Study of surface contamination on ultralow background (ULB) materials

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Low Radioactivity Techniques 2019
Detector components and surrounding materials: a significant background source

SuperCDMS SNOLAB detector
The usual suspects

Uranium-238

Thorium-232

Potassium-40
Validation of all materials: a challenging task

→ Extremely stringent radiopurity requirements

- Ultra sensitive analytical techniques
- Meticulously clean analytical procedure specifically developed
- Dedicated facilities
- R&D to develop ultrapure materials (*i.e.*, electroformed copper)

For reference:

<table>
<thead>
<tr>
<th>1 ppt Th</th>
<th>4.1 mBq/kg</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 ppt U</td>
<td>12.4 mBq/kg</td>
</tr>
</tbody>
</table>
After validation, will materials remain “ultraclean” forever?

→ Surface contamination!

- Manufacturing and processing
- Handling for assembly
- Machining
- Moving and storage
- Exposure to dust, even in clean rooms!
ICP-MS: a powerful tool

- Direct, fast, quantitative
- Surface and bulk

- Understanding
- Identifying rather than observing (too late!)
- Quantifying and controlling
Machining, handling, exposure to dust

Block of HDPE:
- 1850 g
- 1600 cm²

-2845 ng, or 2.8 µg, of $^{232}\text{Th}$ to account for
Manufacturing and processing

Flex cable

<table>
<thead>
<tr>
<th>PI/Cu laminate</th>
<th>$^{232}$Th</th>
<th>$^{238}$U</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>$8.06 \pm 6.30$</td>
<td>$8.72 \pm 3.43$</td>
</tr>
</tbody>
</table>

| Finished cable (whole sample analysis) | $62.8 \pm 5.2$ | $6164 \pm 112$ |

2% HNO$_3$ solution, 30 sec

Leachate analysis, normalized to sample mass

<table>
<thead>
<tr>
<th>From leach 1</th>
<th>$232$Th</th>
<th>$238$U</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>$40.4 \pm 3.0$</td>
<td>7071 ± 1065</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>From leach 2</th>
<th>$232$Th</th>
<th>$238$U</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>$2.29 \pm 0.13$</td>
<td>$40.2 \pm 12.9$</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>From leach 3</th>
<th>$232$Th</th>
<th>$238$U</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>$1.34 \pm 0.58$</td>
<td>$16.5 \pm 5.8$</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Leached sample</th>
<th>$232$Th</th>
<th>$238$U</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>$35.4 \pm 2.9$</td>
<td>$55.1 \pm 16.6$</td>
</tr>
</tbody>
</table>
Exposure to dust: direct measurement of dust activity

- Surface exposure
- Surface leaching
- Quantitative analysis

PFA (Perfluoroalkoxy alkane)
For reference $1 \text{ fg} = 10^{-15} \text{ g}$
K ~ 1.4 E+4 ppm
Th ~ 7.2 ppm
U ~ 1.2 ppm

K ~ 99.94 %
Th ~ 0.051%
U ~ 0.009%

Room air – Class 10000 clean room comparison

- Accumulation rate scaling of 100X, as expected
- Exposure in a Class 10 area (30 days): instrumental background level

PFA surface, 30 day exposure
2.8 μg of $^{232}$Th (→ ~1g dust???) on HDPE block surface
- Removed with specific cleaning procedure
- ICP-MS → material assay at ppt levels, not an upper limit

~6 ng g$^{-1}$ of $^{238}$U measured in a flex cable
- Leaching + ICP-MS:
  - Identification: $^{238}$U localized on the surface
  - Reduction: 1$^{st}$ 30 sec mild leaching pulled out all $^{238}$U surface contamination

ICP-MS: first direct measurement of dust activity
- Relative contribution from K, Th and U
- Deposition rate
In conclusion

- Surface contamination: a potentially limiting source of background

How can we support ULB detectors?

- ICP-MS: a very powerful technique
  - Rapid, direct identification and quantitation
  - Developing procedures to control and reduce:
    - Cleaning
    - Working with manufacturer

- Dust activity measurement
  - Contribution to contamination from exposure to dust (even in clean rooms!)
  - Study of contribution in significant locations
    - Valuable for planning assembly and installation of detectors
    - Collaboration with underground labs, work in progress for a publication
Thank you

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Khadouja Harouaka

DOE Detector R&D for High Energy Physics (KA-25)
BACK UP SLIDES
1 year exposure in a Class 10000 clean room

Si wafer
Surface ~ 700 cm²
Thickness 0.77 mm
Density 2.33 g cm⁻³

https://www.svni.com/silicon-wafers/300mm-wafers/