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IMWS

W3+ FAIR JENA
25.-26.09.2024

State of the Art Optical Thin Film Analyses for Industrial Applications

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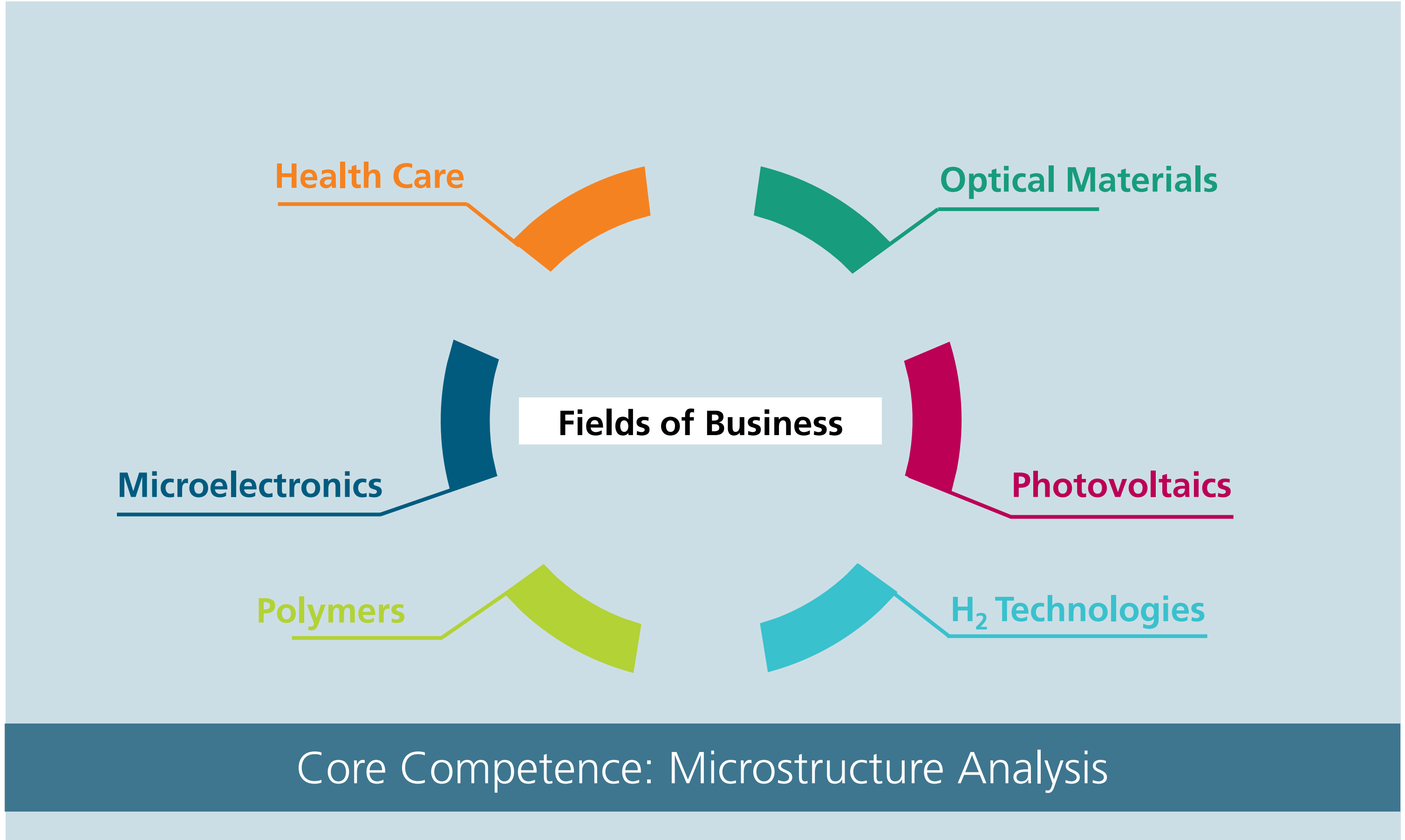
Fraunhofer IMWS

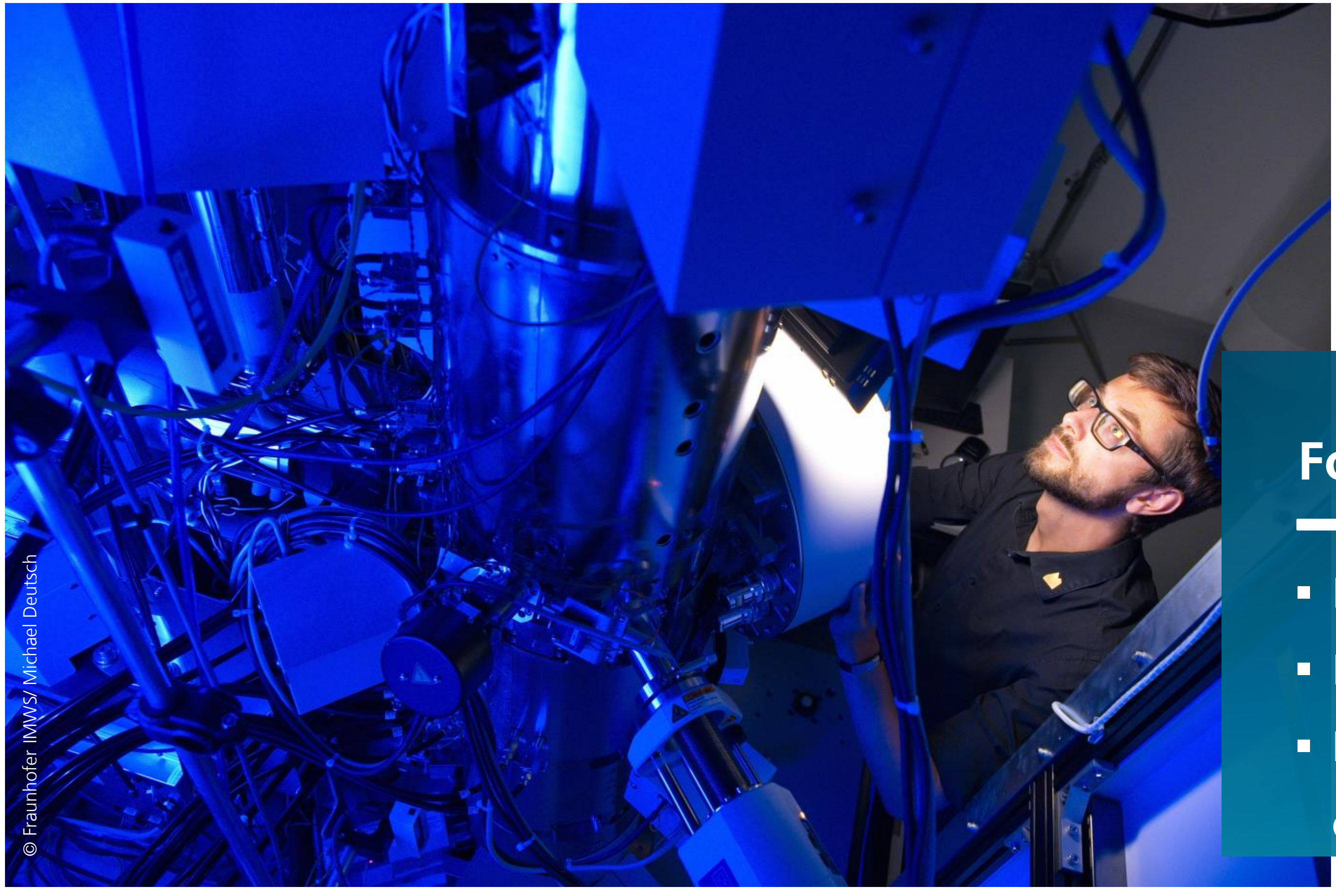
Who we are



The Fh IMWS is a methodologically oriented portfolio institute.

