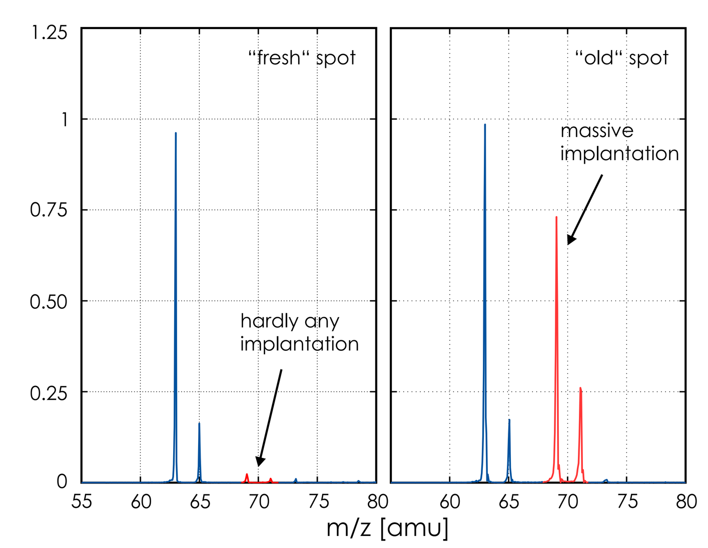


High sensitivity:
10 pA FIB current
300 ms accumulation time



Sample target:
TEM grid (Cu) filled with conducting silver

Resulting spectrum of TEM grid:
700 pA FIB current (Gallium) @ 30 keV,
200 ms accumulation time



Target defect:
Sputtering of a few seconds leads to massive implantation of gallium

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