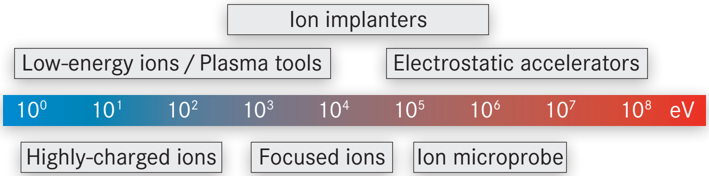
IBC.

Ion Beam Center

HZDR

THE IBC AT A GLANCE

The Ion Beam Center (IBC) at the HZDR is a leading European user facility for basic and application-oriented studies in the field of physics and materials science with ions. The IBC operates various machines and dedicated end-stations, providing ion beams of almost all stable elements in a wide energy range from eV to MeV.
The focus is on the modification and analysis of novel materials for information technology, electronics or energy systems. Ion beam analysis techniques are routinely used for materials science, but are of increasing importance for interdisciplinary sciences, such as geochemistry, climate research or resource technology. As a "universal tool" for surface modification, ion beams comprise great potential for industrial applications.



Main areas of competence

- Ion beam interaction with materials
- Ion beam modification of materials
- Ion-induced self-organization of nanostructures
- Ion-induced ordering/disordering effects
- Ion beam analysis
- Accelerator mass spectrometry

We provide

- User access for researchers world-wide
- Ion beam services for industry
- Scientific/technical support
- Joint research activities and projects
- Users hands-on training

Contact to the IBC User Office:
ibc@hzdr.de

Detailed information:
www.hzdr.de/ibc

USER ACCESS

As an international competence and user center, the Ion Beam Center (IBC) stands for many years of scientific and technical expertise in the field of ion beam physics and applications available for users from research and industry.

For researchers

Access to the IBC is offered free of charge for researchers all around the world. The access is provided on the basis of a proposal procedure. The scientific quality of proposals, which can be continuously submitted, is evaluated and ranked by an external and international user-selection panel. Fast-track access is offered for small scale test/pilot experiments after direct approval by IBC experts.
Beside hands-on experiments, which means researchers conduct or attend experiments on-site, the IBC also offers hands-off service. In this case, users have their experiments performed by IBC scientists without on-site attendance. Small scale services for research institutions can also be offered against payment, thereby avoiding the proposal procedure.

For industry

Access to the IBC for industrial/commercial ion beam services is offered by the HZDR spin-off company HZDR Innovation GmbH based on individual contracts. Requests for ion beam services are not evaluated by external reviewers and are kept strictly confidential.

Detailed information:
For researchers: **www.hzdr.de/ibc**
For industry: **www.hzdr-innovation.de**