Optical Materials

Tailored microstructure diagnostics



Focus and know-how

- Microstructure-based development of glasses and ceramics
- Microstructure-based laser process development
- **Microstructure analysis of thin films, glasses and ceramics**

Optical Coatings

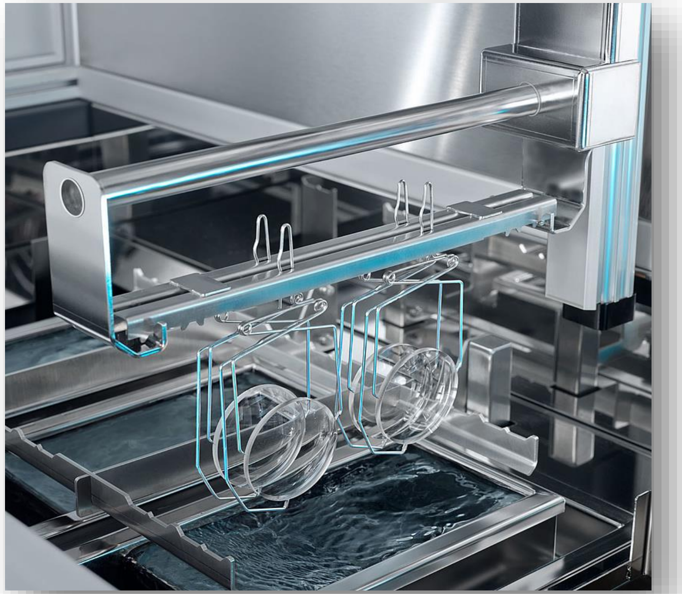
Cutting Edge Analytical Techniques

- FIB-SEM (+EDX)
  - Imaging of surfaces and cross sections
  - Composition (0.1at%)
- HR-(S)TEM (+EDX)
  - Cross section
  - Microstructure & composition
- ToF-SIMS
  - Surface analysis
  - Depth profiling
  - Contaminations (ppb)

Ophthalmic lens coatings

A complex hybrid system

- 2001: 23% short sighted world wide.
- Increasing in younger age groups.
- In 2050, 50% of the world population will be myopic.

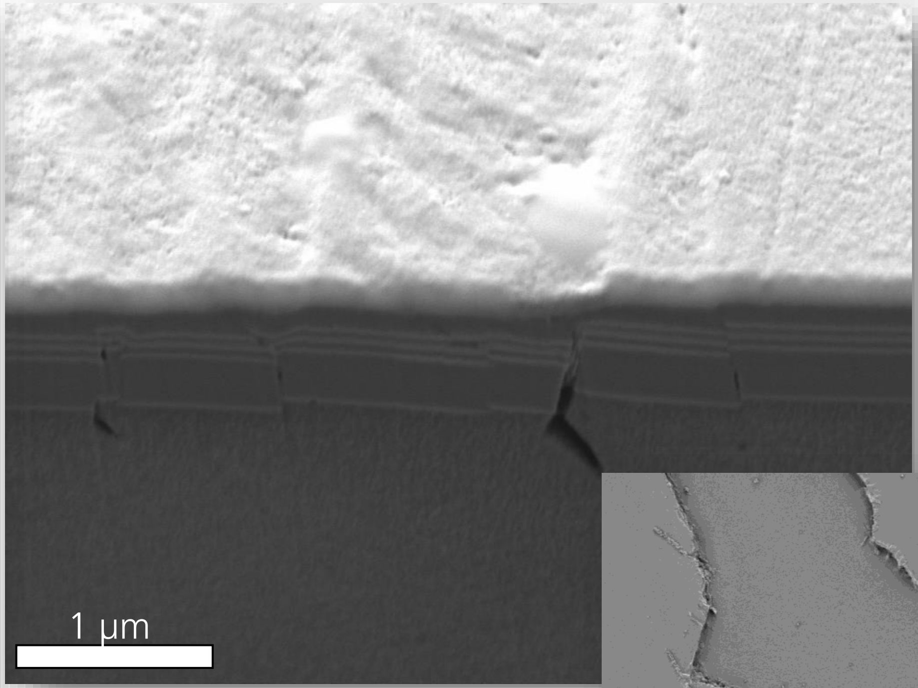


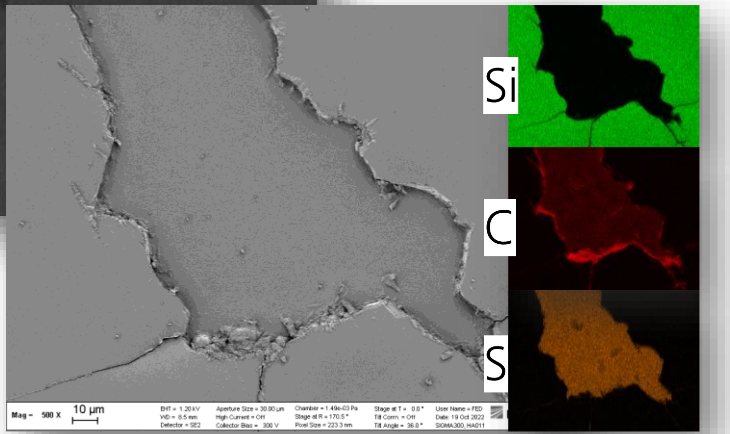
Typical coating stack

Layer	Thickness
Top coat	1-2 monolayers
Broadband anti-reflective	Few 100 nm
Anti-static (included in AR)	< 10 nm
Hard coating	~ 3 µm
Hard coating primer	~ 800 nm
Polymer substrate	~ mm

Ophthalmic lens coatings

SEM-FIB-EDX

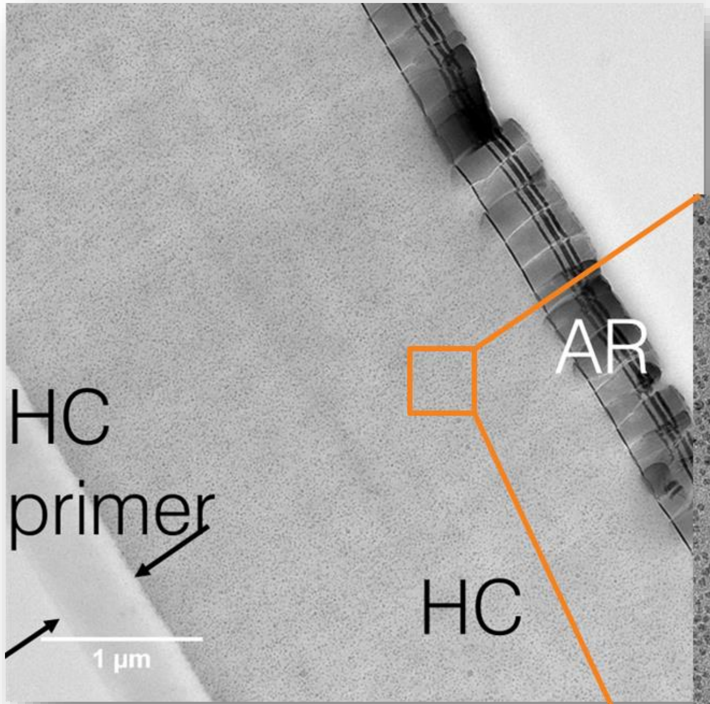


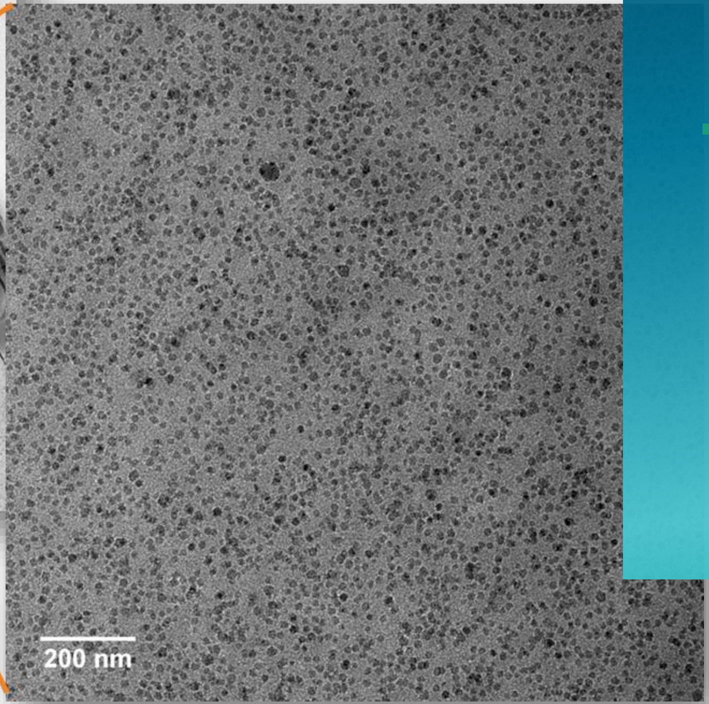


- SEM: delamination of the coating system.
- FIB: cross sectioning
- EDX: Distribution of
  - Ti (AR),
  - S (substrate)
  - Si (AR and HC)
- Complete delamination of AR and hard coating

