Ion Beam Analysis

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Aim

• To determine the elemental composition of thin films on the surface solid Target
• Enables technology for thin film scientists and engineer
• Possible applications are:
  – Microelectronics
  – Forensic etc.
Part 1: Accelerator & PIXE

Van de Graaff Accelerator

Energy gain = qV
Maximum Voltage
≈ 25 MV

9/24/2014
Parameters of EG-5 Accelerator

- Energy Region: 0.9-3.5 MeV
- Beam intensity for H\(^+\): 30\(\mu\)A
- Beam intensity for He\(^+\): 10\(\mu\)A
- Energy Spread < 500 eV
- Number of beam lines: 6
PIXE- Particle Induced X-ray Emission Method

• Proton beams are mainly used
  – Ionization of atom
  – Si(Li) Detector
  – Energy resolution about 150eV
Moseley’s law

Moseley law

\[ \sqrt{\frac{\nu}{R_c}} = \frac{Z - S_n}{n} \]

- \( Rc \) – Rydberg’s constant
- \( Z \) – atomic number
- \( Sn \) – screening constant
- \( n \) – main quantum number
- \( \nu \) – frequency of X-ray quantum
PIXE Results

Sample N1
$E_p = 2.005$ MeV

Energy, keV

X-Ray yield

Si, S, Cl, K, Ca, Ba, Fe, Mn, Cu, Zn, As, Sr, Zr
Aerosol analysis by PIXE & RBS

<table>
<thead>
<tr>
<th>Element</th>
<th>Concen. At. %</th>
<th>Method</th>
<th>Element</th>
<th>Concen. At. %</th>
<th>Method</th>
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<tbody>
<tr>
<td>C</td>
<td>41</td>
<td>RBS</td>
<td>K</td>
<td>0.1</td>
<td>PIXE</td>
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<tr>
<td>N</td>
<td>20.5</td>
<td>RBS</td>
<td>Ca</td>
<td>0.53</td>
<td>RBS</td>
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<tr>
<td>O</td>
<td>28</td>
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<td>Mn</td>
<td>0.007</td>
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<tr>
<td>F</td>
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<tr>
<td>Mg</td>
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</tr>
<tr>
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<tr>
<td>Si</td>
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<td>Sr</td>
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<tr>
<td>Cl</td>
<td>0.01</td>
<td>PIXE</td>
<td>Ba</td>
<td>0.01</td>
<td>PIXE</td>
</tr>
</tbody>
</table>
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Part 2: RBS-Rutherford Backscattering Spectrometry Method

- Near-surface layer analysis of solids
- Elemental composition
- Depth profiling of individual elements
- Very sensitive for heavy elements
- Less sensitive for light elements
Experimental chamber
RBS

• Kinematic Factor

\[ K = \frac{M_1^2}{(M_1 + M_2)^2} \left\{ \cos \theta \pm \left[ \left( \frac{M_2}{M_1} \right)^2 - \sin^2 \theta \right]^{1/2} \right\}^{1/2} \]

• Cross-section

\[ \sigma_i = \left( \frac{Z_1 Z_i e^2}{2 E \sin^2 \theta} \right)^2 \left\{ \cos \theta + \left[ 1 - \left( \frac{M_1}{M_i} \right)^2 \sin^2 \theta \right]^{1/2} \right\}^{1/2} \left[ 1 - \left( \frac{M_1}{M_i} \right)^2 \sin^2 \theta \right]^{1/2} \]
Program used for the analysis of experimental results was SIMNRA

Experimental condition

- Calibration
  - Offset=27.95keV
  - Energy/channel=2.185

- Number of particles
  - 1.56E11

- Thickness
  - Nb =161nm
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Part 3: ERD - Elastic Recoil Detection

- Forward Recoil
- Good for light elements (H, D)
- Al foil
RBS

Counts vs. channel

- Experimental curve
- Simulated curve

Elements:

- **C**: 41% (Experimental), 45% (Simulated)
- **H**: 19% (Experimental), 13% (Experimental), 13.5% (Simulated), 19% (Simulated)
- **Si**: 40% (Experimental), 42% (Simulated), 40% (Simulated)
Conclusion

• Three methods were used in order to obtain information about elements depth contents for different elements from hydrogen to barium

• Sensitivity of method for heavy elements less than 0.001 atomic %
Acknowledgements

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From left to right : Dr A.P Kobzev, Sintwa Nolufundo, Luhkwa Rendani, Sinazo Mselana and Dr Mirosław Kulik