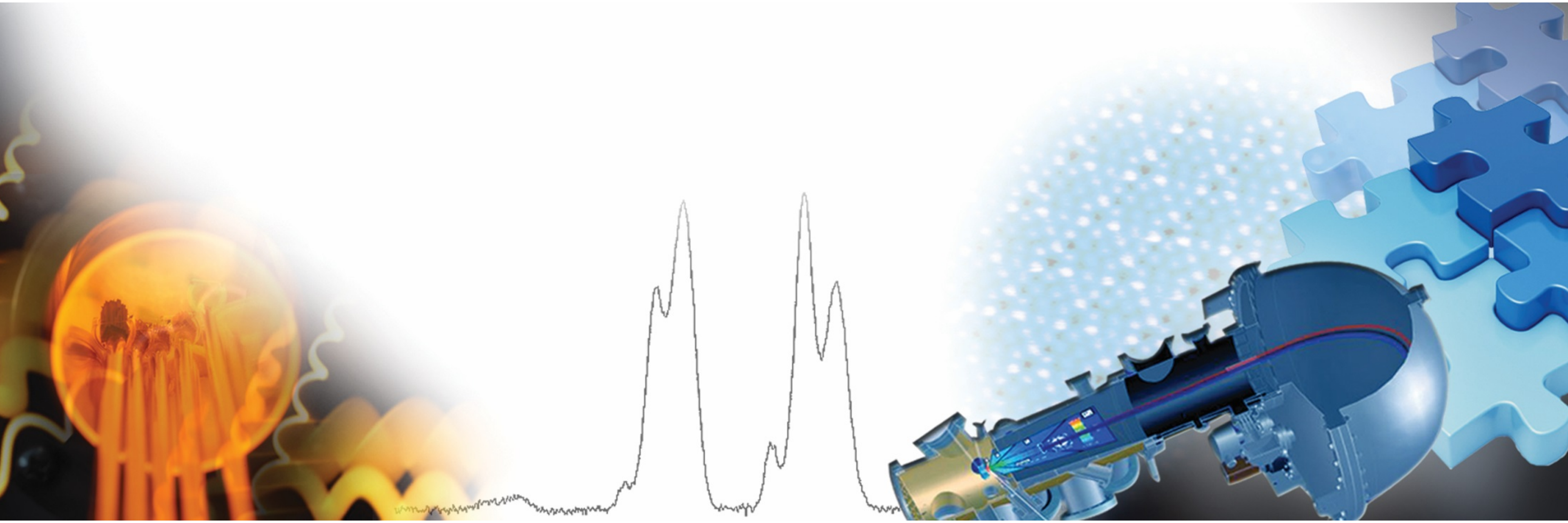

Helmholtz Energy Materials Characterization Platform

Harald Bolt

7th April 2016, HELSMAC, Cambridge

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CHARACTERIZATION PLATFORM

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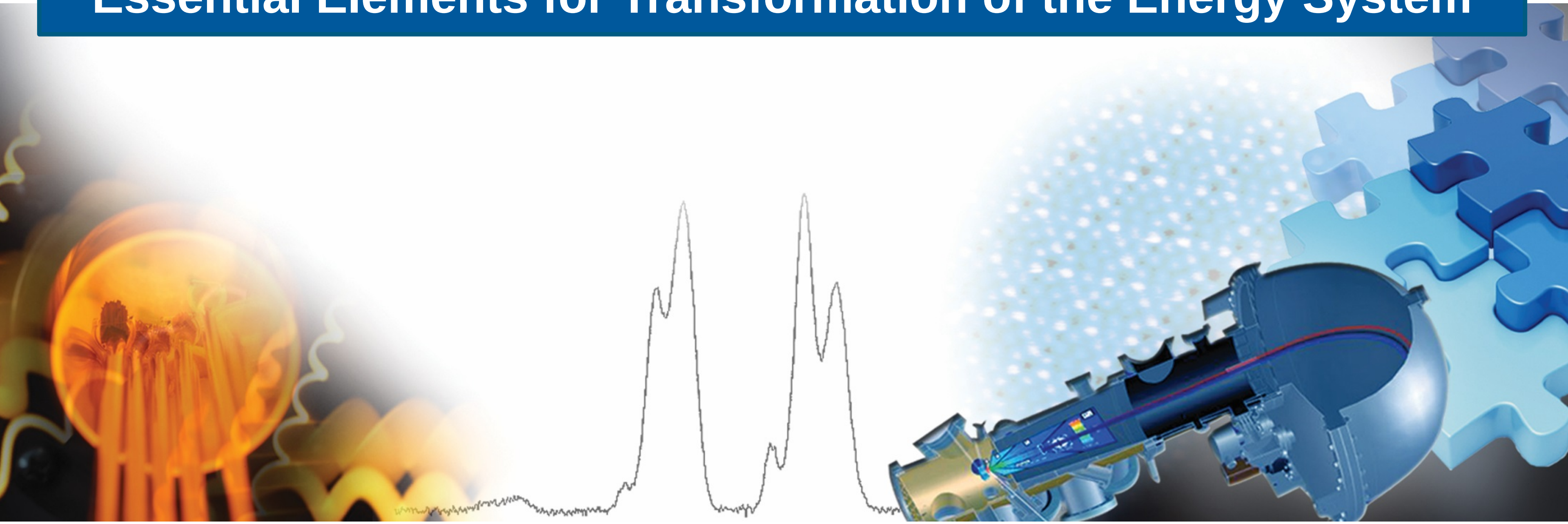
ASSOCIATION

Essential Elements for Transformation of the Energy System



- Storage
- Renewables
- Grids
- Efficiency
- Flexible Power Plants

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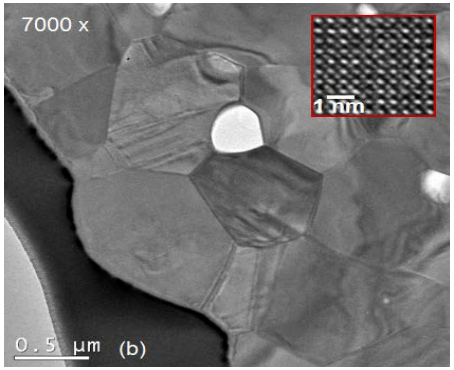
Motivation

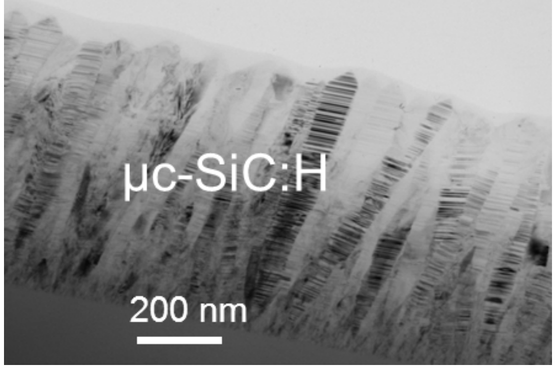
- New materials are essential for the realization of new energy conversion and storage technologies.
  - ➢ central importance for future energy systems

- Timescale for development: 10 -30 years;
  Operation time: 20 – 50 years (long-term stability)

- Material design and the determination of long-term properties require detailed knowledge of the structure and functional properties; from atomic scale to component

