Experimental Beamlines of

GSI Materials Research


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**ERDA**
Ion-Beam Analysis

**Cave A**
High Energy

**UNILAC**
3.6-11.4 MeV/u
Range ~ 100µm

**SIS**
up to 2 GeV/u

**X0**
Sample irradiation
Heavy ion irradiation

X0 Autosampler

- Automatic load-lock system
- Defocused beam (5x5cm²)
- Random ion distribution
- Fluence regime: 1 – 1E13 ions/cm²
- Single ion irradiation
- 50 samples per hour (for 1E8 ions/cm² per sample)
Ion track membranes

cigar-shaped pores in PC
funnel-shaped pores
conical pores in Kapton
pores in mica
etch pits in SiO₂
perforated dead-end pores
Heavy-ion beam Microprobe
Heavy-ion beam Microprobe

- Beam switch
- Object aperture
- Deflector
- Lens
- Target
- Hit detector
- Electronic

3m
Heavy-ion beam Microprobe

- Object aperture
- Beam switch
- Deflector
- Lens
- Target
- Hit detector
- Electronic
- 3m
Biology Setup

Fast and perfect dose control

Unsurpassed targeting accuracy
Heavy-ion beam Microprobe

100µm

typ. 20µm
single-ion lithography

- Single ion irradiation
- Accuracy:
  ... in vacuum: below 1µm
  ... into air: 1.5 µm
- Speed: ~ 100 Hz

10,000 ions in regular pattern etched PET
Sample characterization
Off-line techniques at Materials Research

**Spectroscopy**
- UV/Vis & Infrared
  - Polymer Degradation
  - Phase Transition

**Raman**

**Microscopy**
- AFM / STM
- SEM
  - Surface Analysis
  - Shape and Size of Nanopores and -wires

**Profilometry**
- Swelling effects

**Chemistry Lab**
- Template etching

**Laser Spectroscopy**
- Photon relaxation
In-situ and On-line sample characterization
New M-Branch

UNILAC
3.6-11.4 MeV/u

Cave A
M1 – Electron Microscopy

Fixed beam spot size: diameter = 3mm

On-line beam diagnostic (aperture current)
M1 – In-situ SEM

- Zeiss SUPRA 40 high-resolution scanning electron microscope (1.3 nm at 15 keV)
- 5-axes motorised eucentric sample stage
- In-situ imaging without exposing the irradiated sample to air
M2 – In-situ XRD

- Small beam spot
- Scanning ion beam system (extreme homogeneous irradiation with high flux)
- On-line beam diagnostic (aperture current)
• SEIFERT 4-circle x-ray diffractometer (Cu-K\(\alpha\))
• Position sensitive detector
• Investigation under any angle of incidence enables the quantitative analysis of structural modifications
• Amorphization
• Formation of new ion-beam induced phases
• Special orientation texturing
• Variable beam spot size (Slit system with max. 4x4cm²)
• On-line beam monitoring by SETRAM
• Extreme sensitive beam view monitor (down to 1E3 ions/cm²)
Sample curvature detection

Irradiation-induced material stress measured by sample curvature detection

University of Jena (Wesch, Steinbach)
Irradiation-induced outgassing of PTFE

University of Sao Paulo (Delgado)
Transmission FT/IR spectroscopy

• Real on-line measurement possible
• Elimination of errors by sample preparation
M3 – All-in-one chamber

- Cryostat
- UV/Vis and fluorescence
- FT-IR
- Long-distance microscopy
- Sample curvature measurement
- Ion beam
- QMS
- Gas flow controller

Control of irradiation conditions:
- Cryostat
- Gas flow controller and QMS
High temperature irradiation

Sample temperature up to 950 °C (area 4x4cm²)
Within a second BMBF project starting 2010

- On-line Raman spectroscopy
- In-situ AFM in an UHV Chamber
- High energetic ERDA (UHV)
- Photoluminescence
Summary

Sample irradiation …at X0 (random ion distribution)
…at μ-Probe (controlled single-ion irradiation)

Off-line techniques: Electron microscopy, AFM, STM,
optical spectroscopy (Raman, IR, UV/Vis) etc.

On-line and in-situ beamlines at the new M-branch
SEM, XRD, IR etc.

Surface modification
M1 and M3

Structural bulk modification
M2 and M3
Thanks to…

GSI Materials Research group

collaborating Universities of the M-Branch
(Darmstadt, Dresden, Göttingen, Heidelberg, Jena, Stuttgart)

and thanks for your attention!
Dose distribution of swift heavy ions

- Photons
- Ions
Ion track membranes
Track morphology

5.0 keV/nm

0 2 4 6 8 10 12
energy loss (keV/nm)

0 2 4 6 8 10 12
energy (MeV/u)

O Ar Kr

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Track etching

UV treatment

Irradiation

chemical etching
(NaOH, NaOCl, HF)

Kapton
Track etchable POLYMERS

- **PET**: polyethylene terephthalate (Mylar, Hostaphan)
- **PC**: polycarbonate (Lexan, Makrofol, CR39)
- **PI**: polyimide (Kapton, Upilex)
- **PP**: polypropylene
- **PVDF**: polyvinylidene fluoride

30 µm Makrofol N
6M NaOH @ 50 °C
Characteristics: pattern is very sensitive to alignment due to large aspect ratio of pores.
Replica method

- Ion track membrane
- Filling of pores in galvanic cell
- Dissolution of polymer
- Free-standing metal needles