Ophthalmic lens coatings

HR-TEM

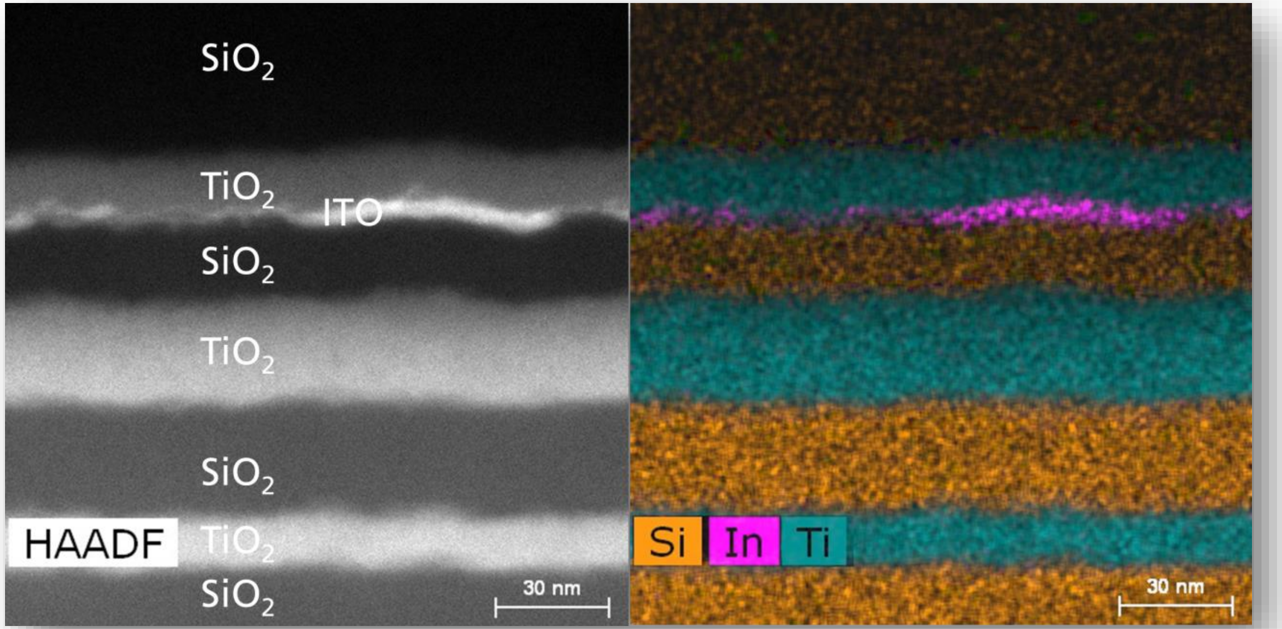




- TEM: high-res overview of the complete coating system (AR, hard coat, primer).
- Distribution, density gradients or agglomeration of nano particles can be detected.

Ophthalmic lens coatings

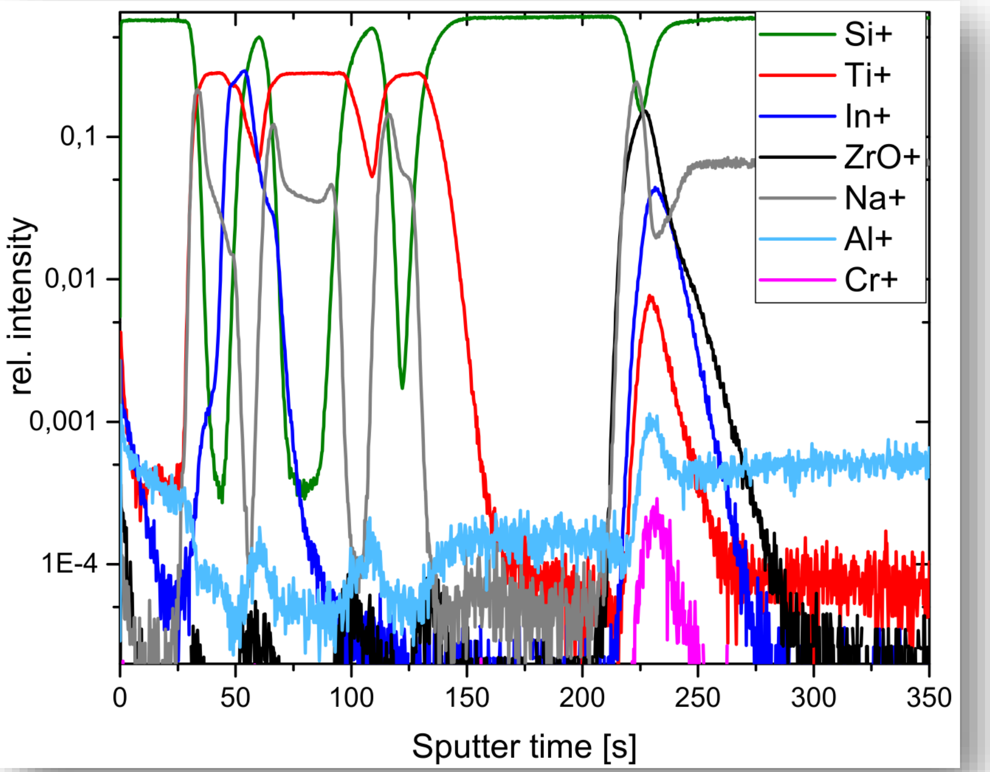
STEM-EDX



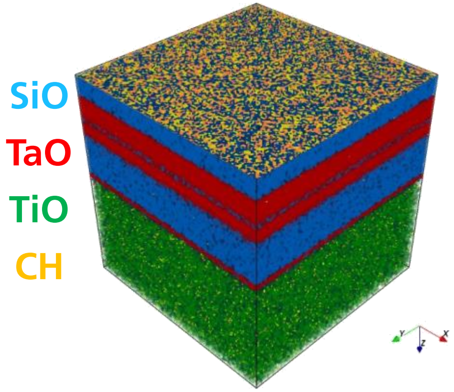
- STEM-EDX: high-res imaging and elemental distribution of the AR stack.
- Interface roughness, layer inhomogeneities and diffusion can be visualized.