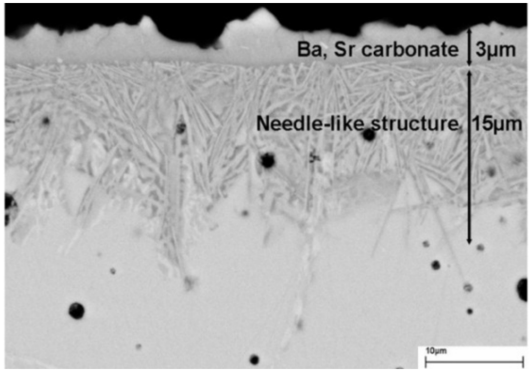


Defects and microstructure in perovskites



Microstructure of SiC:H

72 vol% N_2, 18 vol% O_2, 10 vol% CO_2



Stability in CO_2 containing the atmosphere

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Lorenz Singheiser, Institut für Energie- und Klimaforschung, Werkstoffstruktur und- eigenschaften, Forschungszentrum Jülich GmbH

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Energy-material research in Helmholtz

	Design	Processing	Operation
Modelling/ Simulation	Atomic/ Mesoscopic	Process Simulation	Damage Mechanisms/ Lifetime
Processing and Testing	Lab Scale	Pilot Scale	Operational Exposure
Characteri-zation	Nano Level: Structure, Composition, Functions	- In Situ (process) - Integrity - Compound Function	- In Situ (operation) - Damage Evaluation - Failure Parameters

yellow POF- and Portfolio topic „Materials Research for Future Energy Supply“

orange HEMCP subjects in the energy materials research context

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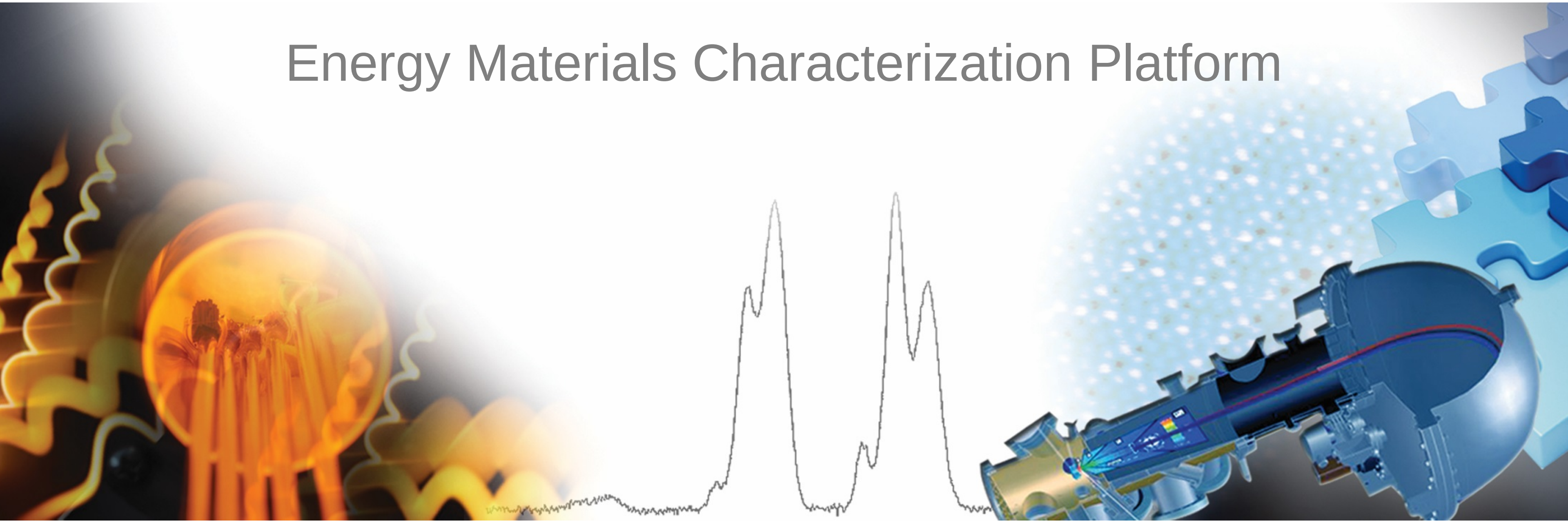

- Infrastructure supported by the Helmholtz Association
- Unique collection of devices and analytical methods
- Seven research institutions under one virtual roof
- Wide range of options for research issues on materials for energy technology

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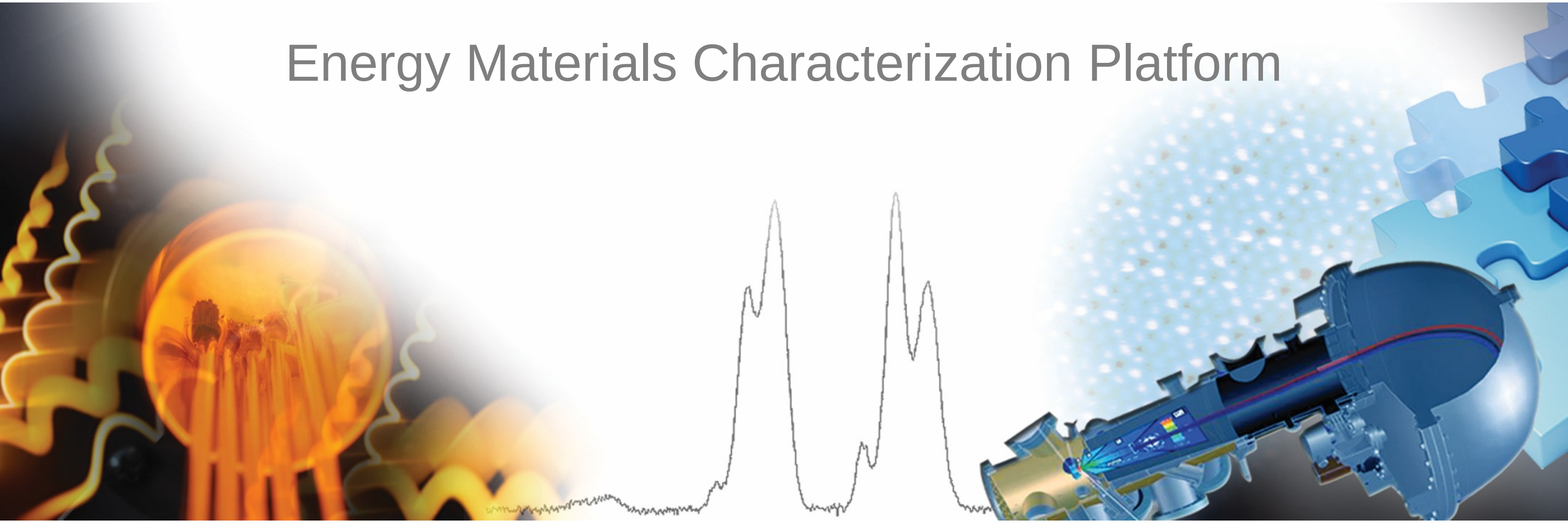