ION BEAM ANALYSIS

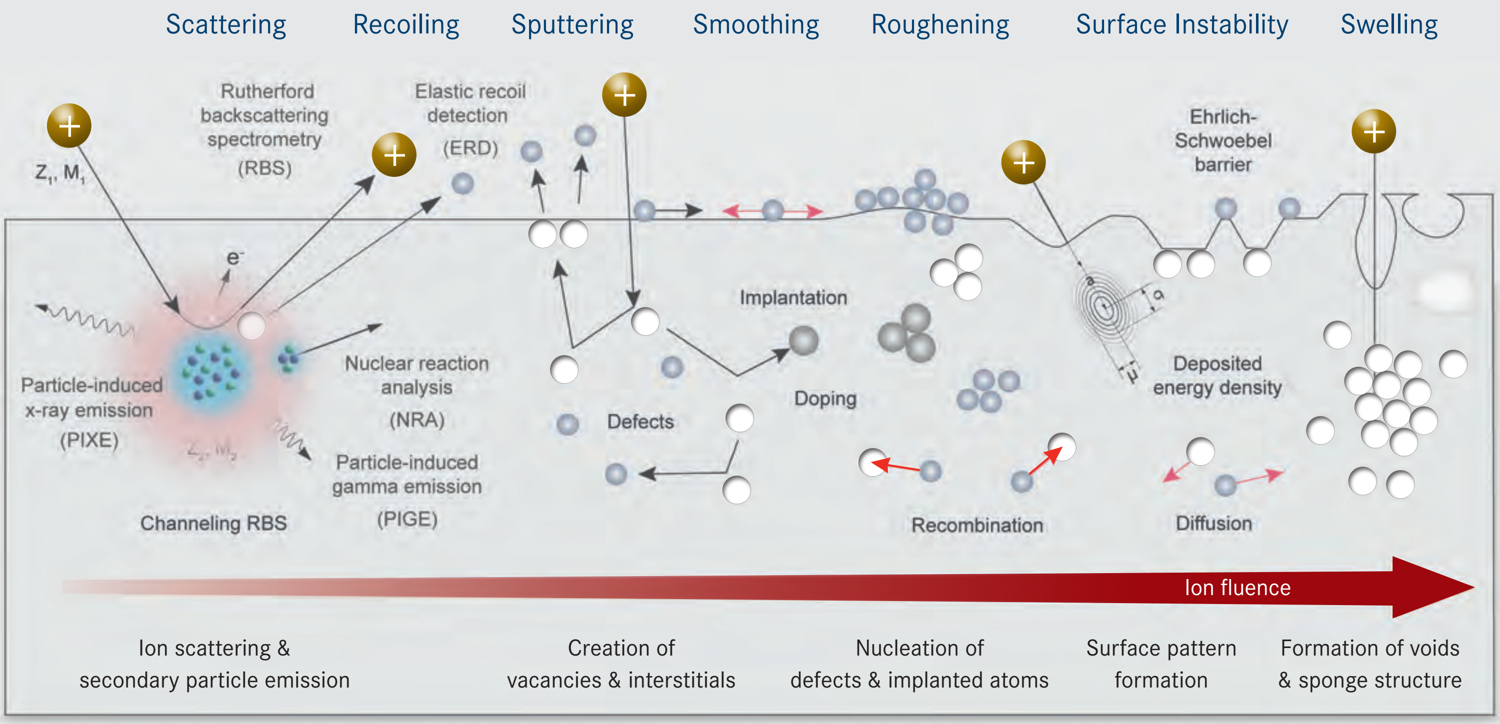
- Elemental mapping and depth profiling
- Light element analysis
- Hydrogen analysis and depth profiling
- Crystal damage analysis
- In-situ process characterization
- Ion microscopy
- Long-lived radionuclides
- Analysis using reactive gases or liquids
- External proton beam

Quantitative, standard-free, non-destructive, 2D/3D capabilities, down to nm resolution

