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Analytical Methods

Secondary Ion Mass Spectrometry (SIMS)



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Technical Parameters

Magnetic Sector SIMS System:
CAMECA IMS WF

Primary Beam: O and Cs Ion Sources
Signal Detected: Secondary Ions

Elements Detected: H – U

Lateral Resolution: 10 μm

Depth Resolution: 1 – 3 nm

Detection Limits: 10^{13} - 10^{16} at/cm³

B / HE: $5 \cdot 10^{13}$ at/cm³

B / LE: $2 \cdot 10^{15}$ at/cm³

As / HE (HMR): $5 \cdot 10^{13}$ at/cm³

As / LE (HMR): $2 \cdot 10^{16}$ at/cm³

P / HE (HMR): $2 \cdot 10^{14}$ at/cm³

P / ME (HMR): $1 \cdot 10^{15}$ at/cm³

P / LE (HMR): $5 \cdot 10^{16}$ at/cm³

HE – High Energy; LE - Low Energy

HMR – High Mass Resolution



Application areas

- Dopant and impurity depth profiling
- Composition and impurity measurements of thin films
- High-precision matching of process tools, such as ion implanters and CVD etc.

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Time-of-Flight Secondary Ion Mass Spectrometry (TOF-SIMS)



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Technical Parameters

Time-of-flight mass spectrometer:
ION-TOF 5

Primary Beam:

Analysis Gun:

Liquid Metal Ion Gun (LMIG)

Bi_1 , Bi_3 und Bi_3^{++} Ions/Clusters

Sputter Gun: O und Cs

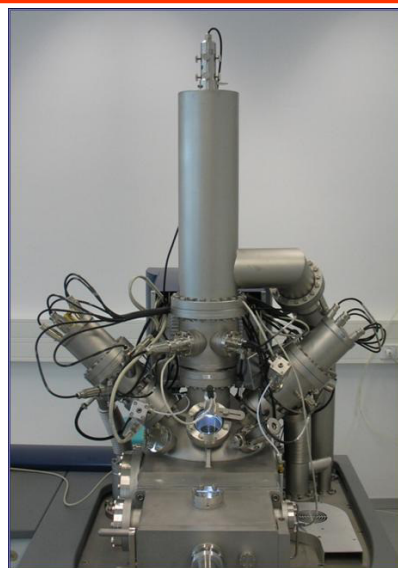
Signal Detected: Secondary Ions

Elements Detected: H – U

Lateral Resolution: 90 nm (Imaging)

Depth Resolution: 1 – 3 nm (Profiling)

Detection Limits: 10^9 - 10^{10} at/cm² (sub-monolayer)



Application areas

- Surface microanalysis of organic and inorganic materials
- Ion imaging of surfaces
- Dopant and impurity depth profiling
- Composition and impurity measurements of thin films

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Focused Ion Beam (FIB)



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Technical Parameters

FIB-SEM System:

NVision 40

Primary beam:

SEM (Gemini Zeiss): e^- 1 - 30 kV

FIB (Seiko Zeta): Ga^+ -Ions 5 - 30 kV

Lateral resolution: REM: 1.1 nm @ 20 kV

2.5 nm @ 1 kV

FIB: 4.0 nm @ 0.1 pA

Signal Detected:

Secondary electrons

(SE, In lens, EsB, STEM Detectors)

EDX-System:

SDD-Detector Bruker Xflash 4010

Elements Detected: B – U

Lateral Resolution (EDX): $\geq 1 \mu m$

Depth resolution (EDX): 0.5 – 3 μm

Energy resolution (EDX): 125 eV

Detection Limits (EDX): 0.1 – 1 at%



Application areas

- High resolution cross-section images of small sample features
- SEM Imaging
- TEM sample preparation
- „on-chip“ circuit modification (FIB Cuts, W, C and SiO_2 deposition)
- In-situ STEM Imaging
- Chemical Microanalysis by EDX (point analysis, line scans, mapping)

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Scanning Electron Microscopy (SEM)



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Technical Parameters

SEM System:

Hitachi S-4500

EDX Detector Noran System Six

Primary Beam: Electrons 5 - 25 kV

Signal Detected:

- Secondary electrons
(SE, BSE Detectors)
- X-rays (EDX)

Elements Detected: B-U (EDX)

Lateral Resolution: SEM: 2.0 nm @ 25 kV
2.5 nm @ 1 kV

EDX: $\geq 3 \mu\text{m}$

Depth Resolution: EDX 0.5 – 3 μm

Detection Limits: EDX: 0.1- 1 at%



Application areas

- High resolution SEM images
- Elemental analysis by EDX (point analysis, line scan and mapping)

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Transmission Electron Microscopy (TEM)



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Technical Parameters

TEM System:

FEI Tecnai Osiris

Super-X windowless silicon drift detector

Primary Beam: Electrons 200 keV

Signal Detected:

- Transmitted electrons
- Scattered electrons
- X-rays

Elements Detected: B-U (EDX)