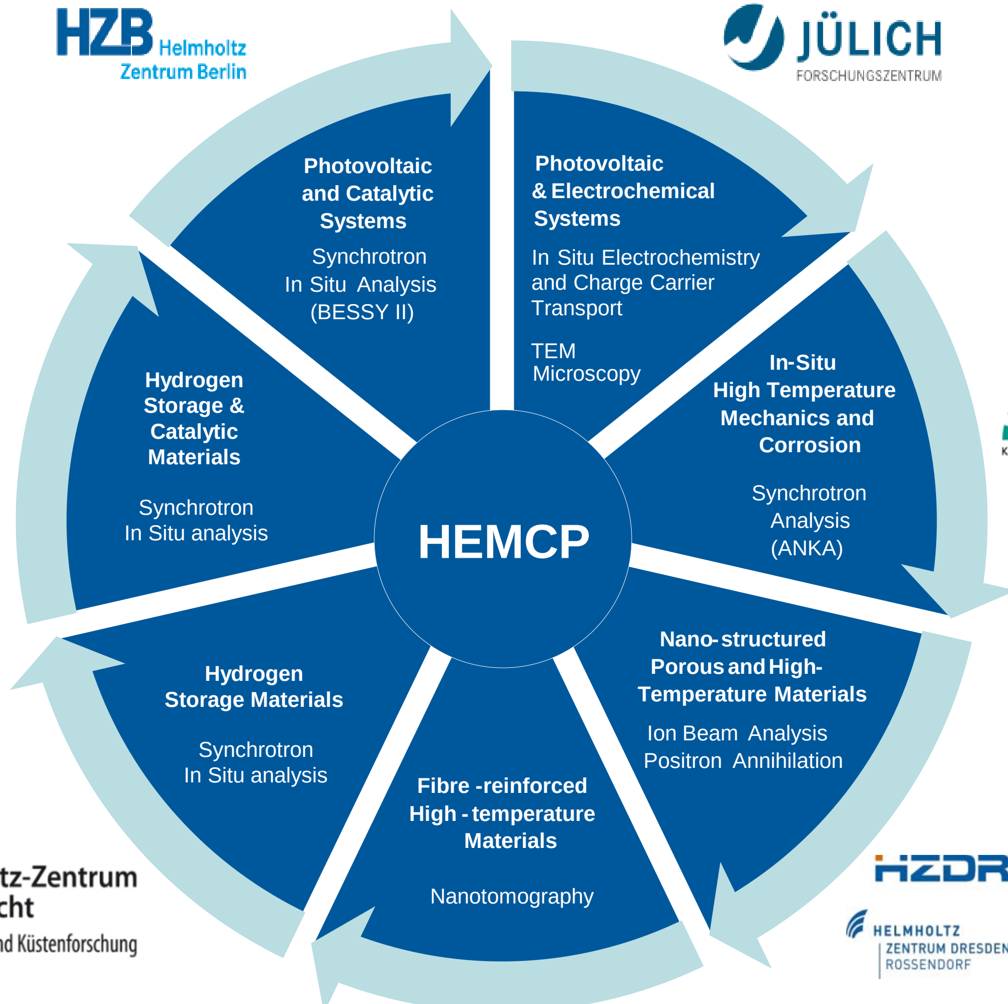
- Development of efficient and sustainable energy conversion and storage technologies
- Time and spatial resolution (3D) information on structural, electrical and chemical properties under preparation and operating conditions (in-situ methods)

HEMCP: Participating Helmholtz Centers, Subjects

Complementary consolidation of **large scale equipment** and **high-end-analytics**

In-situ characterization platform

Platform for collaboration between centres, with universities and industry



HEMCP: Funding

Investment (in €)

Center	Funding
FZJ	15.500
KIT	6.800
HZDR	6.300
HZB	6.600
DLR	1.730
HZG	1.700
Total	**38.630**

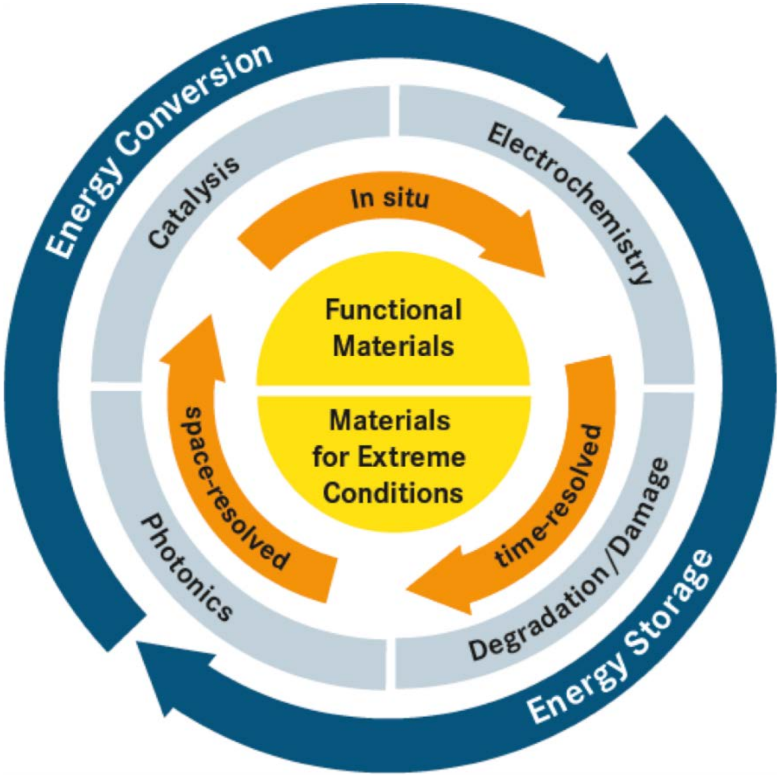
Gefördert durch:
Bundesministerium für Wirtschaft und Energie
aufgrund eines Beschlusses des Deutschen Bundestages

GEFÖRDERT VOM
Bundesministerium für Bildung und Forschung

Energiewende Umschalten auf Zukunft

- Particular relevance of HEMCP on research policy (“Energiewende”)
- Substantial funds of the centers;
- DESY: in-kind contribution

HEMCP: Research fields

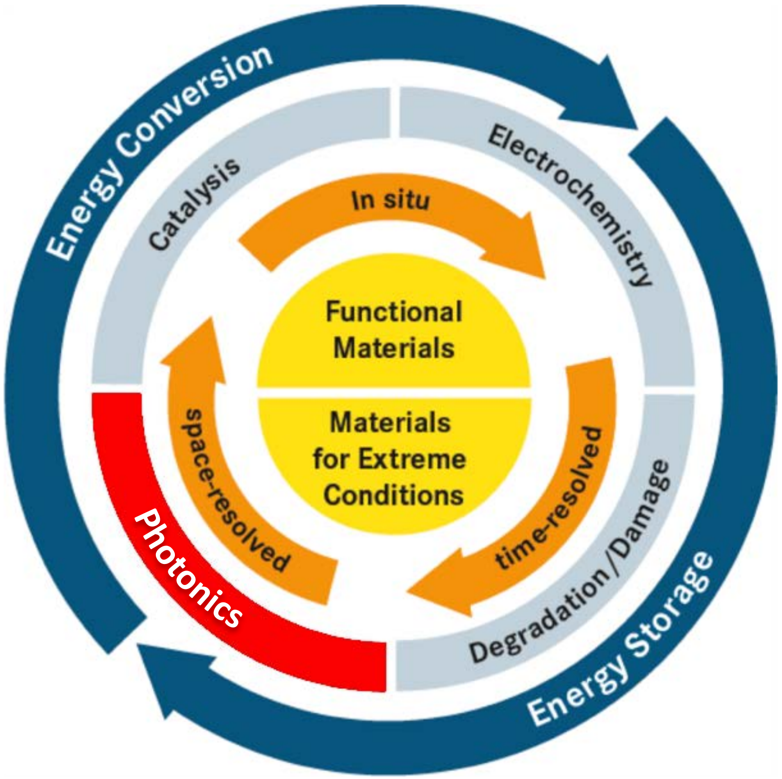


Energy Conversion and Storage

HEMCP concentrates on technology areas where improvements are especially dependent on progress in material science:

- Photovoltaic systems
- Chemical conversion and storage
- Electrochemical energy conversion and storage
- Thermal energy conversion

HEMCP: Research fields



Photonics (esp. PV)

- Improvement of functional layers and interfaces relies on precise analysis of electronic and chemical properties
- Characterization methods and simulation capabilities to analyze optoelectronic properties
- All relevant length scales from atomistic resolution of nanostructures and elementary processes up to the yield analysis of modules or photovoltaic systems.