Ophthalmic lens coatings

ToF-SIMS

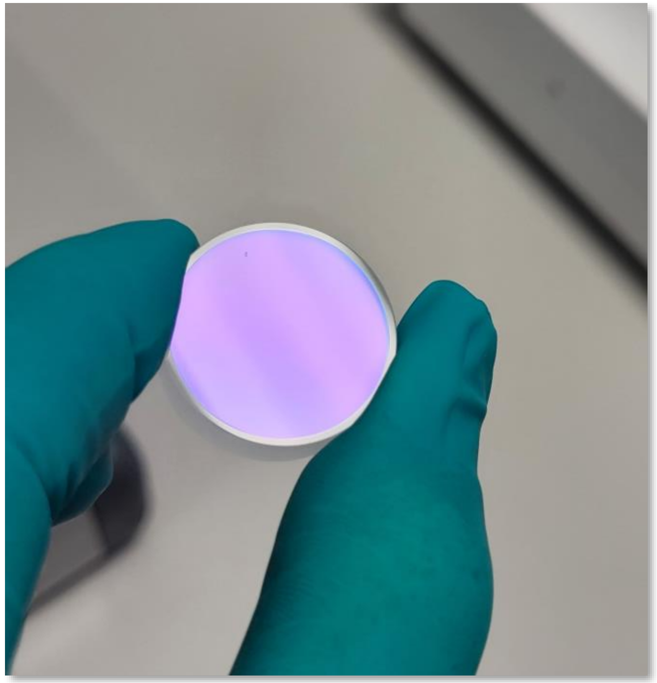


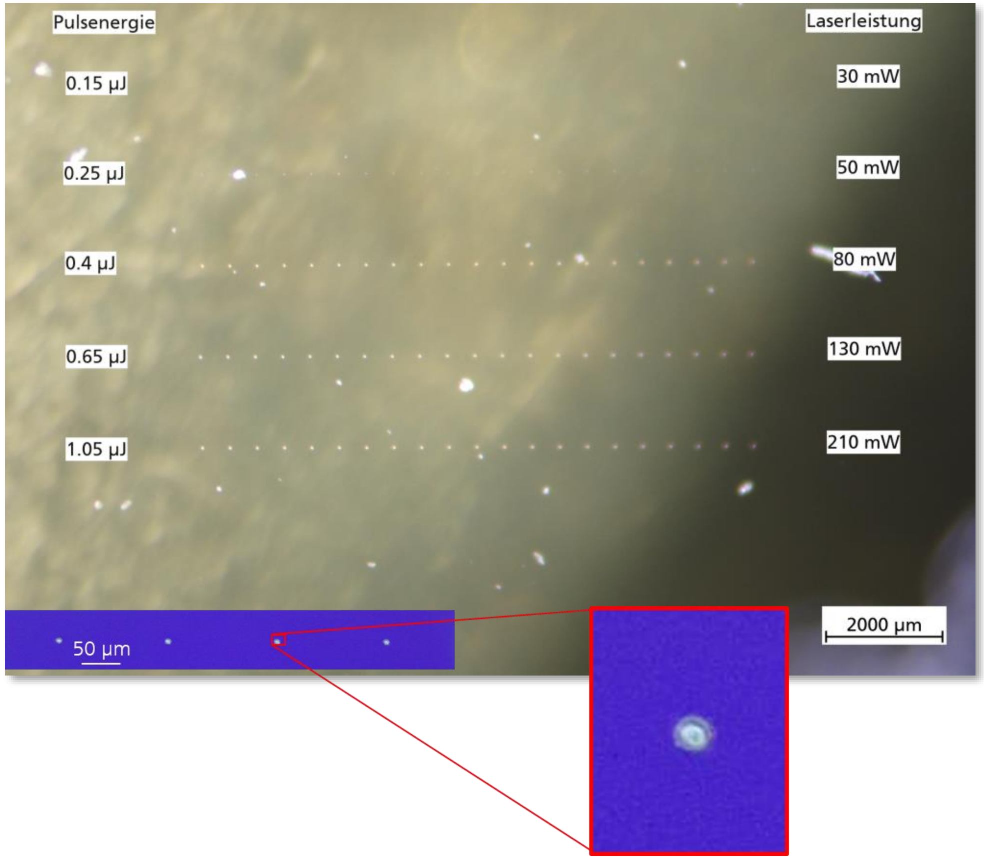
- ToF-SIMS depth profiles:
  - Main AR components
  - Contaminants (sample surface, AR/HC interface)
  - Organic depth profiling
  - Detection of volatile components



Laser mirror coatings

State of the Art Methods applied to (damaged) Laser Mirrors

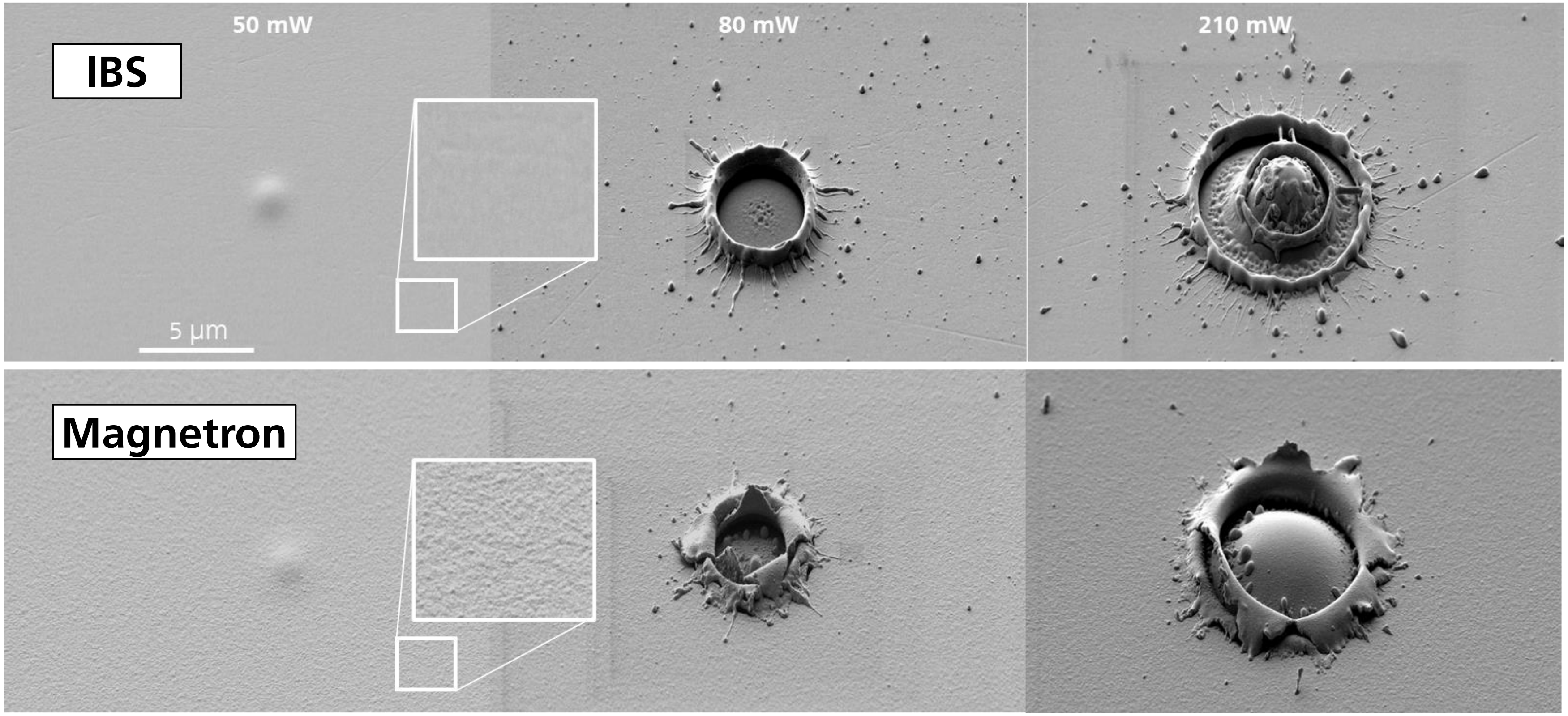




- 2 purchased laser mirrors (355 nm):
- Reverse engineering
- Laser damage evaluation:
  - Focused laser @514 nm, 211 fs, 30-210 mW

Laser mirror coatings

SEM



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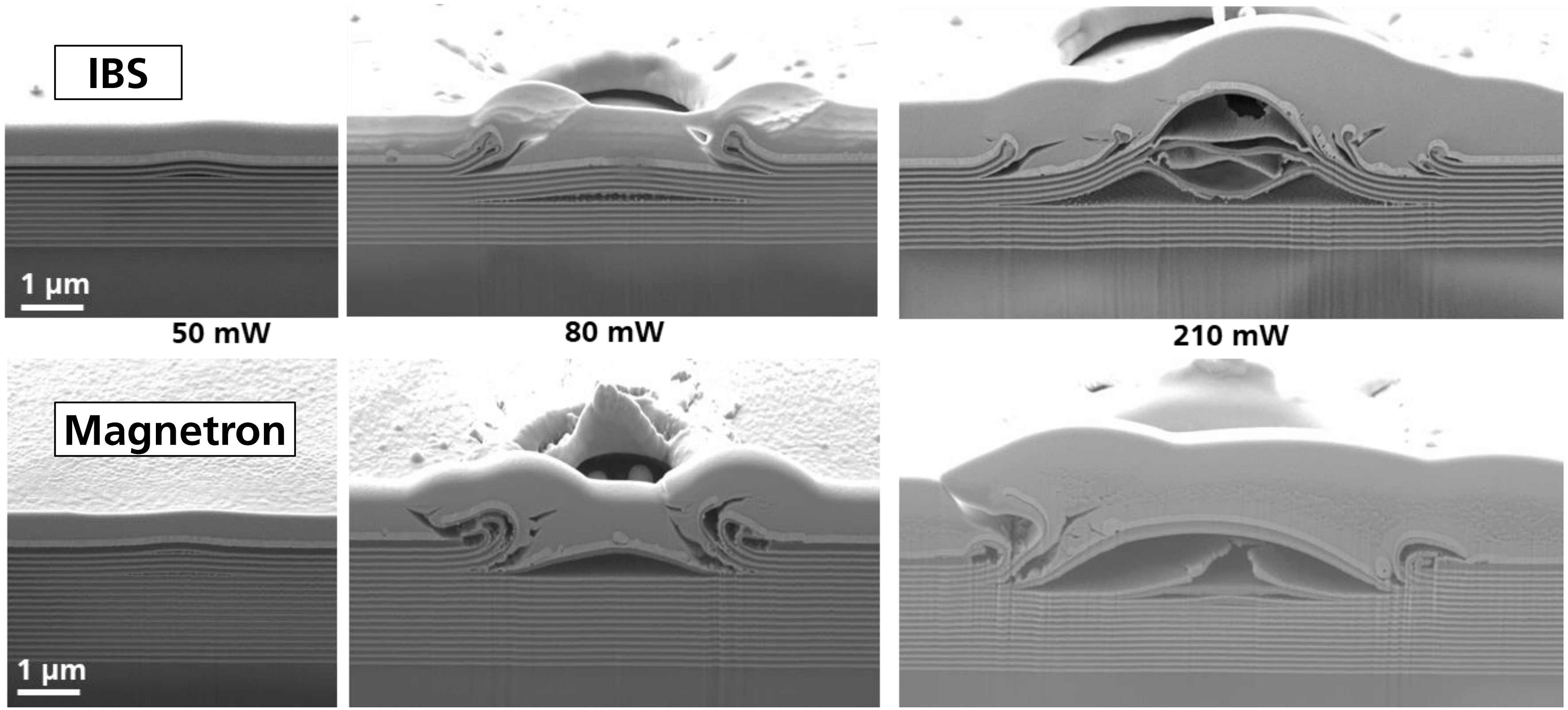
Laser mirror coatings