Lateral Resolution: TEM: 0.26 nm

STEM: 0.18 nm

EDX: 5 nm

Detection Limits: EDX: 0.1 - 1 at%

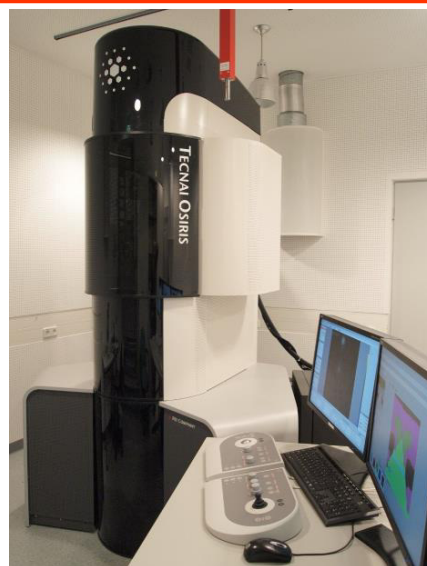
EELS: 1 at%

EELS Energy Resolution: 1.1 eV

Goniometer: α : -35° - 35°

β : -30° - 30°

STEM: BF, DF, HAADF Detectors



Application areas

- Cross-section and plan-view (S)TEM analysis
- Failure analysis of integrated circuits
- Determination of crystallographic phases
- Crystal defect characterization
- Ultra small area elemental analysis by EDX and EELS

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X-Ray Photoelectron Spectroscopy (XPS)



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Technical Parameters

Photoelectron Spectrometer:

PHI VersaProbe II

X-Ray Source: Aluminium anode (Al K α ,
photon energy 1486,6 eV)

Ion Source: Ar⁺ Ions (Energy 0.25-5 keV)

Primary Beam: mono chromatised
AlK α - 1486,6 eV

Signal Detected: Photoelectrons

Elements Detected: Li – U Chemical
bonding information

Lateral Resolution: 10 μ m – 100 μ m

Depth Resolution: 2 - 5 nm (Profiling
Mode)

Detection Limit: 0.5 at%



Application areas

- Surface analysis of organic and inorganic materials
- Determining composition and chemical state information from surfaces
- Depth profiling for thin film composition
- Thin film oxide thickness measurements

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Auger Electron Spectroscopy (AES)



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Technical Parameters

Auger Electron Spectrometer:

Physical Electronics PHI 670 Nanoprobe

Ion source: Ar⁺ Ions (Energy 1-5 keV)

Primary Beam: focused electron beam (1 - 25 keV) – Field emitter

Signal Detected: Auger electrons,
Secondary electrons

Elements Detected: Li-U; Chemical
bonding information

Lateral Resolution: 100 nm

Depth Resolution: 2 – 3 nm (Profiling
mode)

Detection Limits: 0.1-1at% sub-monolayer



Application areas

- Surface analysis
- Particle analysis
- Small-area depth profiling
- Defect analysis
- Thin film composition analysis

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Hall Effect Measurement System



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Technical Parameters

Lakeshore 7600 System

Magnetic Field: 0-1.8 Tesla

Temperature: 15K -800 K

Software:

Quantitative Mobility Spectrum Analysis Software (QMSA) calculates the mobility and concentration of different charge carriers (holes and electrons)



Application areas

- Measurement of resistivity and Hall coefficient by Van-der-Pauw method (10 m Ω -10 M Ω)
- Temperature- and field-dependent determination of sheet carrier density and carrier mobility

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X-ray Diffraction (XRD) X-ray Reflectivity (XRR)



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Technische Parameter

X-Ray Diffractometer

RIGAKU SmartLab (9 kW rotating anode, Cu) 18 kW Rotating Anode X-ray Generator with Dmax 1500 und Triple-Crystal Diff.

SmartLab

Variable X-Ray optics, Bragg-Brentano and parallel beam with crystal collimator and analyzer (2θ : 0 – 130°, Φ - and χ -Rotation □, "in-plane"-Option, 1100°C-Temperofen

Dmax1500

XRR from 0° to about 10° 2θ

XRD im wide angle range up to 105° 2θ

Triple-Crystal Diffractometer

Ge-400 2x Channel-cut collimator

Angle range $\Delta\theta$: ± 3600 arcsec

Step width: 0.01 arcsec



Application areas

- XRR measurements of smooth layer systems determination of layer thickness, roughness, and density (thickness range: 1 – 500 nm) XRD
- XRD measurements for phase analysis, in-situ high-temperature studies
- HR-XRD measurements of single crystals with epitaxial layer structures (e.g. Si_{1-x}Gex) or implantation layers, determination of layer thickness, strain, and content of dopants
- Pole figure and in-plane measurements
- Rocking curve and reflectivity curve simulation and fitting program RCRRefSimW 1.09

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Raman - Spectroscopy



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Technical Parameters

Raman-Spectrometer:

Renishaw inVia Raman Microscope

Measurement geometry:

Backscattering

Measurement range: 100 cm⁻¹ - 3200 cm⁻¹

Excitation wavelength:

UV: 325 nm

Visible: 457 nm, 488 nm, 514 nm, 633 nm

Polarisation: normal, orthogonal, circular

Lateral resolution: minimum spot size:
0.6 µm

Scanning and Mapping:

Minimum step: 0.1 µm

Scan range: 30 x 30 mm²



Application areas

- Thin layer composition (Si, Ge, C)
- Characterisation of intrinsic stress
- Quality of Graphen thin layers
- Defect analysis

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