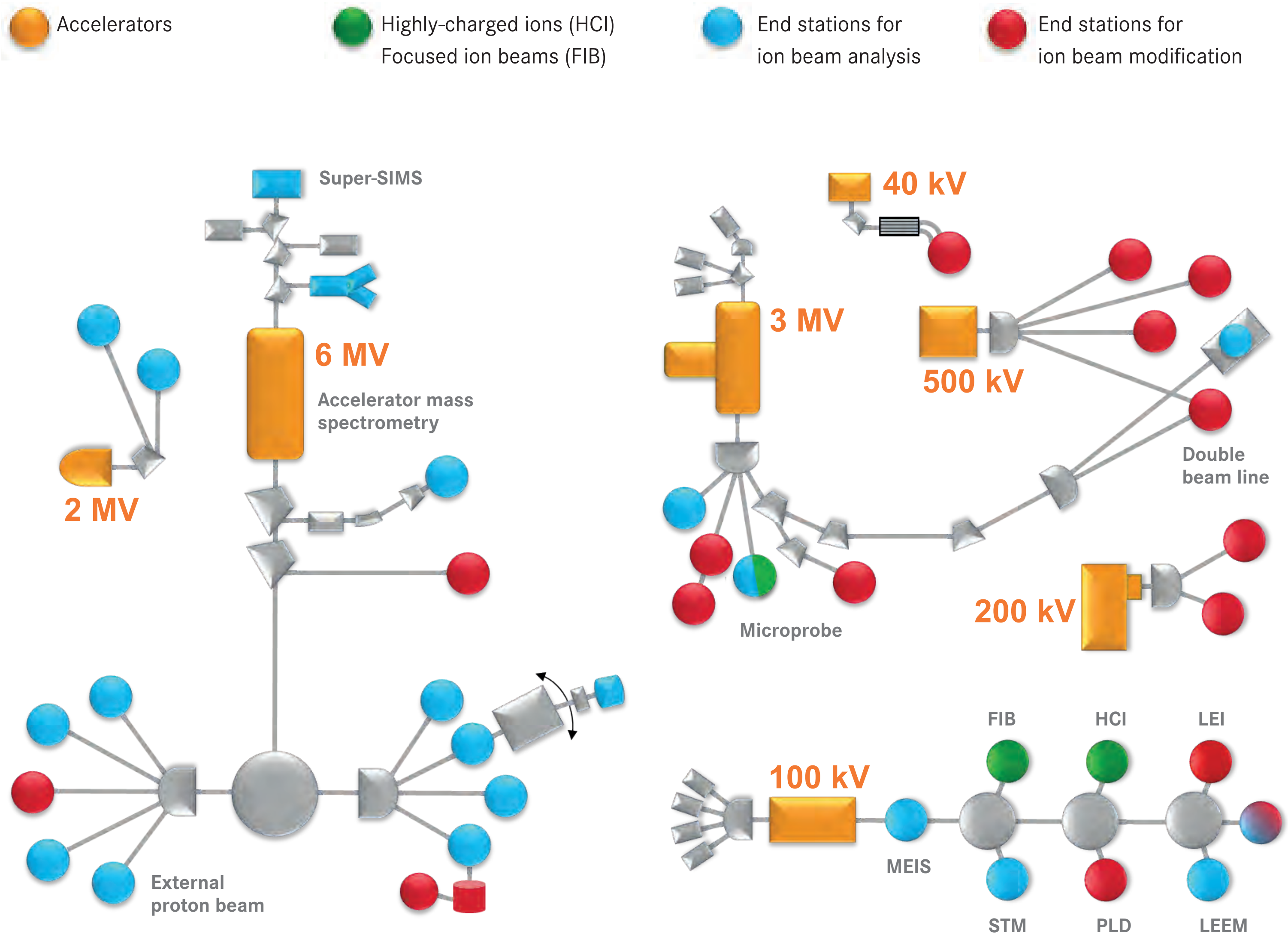
ION BEAM MODIFICATION

- Ion implantation and doping
- Ion-induced ordering/disordering
- Nanostructure fabrication
- Thin-film modification
- Surface patterning
- Surface functionalization
- Ion-induced defect generation
- Nuclear and astrophysical applications
- Fabrication of standards

Ultra-high precision of processing, nm resolution, broad beams, focused ions, highly-charged ions



THE ION BEAM CENTER @ HZDR



Stand-alone tools

Focused ion beams / ion microscopy

Highly-charged / low-energy ions

Add-on services

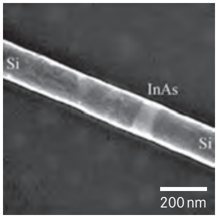
AMS sample preparation

Structural analysis

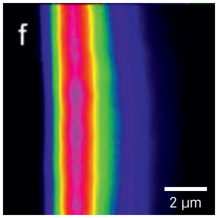
Clean-room processing

ION IMPLANTATION / IRRADIATION

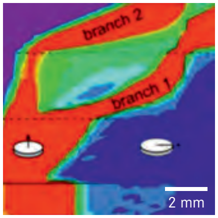
The IBC operates three ion implanters and three high-energy ion accelerators with end stations for the ion beam modification of materials. Almost the entire periodic table of elements can be very precisely implanted in virtually any solid target material with tunable depth and concentration profiles. Double beam irradiations are possible at a specific end station. Special equipment for commercial ion beam services (up to ø 200 mm wafers) is available, too.



Ion beam synthesis:
Local synthesis of InAs regions in Si nanowires



Chemical doping:
Enhanced lasing by carbon implantation of waveguides



Ion-induced disordering:
Magnetic phase transition in Pt/Co/Pt films after irradiation

Parameter	Description
Ion species	H - Bi (stable nuclides, poly-atomic ions)
Ion energy	100 eV – 60 MeV
Depth range	few Å – 150 µm
Fluence	10^{7} – 10^{18} cm^{-2}
Incidence angle	Standard 0°, 7°; others on request
Beam current	nA – mA
Sample size	Small pieces (cm²) - ø 200 mm wafers
Temperature	Liquid nitrogen – 1100°C
Special features	Dual beam irradiation, fluence gradients, defined partial gas pressures

Examples

- Precise chemical doping, fabrication of SIMS standards
- Synthesis and self-assembly of nanostructures
- Modification of thin-film properties
- Surface functionalization
- Defect generation for laser applications or radiation hardness testing

Contact

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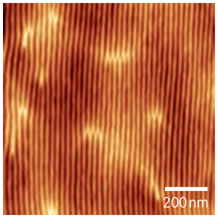
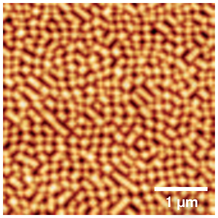
LOW-ENERGY / HIGHLY-CHARGED IONS

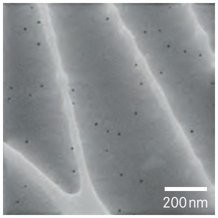
Low-energy ions (LEI) interact only with the first few monolayers of a solid without affecting the bulk properties. Furthermore, highly charged ions (HCI) carry a high amount of potential energy which is released and deposited into the electronic system of the surface. Thus, LEI and HCI beams can be used to change the morphology and the properties of surfaces and ultrathin films.