SEM + FIB



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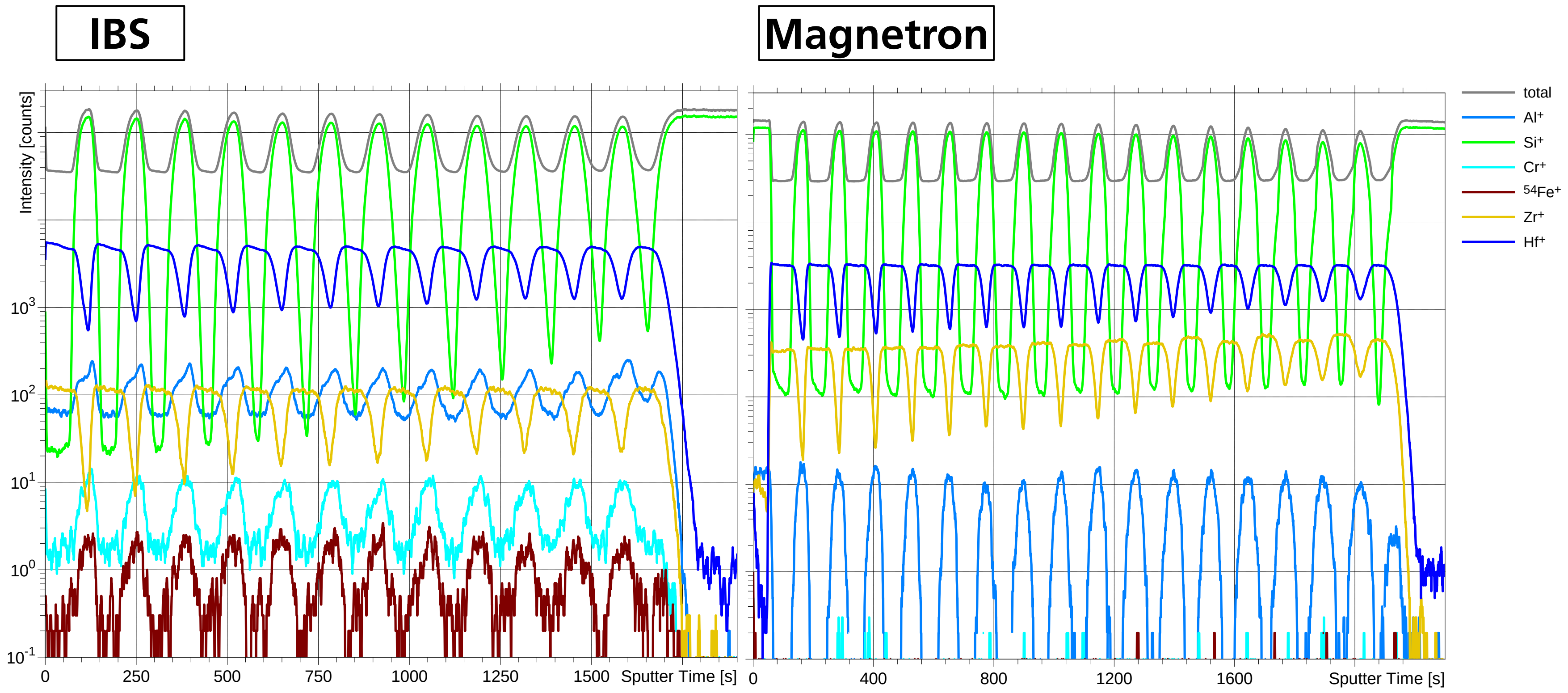
Laser mirror coatings

