EDS Detectors and How They Work

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2024
Outline

• Background
• EDS Detector Components
• EDS Detectors at NUANCE
EDS Background
What is EDS?

Energy Dispersive X-ray Spectroscopy

EDS

EDX
Secondary Electrons

Backscatter electrons

Characteristic X rays

Bremsstrahlung Radiation
## X-ray Analysis Techniques

<table>
<thead>
<tr>
<th></th>
<th>In</th>
<th>Out</th>
<th>Info</th>
</tr>
</thead>
<tbody>
<tr>
<td>EDS</td>
<td>Electrons</td>
<td>X-rays</td>
<td>Elemental comp.</td>
</tr>
<tr>
<td>WDS</td>
<td>Electrons</td>
<td>X-rays</td>
<td>Elemental comp.</td>
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<td>XRF</td>
<td>X-rays</td>
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<td>XRD</td>
<td>X-rays</td>
<td>X-rays</td>
<td>Crystal Structure</td>
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<tr>
<td>XPS</td>
<td>X-rays</td>
<td>Electrons</td>
<td>Elemental comp/Electronic State</td>
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</tbody>
</table>
EDS Detector Components
EDS Detector Assembly

“Detector”

Cooling

Preamplifier

Pulse Processor

Multichannel Analyzer and Display
EDS Detector Assembly

- "Detector"
- Cooling
- Preamplifier
- Pulse Processor
- Multichannel Analyzer and Display
The Detector

1. Collimator
   - A limiting aperture/cap
   - So stray X-rays don’t get detected

2. Electron Trap
   - A pair of magnets that deflects away electrons
   - It reduces background, minimizes artifacts, prevents sensor damage over time.

3. Window
   - Protective barrier/film between crystal and environment.
   - Prevents contamination on the sensor/crystal and helps maintain vacuum.

4. Crystal (sensor)
   - (Si) Semiconductor
   - Interacts with or “senses” the X-rays
## Windows

<table>
<thead>
<tr>
<th>Type</th>
<th>Name</th>
<th>Thickness</th>
<th>Material</th>
<th>Advantage</th>
<th>Disadvantage</th>
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<tbody>
<tr>
<td>None</td>
<td>Windowless</td>
<td>0</td>
<td>None</td>
<td>No absorption</td>
<td>Contaminates, light artifacts</td>
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<tr>
<td>Be</td>
<td>Beryllium</td>
<td>~7 μm</td>
<td>Be</td>
<td>Robust</td>
<td>Absorption below Na</td>
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<tr>
<td>UTW</td>
<td>Ultra-thin window</td>
<td>300 nm</td>
<td>Polymer</td>
<td>Low-absorbing</td>
<td>Breaks easily</td>
</tr>
<tr>
<td>ATW</td>
<td>Atmospheric thin window</td>
<td>300 nm</td>
<td>Polymer on grid</td>
<td>Low absorbing and robust</td>
<td>Less effective area (most used)</td>
</tr>
</tbody>
</table>
Crystal (the sensor)
Conduction Band

Valence Band
\[ \frac{3.9 \text{ keV}}{3.8 \text{ eV}} = 1030 \text{ electrons} \]

\[-1.65 \times 10^{-16} \text{ C} \]
Crystal (the sensor)
Si(Li)

• Pell (1960) developed process to create detector crystal made to behave like intrinsic silicon.
• Li is highly mobile and can be diffused or "drifted" into Si.
• General idea:
  ➢ Silicon: 4 valence e-
  Boron: 3 valence e- (common impurity):
  Lithium : 1 valence e-
  ➢ Si + B = extra holes, +
  Si + B + Li = neutralized holes
• Problems:
  ➢ Liquid nitrogen needed to reduce thermal noise and Li diffusion
Crystal (the sensor)
Silicon Drift Detector

- Proposed in 1983 by Gatti & Rehak
- High purity silicon
- Pattern of nested ring electrodes with small central anode on backside.
- Less electrode and anode area, smaller path length, more uniform electric field.
  ➢ More counts in less time, less noise, less cooling needed!
EDS Detector Assembly

- "Detector"
- Cooling
- Preamplifier
- Pulse Processor
- Multichannel Analyzer and Display
**Si(Li)**

Liquid nitrogen

~ $-200 \, ^\circ C$

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**SDD**

Peltier Cooling

~ $-20 \, ^\circ C$
EDS Detector Assembly

“Detector”

Cooling

Preamplifier

Pulse Processor

Multichannel Analyzer and Display
Preamplifier

- converts the accumulated charge at the anode into a voltage signal.
- Field Effect Transistors (FETs) or Charge Sensitive Preamplifiers (CSPs)
- Sources of charge
  - Current leakage from applied bias
  - X-ray induced charge to be measured
EDS Detector Assembly

“Detector”

Cooling

Preamplifier

Pulse Processor

Multichannel Analyzer and Display
Pulse processing

- Digitizes the voltage input from the preamplifier
- Optimize and removes noise on x-ray signal
- Differentiates between events arriving at detector close together

Fig. 15. Measurement of steps on a voltage ramp by averaging differing numbers of measurements of the signal. (a) Short $T_p$ permits all steps to be measured, but the variation of each measured step is large, so the X-ray energy is not measured accurately and peaks show poor resolution. (b) Long $T_p$ means that some steps arrive too close together to be measured. However, noise averaging is better and therefore peaks show better resolution.
“Detector”

Cooling

Preamplifier

Pulse Processor

Multichannel Analyzer and Display
Multichannel Analyzer
Specific EDS Detectors at NUANCE
<table>
<thead>
<tr>
<th></th>
<th>Hitachi S-3400</th>
<th>Hitachi S-4800</th>
<th>Hitachi SU8030</th>
<th>Quanta 650</th>
<th>JEOL 7900</th>
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<tbody>
<tr>
<td>OI INCA x-act</td>
<td>OI INCA x-sight</td>
<td>OI X-Max</td>
<td>OI ULTIM MAX</td>
<td>OI ULTIM MAX</td>
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<tr>
<td>SDD</td>
<td>Si(Li)</td>
<td>SDD</td>
<td>SDD</td>
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<tr>
<td>10 mm²</td>
<td>30 mm²</td>
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<tr>
<td>130 eV</td>
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<tr>
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<tr>
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<td>• Linescan</td>
<td>• Large Area</td>
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<tr>
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<td>Cryo Stage</td>
<td>STEM</td>
<td>EBSD</td>
<td>WDS</td>
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<td>STEM</td>
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<td>Hot Stage</td>
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Items to consider

• Size vs Solid Angle
• Energy resolution
Items to consider

- Size vs Solid Angle
- Energy resolution
Items to consider

- Size vs Solid Angle
- Energy resolution
Thank you!

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Register for a virtual EDS training today!