Surface patterning:
Highly-regular nanoripples on GaAs by LEI irradiation at RT



Crystalline nanostructures:
Checkerboard pattern on Ge after LEI irradiation at 300°C



Individual nanopores:
Perforation of carbon nano-membranes by HCI

Field	Parameter	Value
Low-energy ions (LEI)	Ion species	Gas ions (H – Xe)
	Ion energy	20 eV – 20 keV
	Charge state	1^{+}
	Ion flux	10^{13} – 10^{15} cm^{-2}s^{-1}
	Temperature	≤ 600°C
Highly-charged ions (HCI)	Ion species	Noble gases
	Ion energy	20 eV – 20 keV
	Charge state	3^{+} - 45^{+}
	Ion flux	10^{9} – 10^{12} cm^{-2}s^{-1}

Examples

- Topography (periodic patterning, individual nanostructures)
- Structure (amorphization, phase transformations)
- Tuning of surface properties (catalytic, wettability)
- Doping of nano-membranes and 2D materials
- Patterned surfaces as templates for thin-film functionalization

Contact

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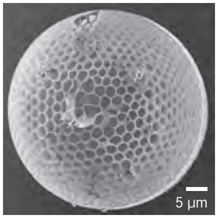
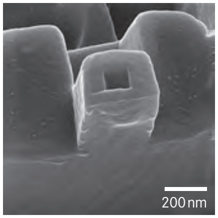
FOCUSED ION BEAMS

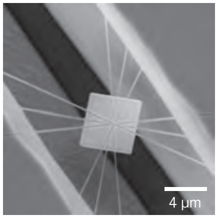
The IBC operates three focused ion beam (FIB) systems for ion microscopy and analysis, local surface modification, nano-patterning, doping, as well as for TEM lamella preparation. Special expertise is available through the use of liquid metal alloy ion sources which enable a mass-separated FIB irradiation of solids by single or poly-atomic ions from a large variety of different elements (from Li to Au).



Imaging of insulating/ biological diatom sample without coating



Milling of nanostructures



Fabrication of micro-/nano-electromechanical systems

Parameter	Cross Beam™ NVision 40	Ion Microscope ORION Nanofab	Mass-separated CANION 31M+
Ion species	Ga	He, Ne	Si, Ge, Co, Ni, Nd, Er, Au, Bi, ...
Energy	5 – 30 keV	10 – 30 keV	10 – 60 keV
Beam currents	pA - nA	pA	pA - nA
Resolution	7 nm (@ 1 pA)	0.5 nm (He) 2.0 nm (Ne)	15 – 100 nm
Special features	TEM lamella preparation	Heating: 500°C, 4-probe current measurements	Heating: 500°C, laser interferometer

Examples

- High-resolution ion microscopy of insulating surfaces
- Surface imaging with extreme large depth of focus
- Micro- and nano-patterning of thin films and surfaces
- Modification of graphene and metal di-chalcogenide materials
- Free-standing nanostructures through local doping and selective etching

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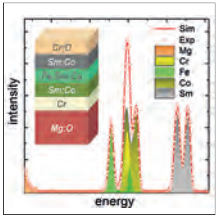
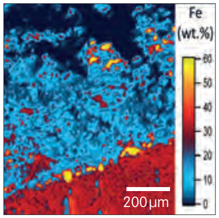
ION BEAM ANALYSIS

The IBC provides all standard ion beam analysis (IBA) techniques for the non-destructive and quantitative chemical analysis of samples (from H - U) with additional element-specific depth profiling up to a depth of several micrometers. In addition, we offer high depth resolution RBS (HR-RBS), laterally resolved element analysis (ion microprobe), and in-situ measurements combining several techniques.