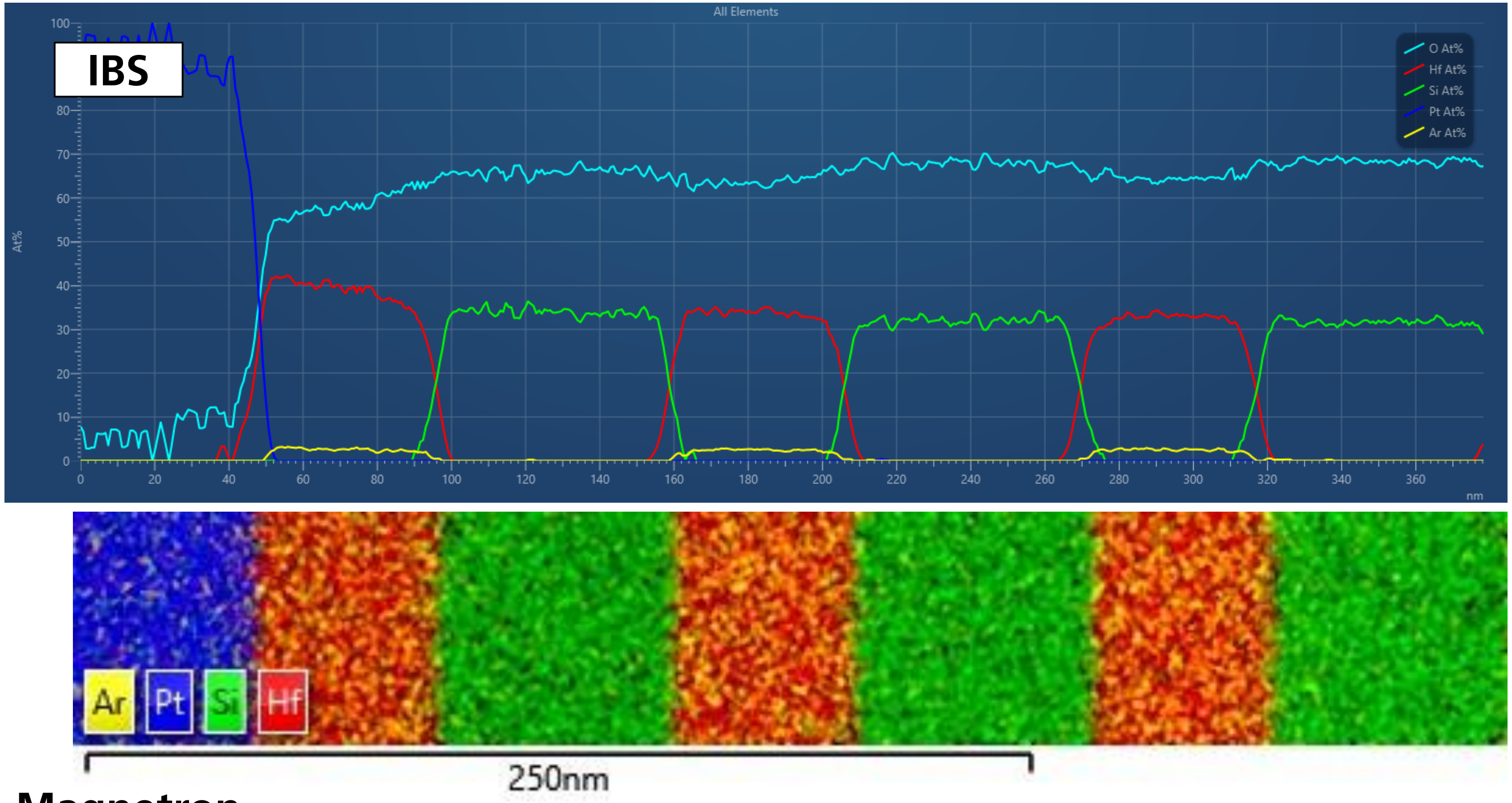
ToF-SIMS



- 2 purchased laser mirrors (355 nm):
- Reverse engineering
  - Contaminations

Laser mirror coatings

STEM-EDX

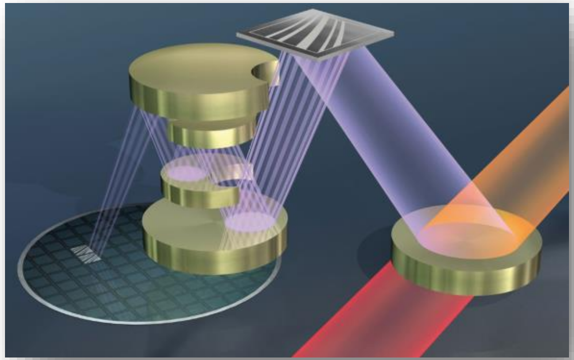


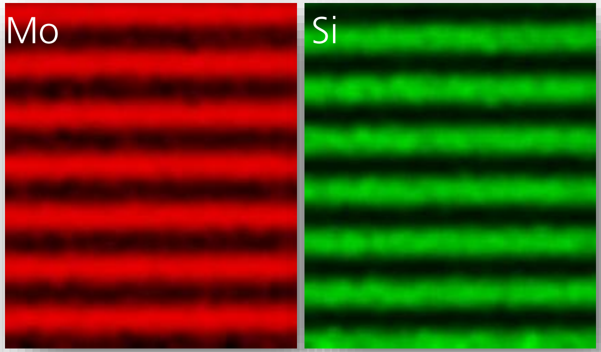
Magnetron

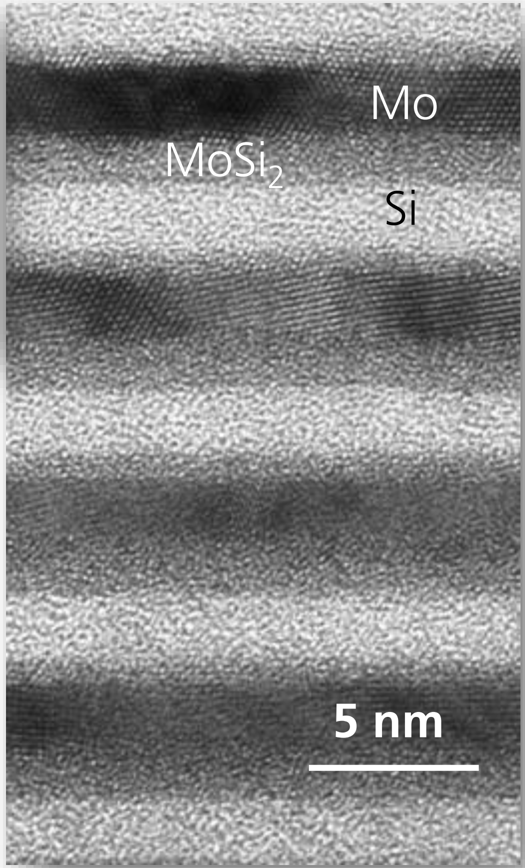
- 2 purchased laser mirrors (355 nm):
- Reverse engineering
  - Contaminations
  - Process information (Ar in HfO_2)

Microstructure Analysis

State of the Art Methods Applied to EUV Multilayers







- EUV: huge market, demanding systems.
- TEM:
  - Layer thickness, homogeneity, crystallinity.
  - Interface layers discernable.

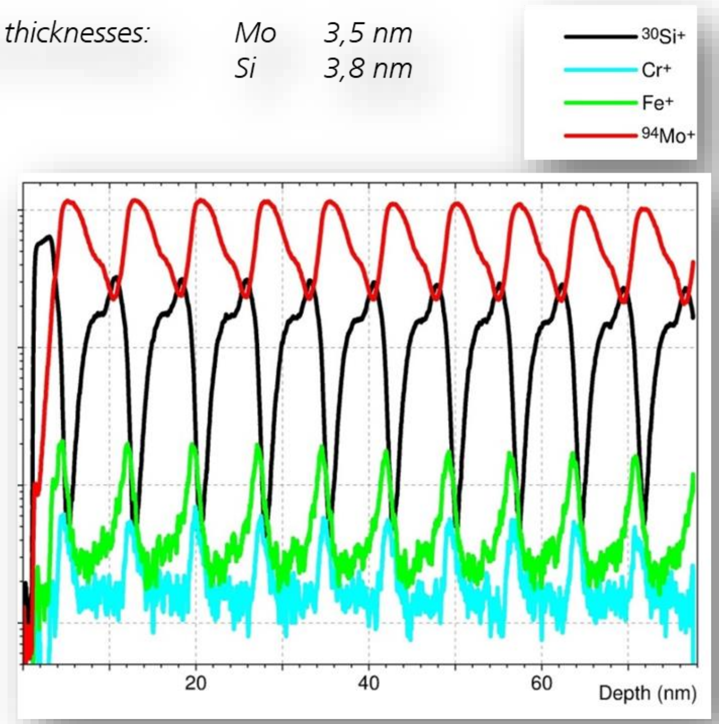
https://www.fraunhofer.de/de/forschung/aktuelles-aus-der-forschung/euv-lithographie.html