Analytical tasks:

- Absorption and reflection from rough structures
- Optoelectronic properties of surfaces and nanoparticles
- Work function „design" and characterization
- Electronic properties and atomic structure of interfaces

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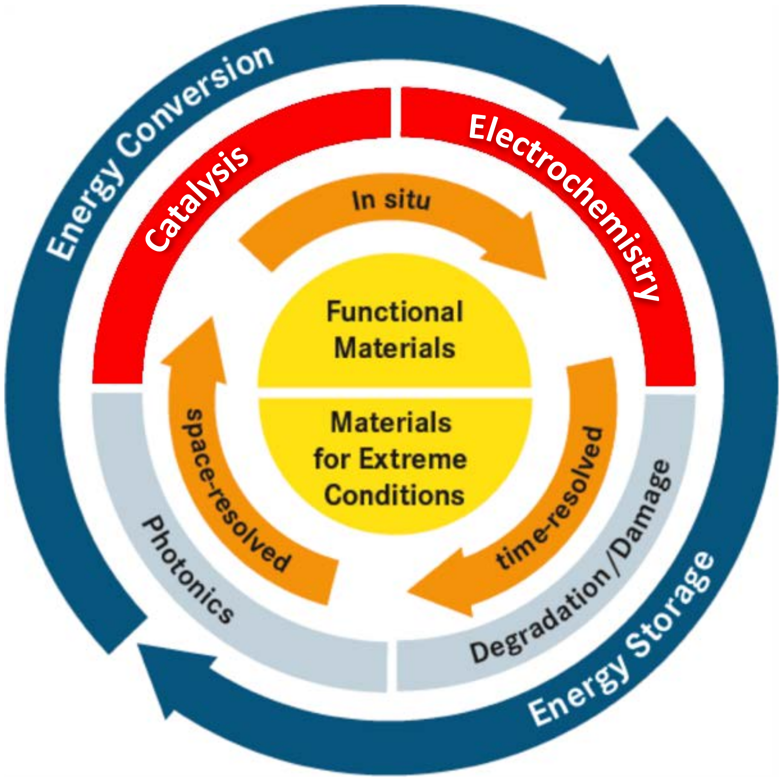
HEMCP: Research fields



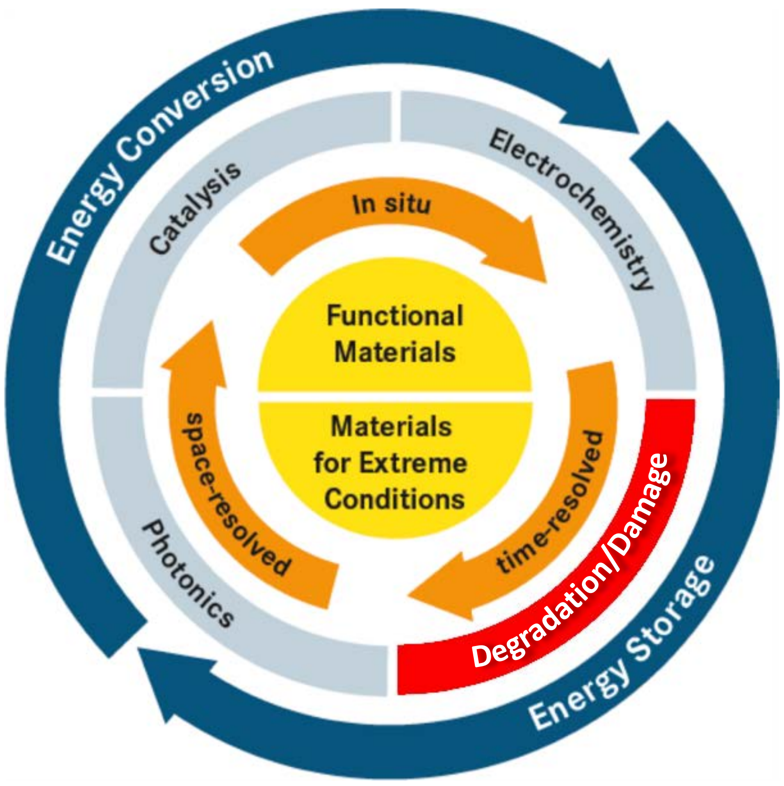
Electrochemistry / Catalysis

- Understanding of electrochemical and catalytic reactions and ionic transport properties
- Understanding of kinetics and mechanisms of the e.g. electrode processes for the development of novel electrolyte and electrode materials.
- Physico-chemical analysis of materials, components and functional interfaces with respect to the defect chemistry

Analytical tasks:

- Surface reactions in liquids and gases
- In-situ chemical and structural analysis
- In-situ analysis of film and interface formation, electronic properties
- Electrode/electrolyte interaction
- Hydrogen loading/deloading kinetics

HEMCP: Research fields



Degradation/Damage

- Analysis of the microstructure of ceramic-based composites and new metallic alloys under highest thermo-mechanical and corrosive loading
- Investigation of degradation and life time predictions and on the other hand to develop improved materials and components.

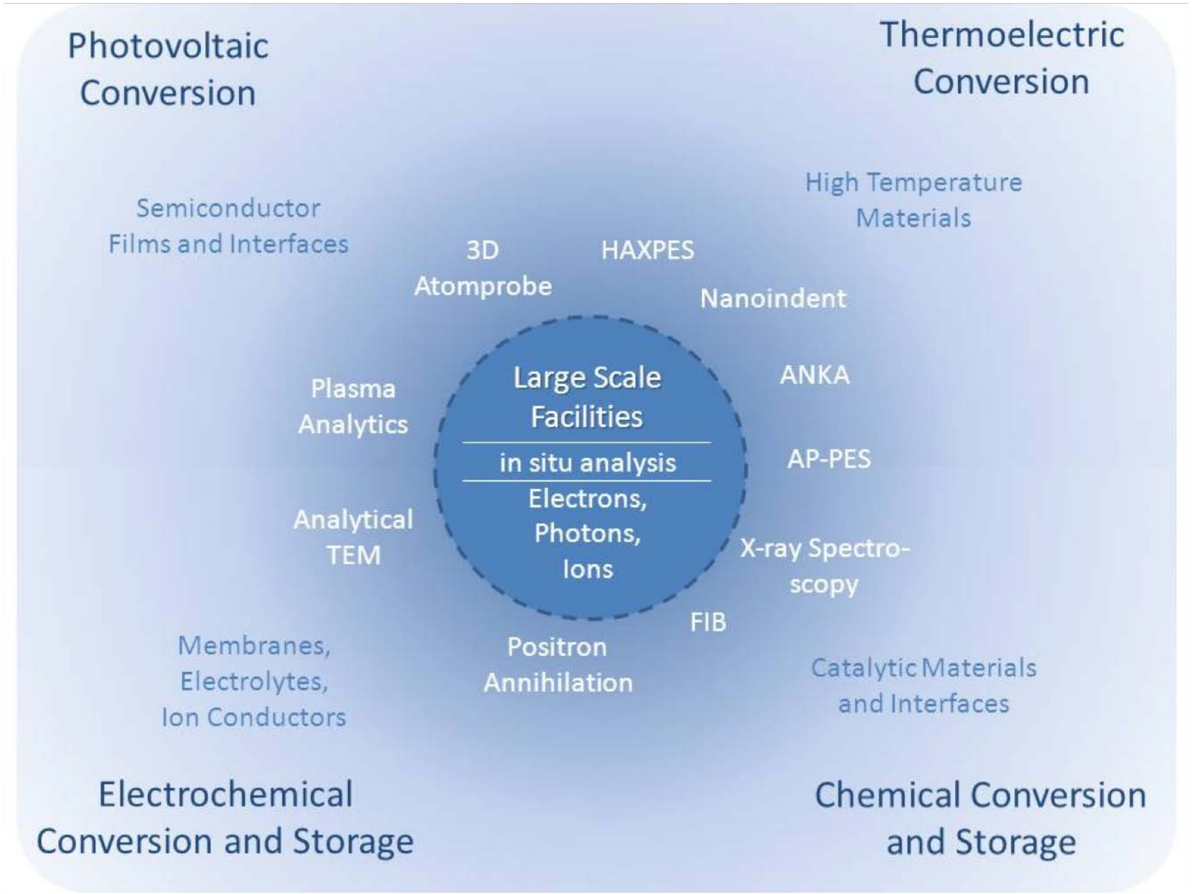
Analytical tasks:

