Inexpensive solid state radiation detector
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Abstract

Traditional technologies for environmental radioactivity measurement such as Geiger counters are relatively expensive and can be difficult to obtain (e.g., there was a worldwide shortage after the 2011 Fukushima incident). They also require a high voltage supply (100-1000V) and only provide a simple particle count rate.

Here we present a low cost (£100), miniaturised (5x5 cm) detector based on solid state technology. It runs at low voltage (from 9V), low current (a few tens of mA) and can interface with a mobile phone or computer via Bluetooth or USB. Unlike other types of solid state radiation detector, it does not need to be cooled. It is capable of simple discrimination between different radioactivity types and energies.

Operating principle

The radiation detector uses a 1cm2 PiN type diode. Energetic particles ionise the depletion layer inside the detector and cause a pulse of current. The height of the pulse is usually proportional to energy.

Although the operating principle is simple, carefully designed electromagnetic screening and signal conditioning circuitry are needed to keep the device’s cost and size down. This work has been partially motivated by the poor performance of other similar devices currently on the market.

Device description

The detector was tested in a lead castle, Fig 6. The lead excludes all gamma radiation and only lets energetic cosmic ray particles reach the detector.

Testing – response to different particles

To compare the response to gamma rays versus cosmic rays, the detector was tested in a lead castle, Fig 6. The lead excludes all gamma radiation and only lets energetic cosmic ray particles reach the detector.

Expected response

The radiation detector can, in principle, respond to all types of ionising radiation. In practice, some types of low-energy particle are excluded by the sensor enclosure or the noise threshold of the signal conditioning circuitry. The predicted response is shown in Table 1.

<table>
<thead>
<tr>
<th>Type and origin of particle</th>
<th>Expected response</th>
<th>Detected?</th>
<th>Energy info?</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alphas, betas</td>
<td>Cannot penetrate sensor enclosure</td>
<td>✗</td>
<td>✗</td>
</tr>
<tr>
<td>Low-energy gammas (&gt;100 keV) or X rays</td>
<td>Probably below detector noise floor</td>
<td>✗</td>
<td>✗</td>
</tr>
<tr>
<td>Energetic gammas (&gt;100 keV)</td>
<td>Detected inefficiently via Compton scattering</td>
<td>✔</td>
<td>✔</td>
</tr>
<tr>
<td>Energetic particles, e.g., from cosmic rays or solar storms</td>
<td>Detected efficiently by ionisation if &gt;1 MeV</td>
<td>✔</td>
<td>✔</td>
</tr>
</tbody>
</table>

Table 1 Expected response of PiN detector to different types of particle

In summary, the detector is expected to:
- Count and give energy information for gamma radiation and high-energy ionising particles such as protons
- Count very high-energy ionising particles such as cosmic ray muons

Testing – energy response

The detector was tested with three radioactive sources, each emitting characteristic gamma rays. To reduce the complication associated with 22Na emitting two gammas of different energies (Table 2), the detector was placed under 12mm of lead, which removes about 45% of the 0.511MeV gammas (e.g., Knoll, 2010).

<table>
<thead>
<tr>
<th>Radioactive source</th>
<th>Characteristic gamma energies (MeV)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cobalt-60</td>
<td>1.17, 1.33</td>
</tr>
<tr>
<td>Sodium-22</td>
<td>0.511, 1.275</td>
</tr>
<tr>
<td>Cesium-137</td>
<td>0.661</td>
</tr>
</tbody>
</table>

Table 2 Gamma-ray emissions from radioactive sources

Fig 5 shows that the detector can resolve different gamma energies. The error in the 22Na point is from the contribution of 0.511 MeV gammas. This contribution could be straightforwardly removed by using a different source or slightly modifying the experiment.

References


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