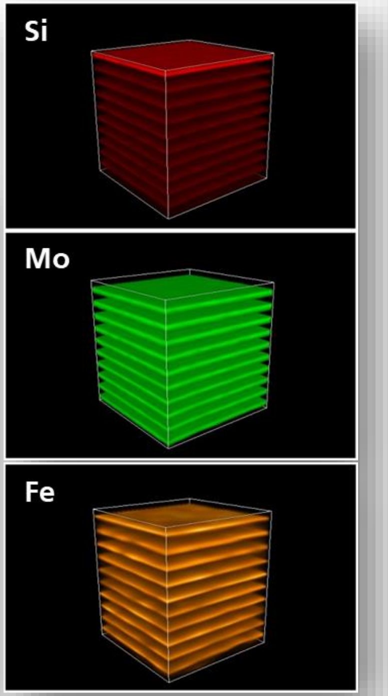
Samples: Fraunhofer IOF

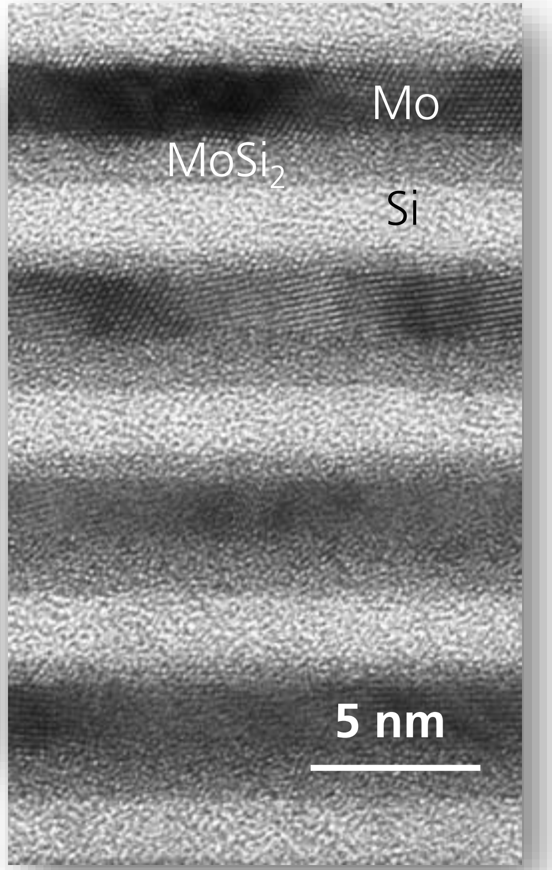
Microstructure Analysis

State of the Art Methods Applied to EUV Multilayers

layer thicknesses: *Mo* *3,5 nm*
Si *3,8 nm*



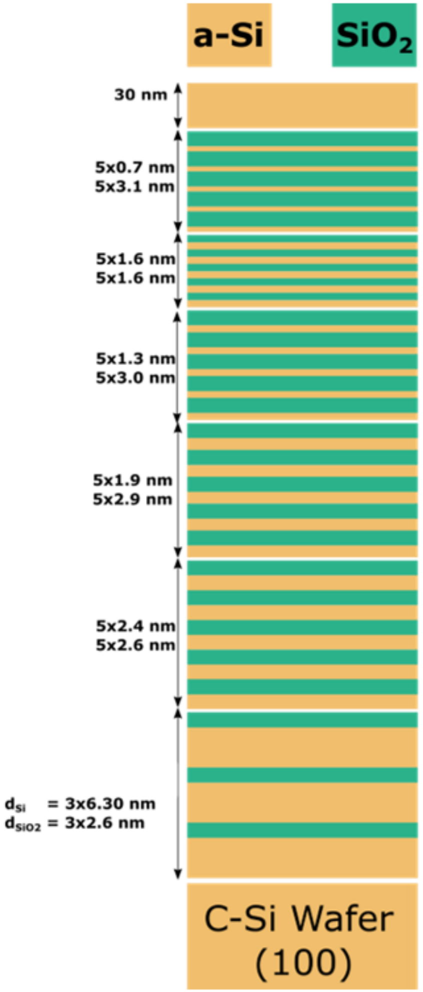


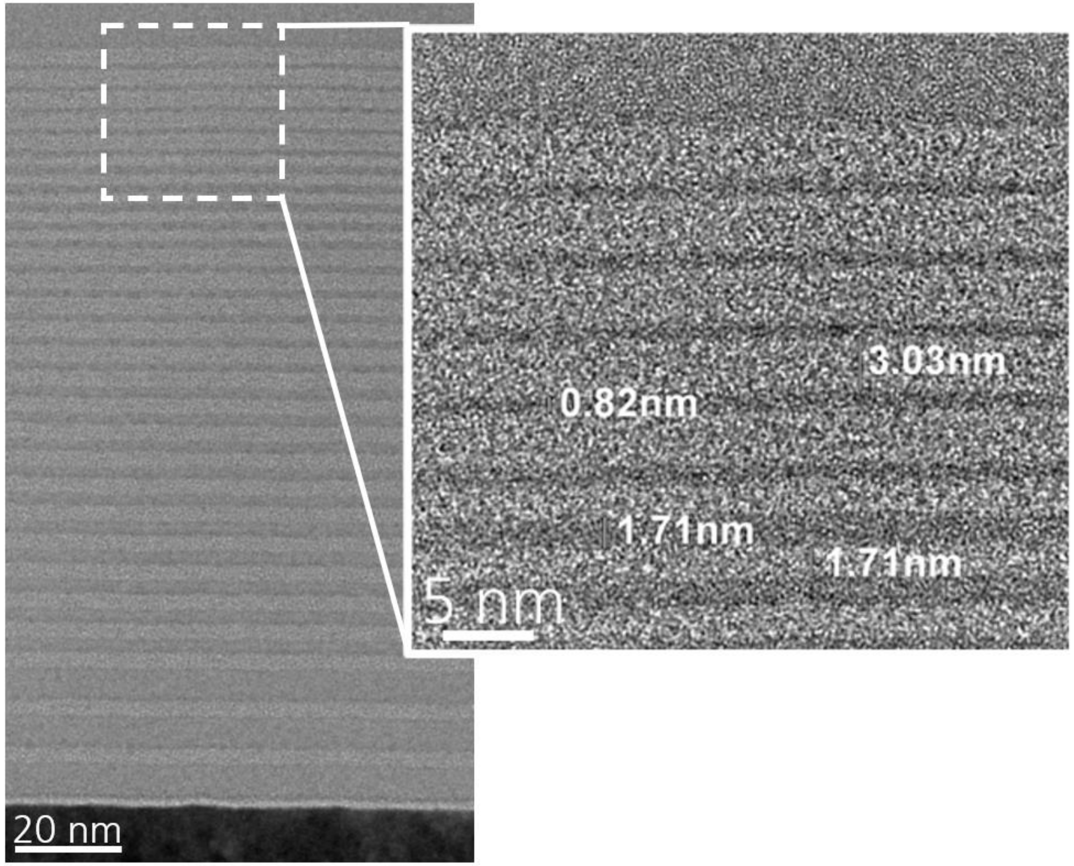


- EUV: huge market, demanding systems.
- TEM:
  - Layer thickness, homogeneity, crystallinity.
  - Interface layers discernable.
- ToF-SIMS:
  - contaminations

Ultra Thin Films: Nanolaminates

HR-TEM





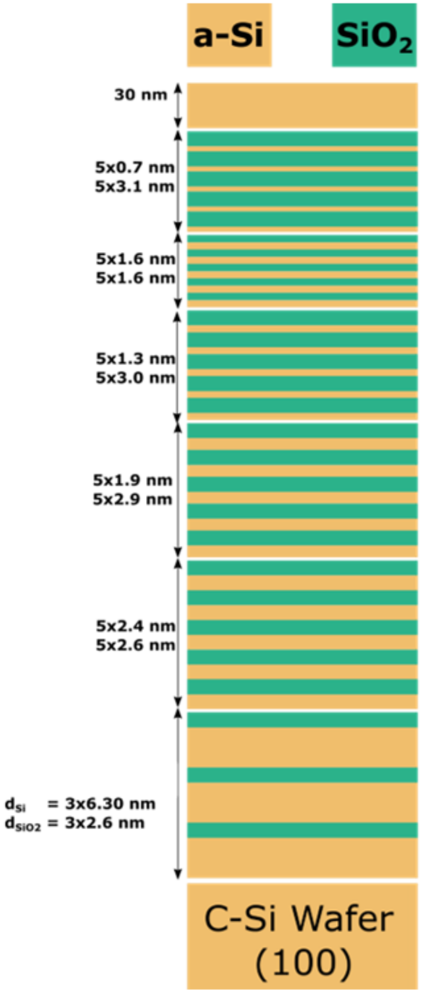
- Nanolaminates: multi-quantum well structures with tuneable band gap/refractive index.
- HR-TEM of whole nano-laminate stack: precise thickness control.

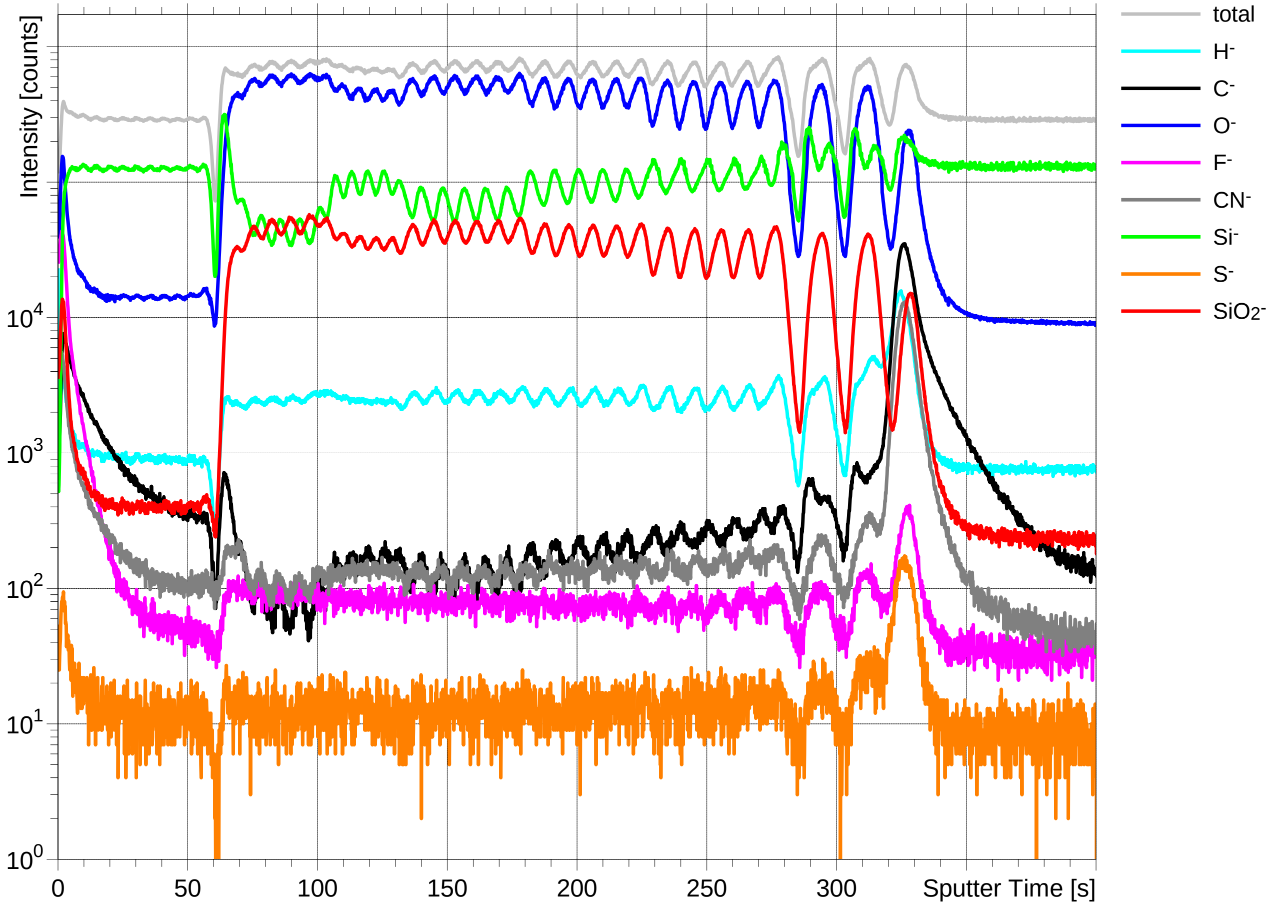
K. Kreuzer et *al.*, Applied Optics 63,5 (2024), https://doi.org/10.1364/AO.515083