- Structural evolution under operating conditions
- Surface reactions in liquids and gases
- Element analysis on atomic scale
- Pore structure of electrodes, electrode/electrolyte interaction
- Fatigue and corrosion reactions of structural materials and functional protective

HEMCP: Instrumentation

Characterization methods

- In-situ methods close to preparation or operation conditions
- Structural characterization of functional nanostructured materials for energy applications
- Enabling of large-scale facilities for in-situ analysis and characterization methods with high resolution



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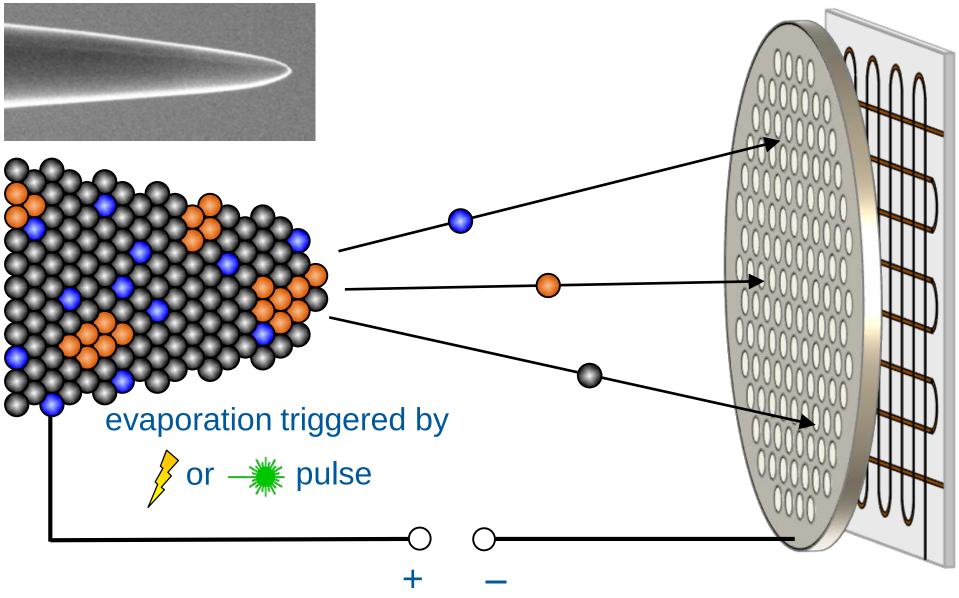
HEMCP: Instrumentation

Instrument	Center
Cryogenic Impact Testing	KIT
Cryo-Heatcapacity Physical Properties Measurement System (PPMS)	KIT
Cryo X-ray Diffraction (Cryo-XRD)	KIT
Field Emission Scanning Electron Microscope (FEG-SEM)	KIT
Field Emission Scanning Electron Microscope combined with Focussed Ion Beam (FEG-SEM/FIB)	KIT
Raman Microscope	KIT
Focussed Ion Beam (FIB)	DLR
Hard X-Ray Photoelectron Emission Microscopy (HAX-PEEM)	FZJ
3-D Atomprobe Tomography (APT)	FZJ
Transmission Electron Microscopy (TEM) – Titan G2 80-200 Crewely	FZJ
Ambient Pressure Photoelectron Spectroscopy (AP-XPS)	FZJ
Juelich Online Silicon Growth Experiment for Photovoltaics (JOSEPH)	FZJ
Solar Energy Material In-situ Spectroscopy at the Synchrotron (SISSY)	HZB
100 liter milling drum set up (CM100B)	HZG
Hydrogen Tank Test Facility II (HTTF II)	HZG
In-situ Synchrotron Radiation Powder X-ray Diffraction (in-situ SR-PXD)	HZG
Helium Ion Microscopy (HIM)	HZDR
Apparatus for in-situ Defect Analysis (AIDA)	HZDR
Secondary Ion Mass Spectrometry coupled to Tandem Accelerator (Super-SIMS)	HZDR
Transmission Electron Microscopy (TEM) – TalosF200X	HZDR

Instrumentation: Atom probe tomography

Tip-shaped specimen
(R ~ 50 nm)

Position-sensitive
detector

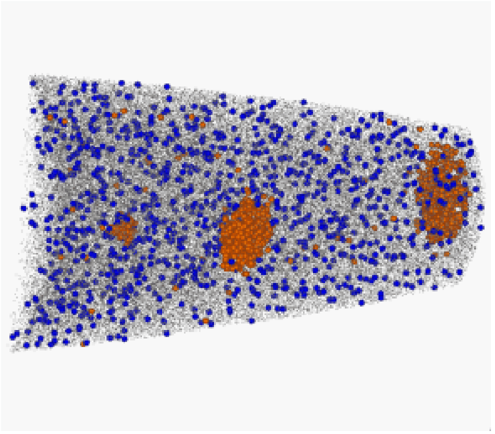


standing voltage 3-12 kV

- High spatial resolution (< 1 nm)
- High mass resolution (m/Δm > 1000)
- High detection sensitivity (down to 10 ppm)
- Equal sensitivity to all elements

…at the expense of analysis volume

Hit position at the detector → X-Y coordinates
Ion evaporation sequence → Z coordinate
Time of flight → chemical identity



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Astid Besmehn, Zentralinstitut für Engineering, Elektronik und Analytik
Forschungszentrum Jülich GmbH

