Diamond detector for a portable $\alpha$-particle spectrometer

$\triangleright 1^{st}$ ADAMAS workshop $\triangleleft$

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1 Motivation.
   - Identification of alpha-particle emitting nuclides.
   - A portable alpha spectrometer

2 Diamonds for Nuclear Spectroscopy.
   - Thin sample of 50µm.
   - Energy resolution.

3 Continuous Air Monitoring Detector form CANBERRA
   - Si detector with special entrance window.
   - Designed for working in harsh environment.

4 Comparison between detectors
   - Working in air
   - and with incident light.
Motivation

The need
- Illegal transport of radioactive material is becoming a problem.
- Rapid methods to identify possible radioactive materials are needed.
- Rather difficult to achieve for alpha particle due to its short range.

What’s in the market
- No-portable stations, auxiliary equipment, some need a NIM crate.
- Main manufactures: ORTEC & CANBERRA.
- Quite costly piece of equipment.

Requirements
- Relatively small dimensions and weight.
- Able to work in air and with light background.
- Low energy consumption.
Single crystal Diamond Detector (Sc-DD)

Sc-DD 50 µm properties

- **Type**: Single crystal
- **Thickness**: 50 µm
- **Size**: 4.5 mm × 4.5 mm
- **Contact**: DLC/Pt/Al (3/16/200 nm)
- **Capacitance**: 24 pF (GSI)
- **Energy resolution**: 29 keV (at GSI) for 50 V bias.
- Manufactured by Diamond Detector LTD (2011)
## CAM properties

<table>
<thead>
<tr>
<th>MODEL</th>
<th>CAM450</th>
</tr>
</thead>
<tbody>
<tr>
<td>Active Area (mm(^2))</td>
<td>450</td>
</tr>
<tr>
<td>Junction Area (mm(^2))*</td>
<td>531</td>
</tr>
<tr>
<td>Active Diameter (mm)</td>
<td>23.9</td>
</tr>
<tr>
<td>Thickness (min/max)</td>
<td>120/325 µm</td>
</tr>
<tr>
<td>Bias (min/max)</td>
<td>+10/90 V</td>
</tr>
<tr>
<td>Bias (typical)</td>
<td>+24/70 V</td>
</tr>
<tr>
<td>Si-Resistivity (min)</td>
<td>3000 Ohm • cm</td>
</tr>
<tr>
<td>Operation Temp. (min/max)</td>
<td>-30/+50 °C</td>
</tr>
<tr>
<td>Storage Temp. (max)</td>
<td>+100 °C</td>
</tr>
<tr>
<td>Alpha Resolution at 15-24 V (FWHM – in keV) in vacuum</td>
<td>38</td>
</tr>
<tr>
<td>Alpha Resolution at 70 V (FWHM – in keV)</td>
<td>34</td>
</tr>
<tr>
<td>Alpha Background (counts/day)</td>
<td></td>
</tr>
<tr>
<td>Beta Resolution at 70 V (FWHM)</td>
<td>17</td>
</tr>
<tr>
<td>Beta Threshold at 70 V</td>
<td>51</td>
</tr>
</tbody>
</table>
Leakage current with incident light

Sc-DD Leakage current measurement

- Measurements with light on/off.
- at 20 °C and 55 % RH.
- Keithly 6517B Electrometer.
- Light has minimum effect on leakage current.

CAM specs from Canberra.
Energy resolution in air

Exposing detectors to room light

- Spectra taken at Extremadura (left) and Huelva (right) Universities.
- $\alpha$-source distance 1 cm. Bias: 24 V (CAM), 50 V (Sc-DD).
- Both detectors are able to detect the alpha emissions in air.
Energy resolution in air

CAM vs Sc-DD

Detectors working in air
- CAM Si detector
- Diamond detector

Table: Energy resolution (keV).

<table>
<thead>
<tr>
<th></th>
<th>CAM</th>
<th>Sc-DD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vacuum</td>
<td>130</td>
<td>70</td>
</tr>
<tr>
<td>Air</td>
<td>299</td>
<td>120</td>
</tr>
</tbody>
</table>

- Both detectors plugged in to the same electronic chain.
- Total exposure time 10 minutes.
Conclusions & future work

Conclusions
- Thin diamond detector can definitely be used for $\alpha$ & $\beta$ ID.
- Don’t need special entrance window (work in open air with light).
- Harsh environments are not an issue.
- Main drawback may be the size, which will affect the absolute efficiency (greater area gets more hits).

Future work
- Increase the size using a “good” thin Pc-DD (Ø 25 mm).
- Design a proper housing for this application.
- Integrate the electronics as much as possible.