Various beams for RBS at IFIN-HH
Various beams for RBS at IFIN-HH

OVERVIEW RBS

E_{sc}: function of K and dE/dx (mass and depth of target nucleus);

Measured spectrum is the sum for all contribution of constitutive elements;

\[ E = K (E_o - E_{loss}^in) - E_{loss}^out \]
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Specific Analysis Performed

COMPOSITION ANALYSIS:

Ti - 47% ; Ni - 43% ; Nb - 10%
Various beams for RBS at IFIN-HH
Various beams for RBS at IFIN-HH

DEPTH PROFILING OF ELEMENTAL CONCENTRATION:

Experimental and simulated RBS spectra and corresponding calculated concentration for a buried oxygen layer in Si before and after thermal annealing at 1000°C
Various beams for RBS at IFIN-HH

RBS with 2.7MeV He$^+$

Counts

Energy [10keV/ch]

- Si zone
- Buffer Ti layer zone
- Ti layers zone
- Zr layers zone

exp. sim.
Various beams for RBS at IFIN-HH

- For real characterizations different ions, energies and incidence angles are used.

Cyclotron beams used for IBA

<table>
<thead>
<tr>
<th>No.</th>
<th>Ion</th>
<th>Energy (MeV)</th>
<th>Cross section[mm²]</th>
<th>Beam intensity[nA]</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>$^4$He$^+$</td>
<td>2.7-5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>$^2$H$^+$</td>
<td>1.35-2.5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>$^{14}$N$^{+2}$</td>
<td>3</td>
<td>0.25-25</td>
<td>3-100</td>
</tr>
<tr>
<td>4</td>
<td>$^{14}$N$^{+3}$</td>
<td>10</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>$H_2^+$</td>
<td>1.35-2.5</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Experimental and simulated spectra for RBS analysis for 5 pairs of ZrN/TiN layers having 15nm/layer deposited on Si with a Ti buffer layer of 300nm obtained using 2.7MeV He beam (before) and 9.65MeV N beam; the use of N beam lead to better mass separation as well as better depth resolution.
Various beams for RBS at IFIN-HH

What to do for characterization of surface micro-structured materials?

MICRO-BEAMS

There is NEW solution for low cost micro-beams systems

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**Diagram:**
- **Helium** (He) with energy 3 MeV
- **Sample** analysed by RBS
- **Metallic holder**
- **Tapered glass capillary**
- Dimensions: 15mm, 50mm, 60mm
Various beams for RBS at IFIN-HH

- FOCUSING OF MeV ION BEAMS BY TAPERED GLASS CAPILARIES

RESULTS (estimate of focusing effect)

<table>
<thead>
<tr>
<th></th>
<th>$I_{IN}$ [nA]</th>
<th>$J_{IN}$ [nA/mm²]</th>
<th>$I_{OUT}$ [nA]</th>
<th>$J_{OUT}$ [nA/mm²]</th>
<th>Gain [$J_{OUT}/J_{IN}$]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Collimator 3mm</td>
<td>60</td>
<td>8,48</td>
<td>60</td>
<td>8,48</td>
<td>1</td>
</tr>
<tr>
<td>Capillary 2/0,15mm</td>
<td>26,66*</td>
<td>8,48</td>
<td>6</td>
<td>339,5</td>
<td>40</td>
</tr>
<tr>
<td>Capillary 2/0,08mm</td>
<td>26,66*</td>
<td>8,48</td>
<td>3</td>
<td>596,8</td>
<td>70,38</td>
</tr>
</tbody>
</table>

* Beam intensities at the input of capillaries are reduced proportional to the cross sections ratio (4/9).

NOTE: Measured currents are only approximations of real ones, possible contributions of electron currents being neglected!
Various beams for RBS at IFIN-HH

- FOCUSING OF MeV ION BEAMS BY TAPERED GLASS CAPILLARIES

- Low energy ions of Ne$^7+$ are guided through capillary tubes even for small angles of misalignment with the beam axis (N. Stolterfoht et al., Phys. Rev. Lett. 88, 133201/2002)
- The transmitted beam of 8keV Ar$^8+$ through a tapered glass capillary need some tens of seconds to reach its maximum of intensity (T. Ikeda et al., Phys. Rev. Lett. 89, 163502/2006)
Various beams for RBS at IFIN-HH

FOCUSING OF MeV ION BEAMS BY TAPERED GLASS CAPILARIES

RESULTS (energy spectrum of transmitted beam)