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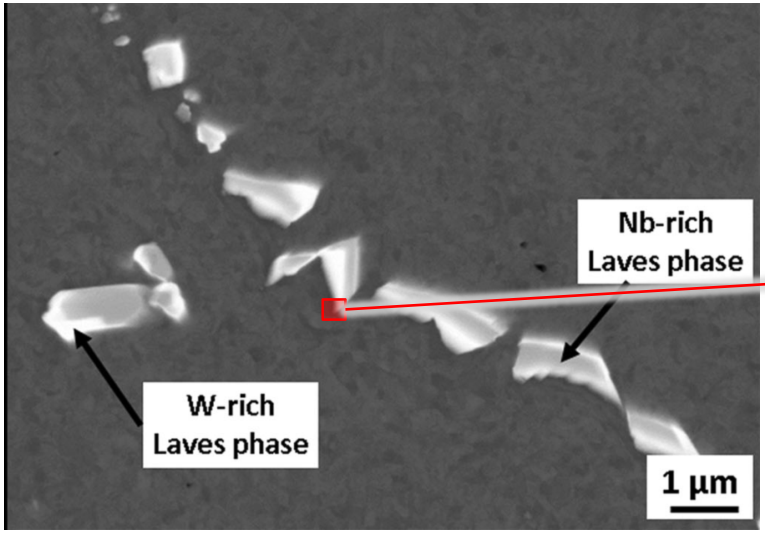
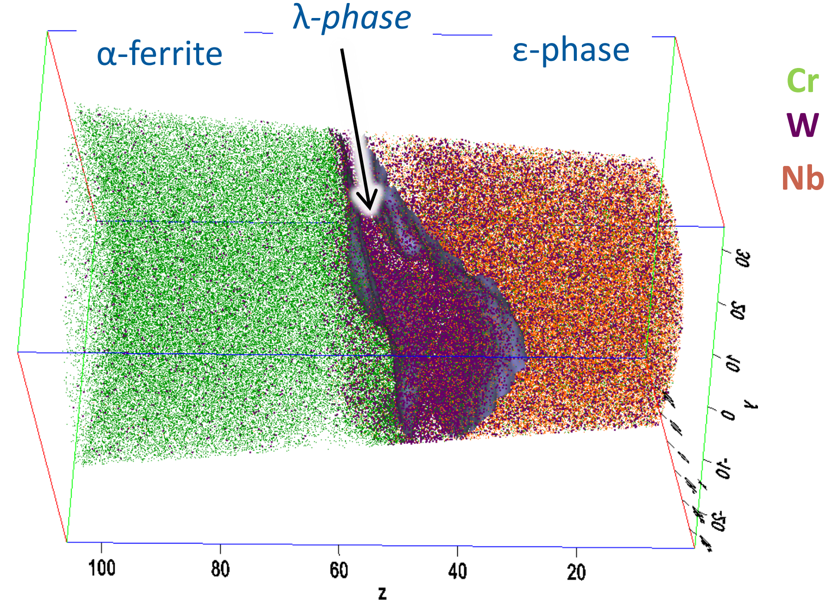
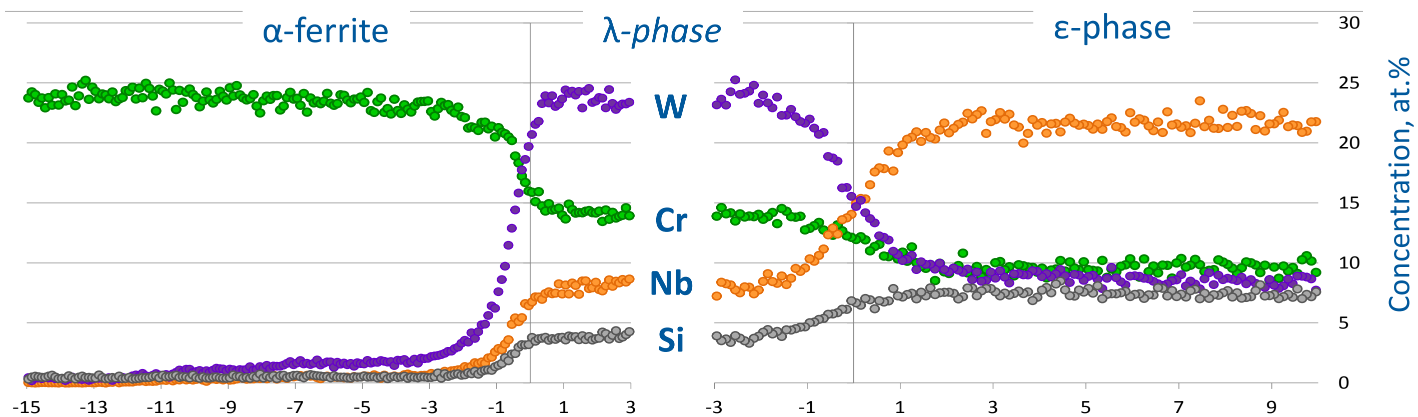
Instrumentation: Atom probe tomography

Crofer 22H - ferritic steel for solid oxide fuel cells interconnects. Laves phase chemistry?



L. Niewolak et al., J. Ph. Equil. Diff. 36 (2015) 471





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Instrumentation: TEM

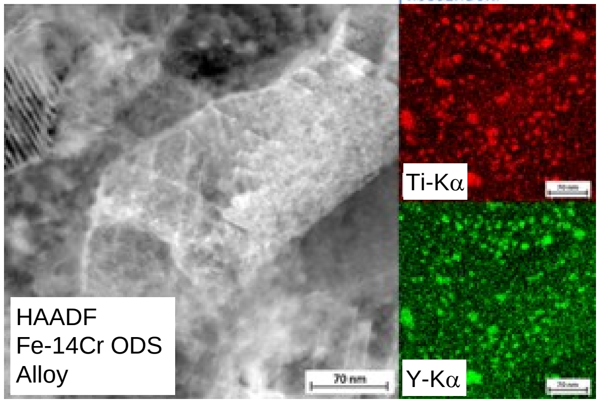
Transmission Electron Microscopy FEI Talos F200X

HZDR
HELMHOLTZ ZENTRUM DRESDEN ROSSENDORF

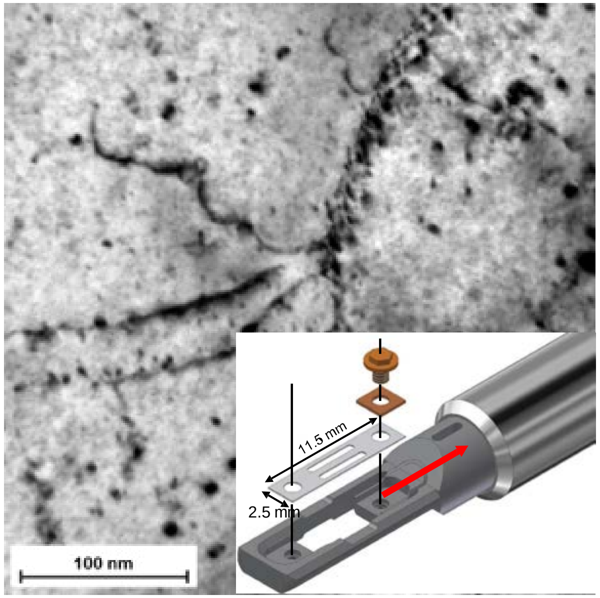
200 kV FEG-TEM equipped with
- High-performance EDXS system for efficient mapping in STEM
- STEM, BF/LAADF/HAADF
- In-situ straining holder

Applications
- High temperature materials for energy applications (e.g. ODS steels)
- Radiation defects in nuclear materials

Scientific topics
- Concentration, size, degree of coherency and composition of nm-sized oxide particles
- Deformation phenomena such as plastic localisation and the underlying mechanisms
- Interaction of dislocations with nm-sized particles and lattice defects under mechanical stress (in-situ straining, long-term objective)