Samples: Fraunhofer IST

Ultra Thin Films: Nanolaminates

ToF-SIMS





- Nanolaminates: multi-quantum well structures with tuneable band gap/refractive index.
- HR-TEM of whole nano-laminate stack: precise thickness control.
- ToF-SIMS: contaminations.

Samples: Fraunhofer IST

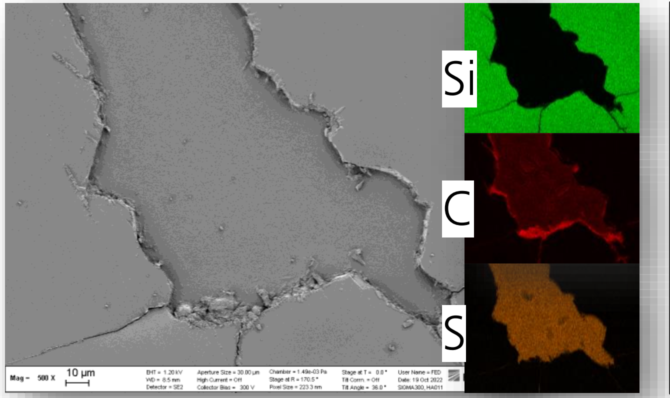
Microstructural Thin Film Analysis

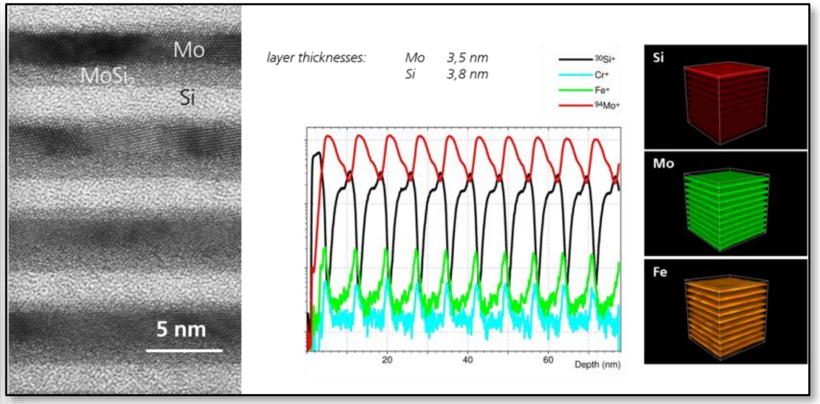
What is it Good for?

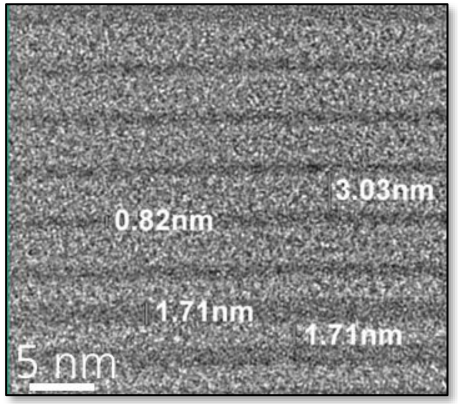
Having a look inside

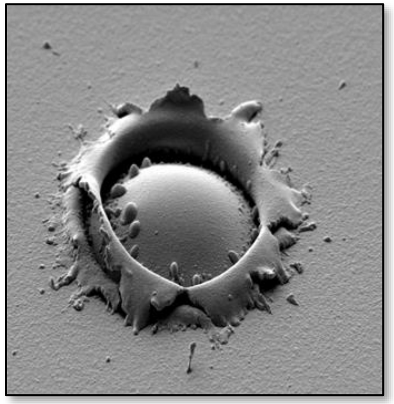
- → Direct results vs. indirect hints or conclusions based on assumptions
- → Target (e.g. failure) regions can be directly assessed
- → Combination of microstructural and chemical information

→ **Microstructure-based process understanding reduces development times**









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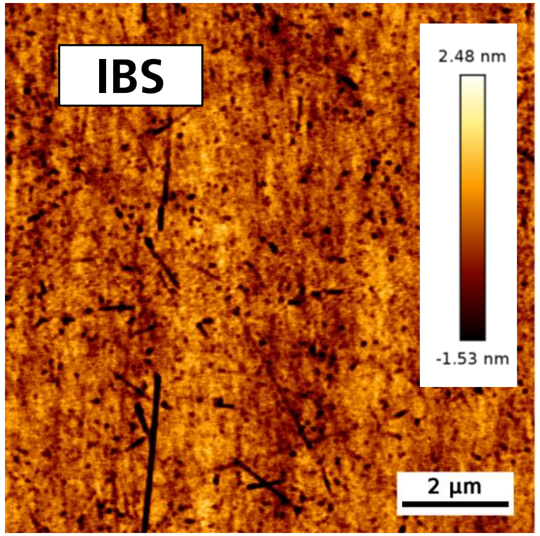

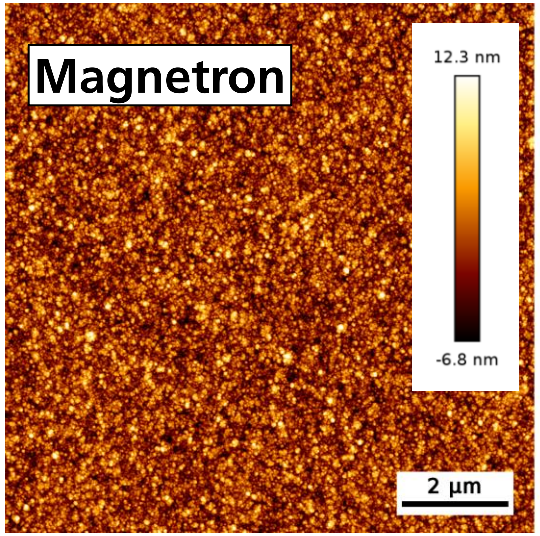

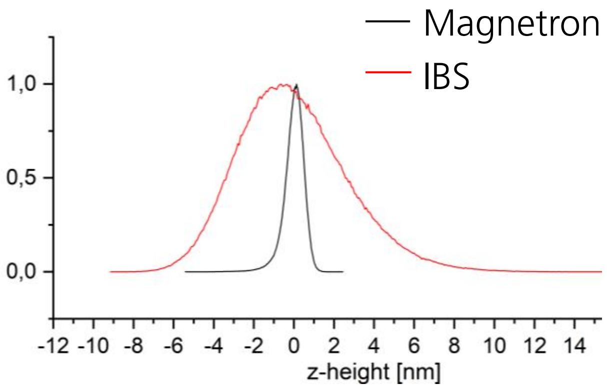

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