Elemental RBS spectrum and simulation of a magnetic multilayer

Analysis of the famous Baldewein clock using the external proton beam



Iron distribution of a sample from an underwater volcano rock obtained by micro-PIXE

Method	Elements	Detection limit [at%]	Resolution	
			depth	lateral
RBS	O – U	0.1	10 nm	0.5 mm
HR-RBS	Al – U	1	2 nm	1 mm
ERD	H, B – Si	0.1	15 nm	1.5 mm
PIXE	Si – U	0.001		
PIGE	Li – P	0.01		
o Standard			-	1 mm
o µ-Probe			-	3 µm
NRA	H, B, C, N, F, O, ...	0.02	5 nm	0.5 mm

Examples

- Quantitative elemental depth profiles of layered materials
- Hydrogen determination and depth profiling
- Lateral elemental mapping (imaging) of geological samples
- Cross-calibration of ion implantation fluences
- Crystal damage investigations using ion channeling

Contact

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ACCELERATOR MASS SPECTROMETRY

For the determination of long-lived radionuclides, decay counting is time consuming or even impossible. By using a high-energy accelerator, accelerator mass spectrometry (AMS) is superior since it does not rely on the disintegration of the radioactive nucleus and provides much lower detection limits in comparison to conventional mass spectrometry. The DREAMS (DREsden AMS) facility at IBC offers excellent chemical sample preparation and measurement capabilities for non-radiocarbon isotopes.

Growth rate and age of deep ocean Mn nodules

Ice core samples for climate change reconstruction

Reconstruction of historical events such as earthquakes, volcanic eruptions, rock falls

Nuclide	$t_{1/2}$ [Ma]	Nuclide ratios of samples [10^{-12}]	Machine blank level [10^{-16}]
^{7}Be	1.5×10^{-7}	(0.01 – 2) ^{7}Be/^{9}Be	3
^{10}Be	1.387	(0.01 - 300) ^{10}Be/^{9}Be	5
^{26}Al	0.705	(0.001 - 60) ^{26}Al/^{27}Al	5
^{36}Cl	0.301	(0.007 - 700) ^{36}Cl/^{35}Cl	4
^{41}Ca	0.104	(0.006 - 9000) ^{41}Ca/^{40}Ca	20
^{129}I	15.7	(0.5 - 200) ^{129}I/^{127}I	200

Examples

- Astrophysics and cosmochemistry
- Climate, geomorphology and hydrogeology
- Nutrition, pharmacology and phytology
- Nuclear decommissioning and safety
- Radioecology and toxicology research

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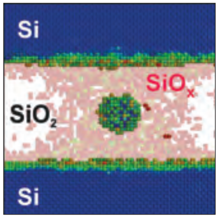
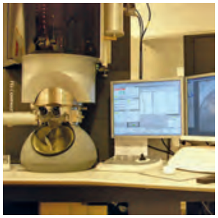
ADD-ON SERVICES

Users of the IBC can take advantage of available add-on services to ensure a successful realization of their experiments. This service comprises application of different sample preparation and structural analysis techniques, and support through the use of specific data analysis and simulation tools. It is offered in combination with an allocated IBC experiment only and limited to appropriate usage of resources.



Ion beam assisted dot fabrication for nanoelectronics (kinetic Monte Carlo simulations)



Structural analysis at the sub-nm level by TEM (Titan 80-300)

Semiconductor processing under clean-room conditions

Sample preparation and processing
(partially in clean-room environment)

- Sample cutting, polishing, chemical cleaning and etching
- Layer deposition and surface patterning with lithography (optical including laser, e-beam, ions)
- Thermal processing with lasers, flash lamps, RTP, furnaces

Access to AMS sample preparation

Measurement and characterization

- Optical and electrical characterization
- Electron microscopy and spectroscopy (SEM, HIM, TEM, AES, XPS)
- X-ray investigations (reflectometry, diffraction, scattering)

Simulation and data analysis

- Simulation of ion-solid interactions (doping, defects, mixing)
- Simulation of surface patterning (sputtering, surface diffusion)
- Data evaluation of IBA spectra

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Helmholtz-Zentrum Dresden-Rossendorf

The long-term goal of the Helmholtz-Zentrum Dresden-Rossendorf (HZDR) is to conduct cutting-edge research in the areas of Matter, Energy, and Health. Strategic collaborations with both national and international partners allow scientists to address some of the pressing challenges faced by modern-day industrialized society:

- How do matter and materials behave under the influence of strong fields and in the smallest dimensions?
- How can energy and resources be utilized in an efficient, safe and sustainable way?
- How can malignant tumors be more precisely visualized, characterized, and more effectively treated?

To answer these scientific questions, several large-scale research facilities, including the IBC, provide unique research opportunities. The HZDR is a member of the Helmholtz Association, has five locations (Dresden, Freiberg, Grenoble, Hamburg, and Leipzig), and employs more than 1,100 members of staff - approximately 500 of whom are scientists.

CONTACT

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