High performance EDXS mapping

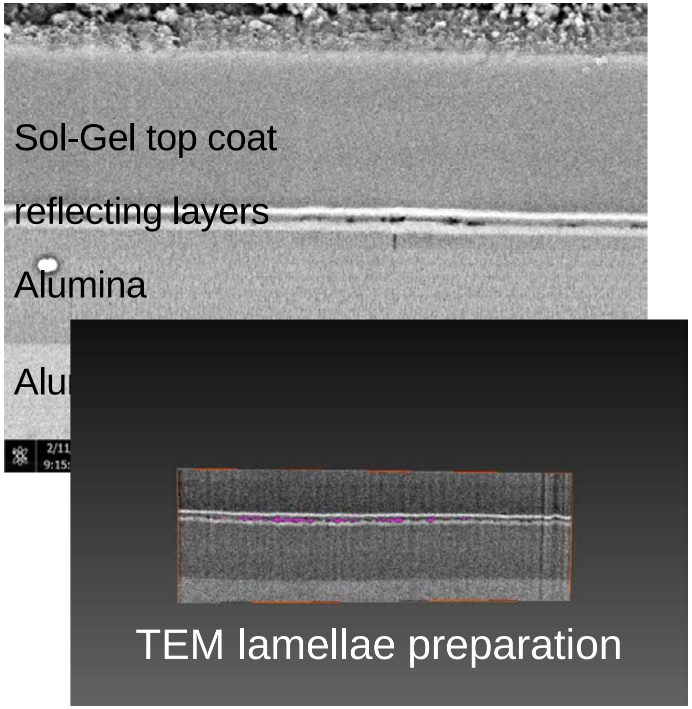


Interaction of dislocations with defects

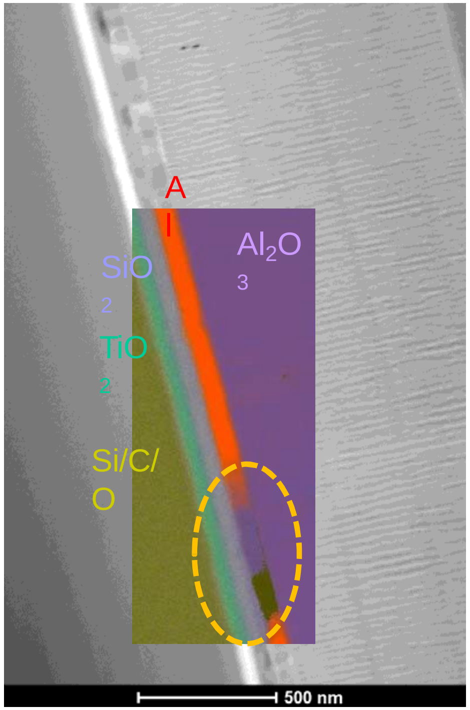
Instrumentation: FIB/TEM

Corrosion phenomena in Al-mirrors
Cross cut of corrosion spot with elemental analysis

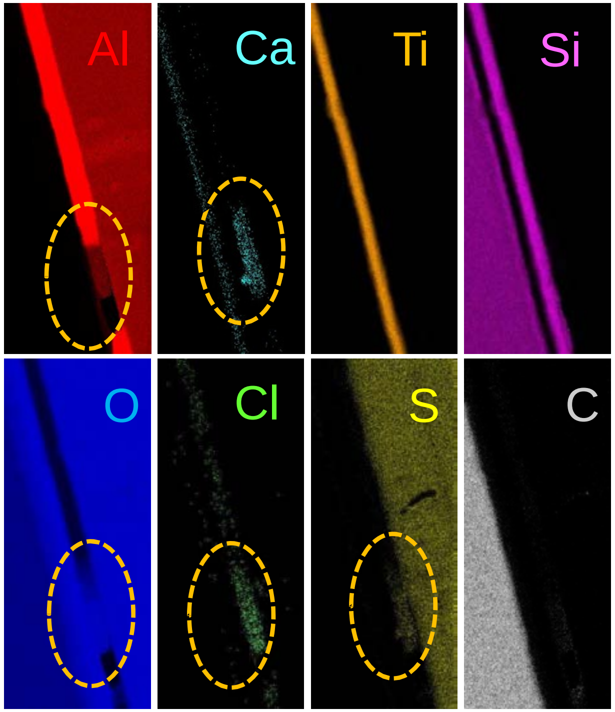
Focussed Ion Beam (FIB)



High Angle Annular Dark Field Imaging



TEM-EDX on FIB-Lamellae



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Stefan Reh, Klemens Kelm and Martin Schmücker Institute for Materials Research
Johannes Wette, Florian Sutter Institute for Solar Research DLR, Cologne

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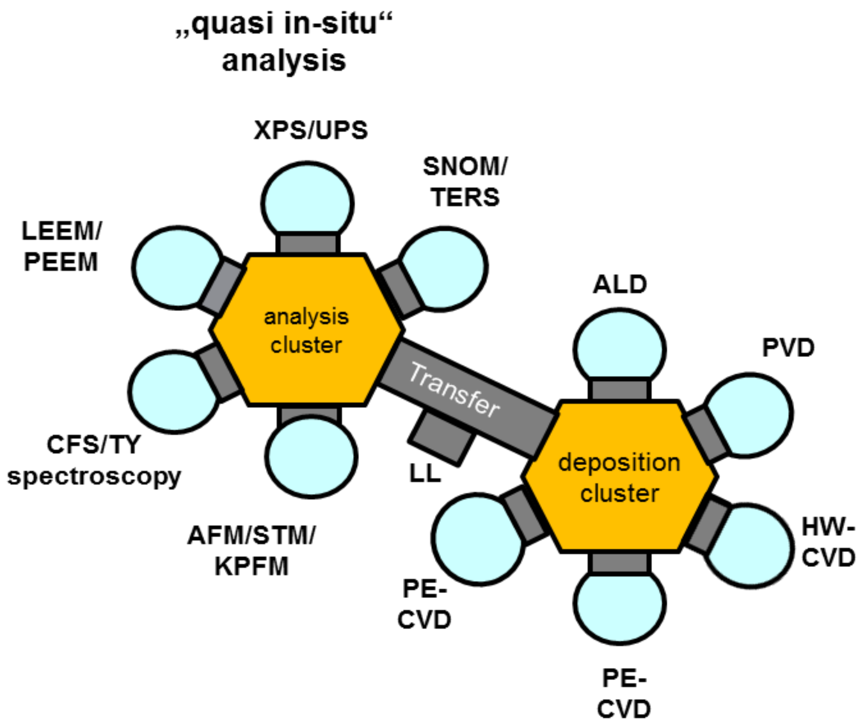
Instrumentation: JOSEPH

Juelich **O**nline **S**ilicon Growth **E**xperiment for **Ph**otovolatics



Preparation of complex layers and nano-structures

- In-situ growth analysis
- In-situ microstructure development and optical properties
- chemical composition and element distribution on nm scale
- electronic properties down to nm scale

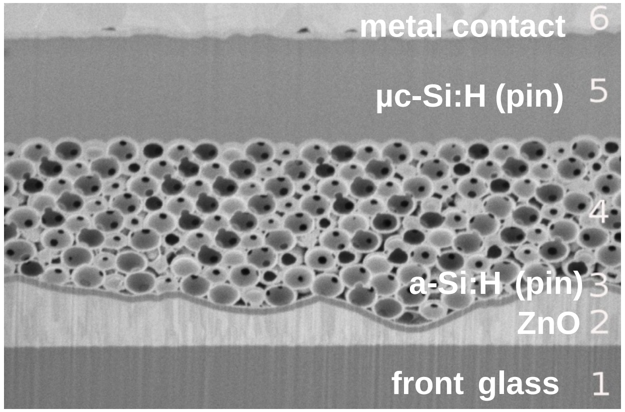
Growth and optoelectronic properties of:

- critical layers
- stacks and interfaces
- embedding of nanostructures for advanced materials and solar cells

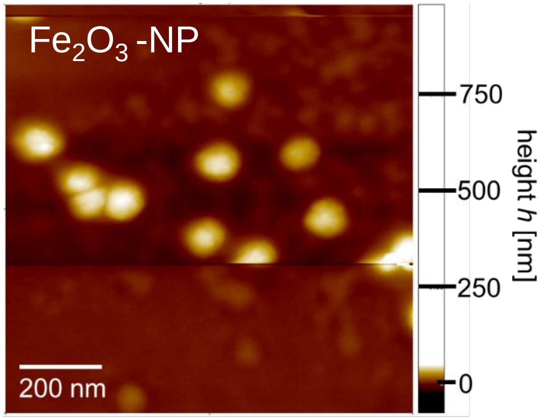
JOSEPH: Tandem cells and First results of KPFM

Novel thin-film solar cells with η > 20 % will consist of multiple layer stacks combining various optoelectronic functionalities, i.e.