RBS spectra for a thick Au sample obtained with direct (a) and transmitted (b) beam
Various beams for RBS at IFIN-HH

- FOCUSING OF MeV ION BEAMS BY TAPERED GLASS CAPILLARIES

EXPERIMENTAL SETUP

Experimental setup for the transmission of 3MeV He beam through a tapered glass capillary

Conical glass capillary and its mounting fixture used in beam focusing experiments
Various beams for RBS at IFIN-HH

- FOCUSING OF MeV ION BEAMS BY TAPERED GLASS CAPILARIES
Various beams for RBS at IFIN-HH

FOCUSING OF MeV ION BEAMS BY TAPERED GLASS CAPILARIES

RESULTS (energy spectrum of transmitted beam)

RBS spectrum for a layered sample of Au$_{100}$nm-Cr$_{16}$nm-Si$_{thick}$ obtained with 3MeV He ions transmitted through a conical capillary ($\Phi_{out}=0.08$mm)

The two RBS spectra shows two components of transmitted beam:
- an undisturbed beam (initial energy and energy dispersion are conserved)
- a fraction of the initial beam having a large energy dispersion
Various beams for RBS at IFIN-HH

RESULTS (energy spectrum of transmitted beam)

Experimental and simulated RBS spectra with transmitted beam of 2.9MeV He through 60\,\mu m tapered glass capillary for a 50nm Au layer on Al substrate.
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RESULTS (energy spectrum of transmitted beam)

Deduced energy spectrum for transmitted beam through 60μm glass capillary; the undisturbed fraction of the beam is app. 50%
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RESULTS (energy spectrum of transmitted beam)

Transmitted beam with proper alignment (up) and misalignment (down)

RBS analysis of Au on Al sample with aligned (point) and misaligned beam (halo)
Various beams for RBS at IFIN-HH

- FOCUSING OF MeV ION BEAMS BY TAPERED GLASS CAPILARIES

Beam profile

- BEAM
- Zn (background)
- W wire (20µm)
Various beams for RBS at IFIN-HH

- FOCUSING OF MeV ION BEAMS BY TAPERED GLASS CAPILARIES

Beam profile

![Beam profile graph](image)

- Data: Data1_R
- Model: Lorentz
- Equation: \( y = y_0 + \frac{(2/A)\pi}{(w/2)^2/(x-x_c)^2 + w^2)} \)
- Weighting: y
- No weighting
- \( \chi^2/\text{DoF} = 0.00085 \)
- \( R^2 = 0.99488 \)

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
<th>Error</th>
</tr>
</thead>
<tbody>
<tr>
<td>( y_0 )</td>
<td>-0.07363</td>
<td>±0.01835</td>
</tr>
<tr>
<td>( x_c )</td>
<td>0.17453</td>
<td>±0.0013</td>
</tr>
<tr>
<td>( w )</td>
<td>0.00333</td>
<td>±0.00531</td>
</tr>
<tr>
<td>( A )</td>
<td>0.13659</td>
<td>±0.0069</td>
</tr>
</tbody>
</table>

Horizontal beam profile

- 80 µm
Various beams for RBS at IFIN-HH

- FOCUSING OF MeV ION BEAMS BY TAPERED GLASS CAPILARIES

Divergence of the beam
Various beams for RBS at IFIN-HH

FOCUSING OF MeV ION BEAMS BY TAPERED GLASS CAPILARIES

Measured divergence for 200\(\mu\)m out capillary = 6mrad
Various beams for RBS at IFIN-HH

FOCUSING OF MeV ION BEAMS BY TAPERED GLASS CAPILARIES

RESULTS (transmitted beam)

Visualization of transmitted beam at 60mm (left) and 360mm (right) distance from the output of glass capillary.
Various beams for RBS at IFIN-HH

- FOCUSING OF MeV ION BEAMS BY TAPERED GLASS CAPILARIES

Wire: 60 micron
- Beam circa 50 micron

Contacts (Au)
- 500 micron
Various beams for RBS at IFIN-HH

FOCUSING OF MeV ION BEAMS BY TAPERED GLASS CAPILARIES
Various beams for RBS at IFIN-HH

Conclusion:
Even a cyclotron is not dedicated for RBS, we can achieve interesting results

Further steps:
Standardization of (simple) RBS for our customers (EN17025)
More detailed studies on capillary focusing and new applications with “micro” beams
New analyzing chamber with better adjustment possibilities
Channeling experiments
New accelerator (tandem) is planned
Various beams for RBS at IFIN-HH

Thank you for your attention