… nanoparticles with high absorption to boost efficiency

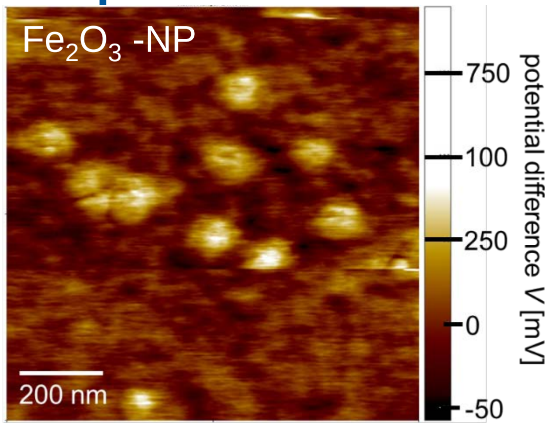


Atomic force microscopy



Topography with nanoscale resolution

Kelvin probe force microscopy



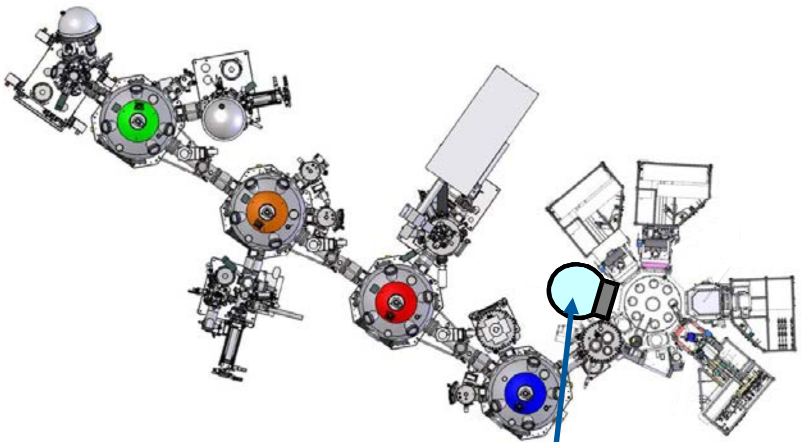
KPFM → contact potential
Reference material → Work function

Cooperation of centers

SISSY@EMIL and JOSEPH

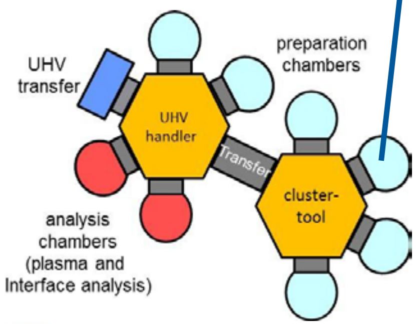
SISSY HZB Helmholtz Zentrum Berlin

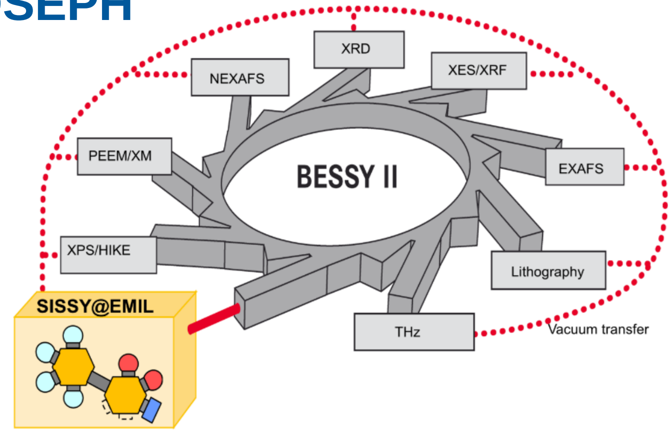
Silicon **I**n-**S**itu lab at the **Sy**nchrotron



JOSEPH JÜLICH FORSCHUNGSZENTRUM

Jülich **O**nline **S**ilicon growth **E**xperiment for **Ph**otovoltaics





- High energy- and depth resolution
- High sensitivity

⇧

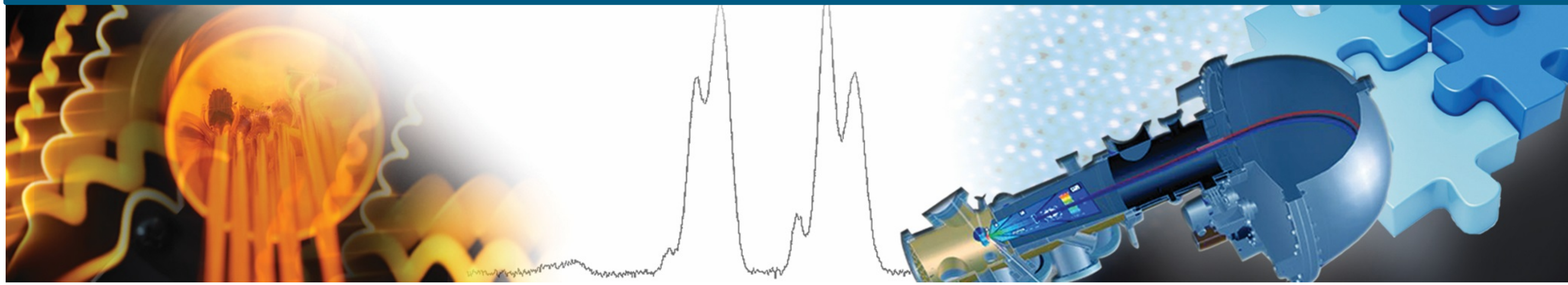
Identical preparation conditions by transfer of processes and chambers

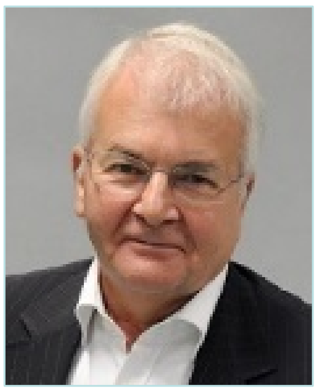
- In-situ diagnosis of layer properties
- In-situ plasma analysis
- Excellent solar cells

⇩

- High throughput, broad spectrum of analytical methods
- Specific, industrially relevant production methods
- Preparation and analysis of complete devices

HEMCP: Contact





www.hemcp.de

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Dr. Astrid Besmehn
HEMCP scientific coordinator and
Team leader Molecular Physics (ZEA-3)

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