Follow-up Multicenter Alpha Counting Comparison

Jeff Wilkinson, Brett M. Clark, Richard Wong, Yi He, Charles Slayman, Michael Gordon, Jennifer Marckmann, Brendan McNally and Tommy Wu
α particles – Why do they matter?

• Alpha particles are directly ionizing, causing soft errors when striking a cell’s sensitive volume.
• Emitted from packaging or IC materials.
How much material is $2 \alpha / \text{khr/cm}^2$?

- ULA materials require ppb impurity levels
- This includes the cleanliness of all manufacturing processes that could contaminate these materials.
- For $^{210}\text{Po}$ contamination a ULA value of 0.002 cm$^{-2}$ hr$^{-1}$ implies 20 atoms/cm$^2$ which is a few pps (parts per sextillion).

*Clark, LBCF workshop, Minneapolis, MN, 2005*
• Ionization and proportional counters have similar construction, differing in the detection method and counting gas that is used.
• Large format counters and samples (1000 cm$^2$) are required to achieve reasonable counting times.
• Particles ionize the counting gas and electrons drift to anodes, forming the output pulse for counting.
• Counting efficiencies range from about 80% to 95%.
• Alphas emitted from non-sample locations, count gas impurities, or from cosmic ray secondaries add to the background signal.
• Beta particle (electron) can result in crosstalk signal.
• Typical background rates are similar to ULA emission rates.
Experiment & Samples

- 9 participating centers, varying equipment.
- LA samples are aluminum alloy, ULA is high purity titanium.
- Each center used its own count methodology.

- LA and ULA samples circulated in round-robin to each center for multiple measurements.

Wilkinson et al., Multicenter comparison of alpha particle measurements…, IRPS 2010
Selected LA Results (Round 1)

- Mean emissivity spans more than 2X.

Repeated measurements at a single center agree with each other.

- No evidence of sample instability.

Wilkinson et al., Multicenter comparison of alpha particle measurements..., IRPS 2010
ULA Results (Round 1)

- Large counting uncertainties can mask any differences in mean values or systematic errors in background determination.
- Variation is more extreme than for LA samples.

*Wilkinson et al., Multicenter comparison of alpha particle measurements…, IRPS 2010*
Conclusions from Round 1

• Alpha emissivity measurements are repeatable at a single lab for LA and ULA sources, within the measurement uncertainty.

• Comparing LA emissivity values between labs is subject to >2X variability.

• Extrapolating LA accelerated test methods to predict soft error rates should be done cautiously.

• A suitable emissivity standard is needed for proper calibration of instruments.
Possible Role of Threshold

- Alphas are created at discrete energies.
- An $\alpha$ traversing a “thick” source (>10 $\mu$m) loses energy creating a continuous energy spectrum incident on the counter.

Low energy threshold is set to reject electronic noise and beta emission.

A sample dependent fraction of the low energy alphas will also be rejected.
Purpose – Round 2

Do differences in the low energy thresholds explain the measurement differences observed in Round 1?
Round 2 Samples

- Ceramic sample should duplicate Round 1 results.
- $^{230}$Th surface deposited sample will not lose counts to low energy threshold. Emission certified by vendor.
- 9 participants, one lost dataset.
# Results from Ceramic Sample

Ceramic Emissivity

<table>
<thead>
<tr>
<th>Sample</th>
<th>Min</th>
<th>Max</th>
<th>Mean (µ)</th>
<th>S.D. (σ)</th>
<th>COV</th>
<th>Max/Min (σ/µ)</th>
</tr>
</thead>
<tbody>
<tr>
<td>R1 LA</td>
<td>20.2</td>
<td>45.5</td>
<td>30.8</td>
<td>9.3</td>
<td>30%</td>
<td>2.3</td>
</tr>
<tr>
<td>R2 #1</td>
<td>13.7</td>
<td>29.9</td>
<td>21.8</td>
<td>5.9</td>
<td>27%</td>
<td>2.2</td>
</tr>
</tbody>
</table>

Very comparable to Round 1 LA measurements.
Results for $^{230}$Th Sample

$^{230}$Th Emissivity

- Similar variability for observed for $^{230}$Th sample.
- Inconsistent with threshold hypothesis.

<table>
<thead>
<tr>
<th>Sample</th>
<th>Min</th>
<th>Max</th>
<th>Mean ($\mu$)</th>
<th>S.D. ($\sigma$)</th>
<th>COV</th>
<th>Max/Min ($\sigma/\mu$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>R2 #1</td>
<td>13.7</td>
<td>29.9</td>
<td>21.8</td>
<td>5.9</td>
<td>27%</td>
<td>2.2</td>
</tr>
<tr>
<td>R2 #2</td>
<td>63.2</td>
<td>106</td>
<td>88.0</td>
<td>14.6</td>
<td>17%</td>
<td>1.7</td>
</tr>
</tbody>
</table>
Adjusted $^{230}$Th Sample Results

$\eta = 1$

Results are now a good match to certified emission value for F.

All measurements are now at or below certified value, suggesting that loss mechanisms are at work.
Window Gap as Loss Mechanism

- For a windowed counter some alphas are lost while traversing the gap below the entrance window.
- Variation in the gap dimension leads to a measurement specific efficiency loss.
- Participants were surveyed following analysis to determine the likely gap during measurement.
**Post hoc** Gap Analysis

Measured Efficiency of Windowed Counter vs. Entrance Gap

\[
f(gap) = 0.871 - 0.0290 \cdot gap
\]

<table>
<thead>
<tr>
<th>ID</th>
<th>Gap (mm)</th>
<th>(\eta_{est.})</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>2.5</td>
<td>83%</td>
</tr>
<tr>
<td>B</td>
<td>?</td>
<td>--</td>
</tr>
<tr>
<td>C</td>
<td>n/a</td>
<td>100%</td>
</tr>
<tr>
<td>D</td>
<td>2.3</td>
<td>84%</td>
</tr>
<tr>
<td>E</td>
<td>6</td>
<td>72%</td>
</tr>
<tr>
<td>F</td>
<td>n/a</td>
<td>100%</td>
</tr>
<tr>
<td>G</td>
<td>1.0</td>
<td>88%</td>
</tr>
<tr>
<td>H</td>
<td>n/a</td>
<td>100%</td>
</tr>
</tbody>
</table>

- Observed variability may largely be explained by losses in reported gaps.
- Measurement C (36% low) is still unexplained.
- Additional loss mechanisms are described in paper.
Conclusions

• Emissivity measurements for low alpha materials continue to demonstrate substantial variability between centers.
• Measurement of ultralow alpha materials is likely to be equally difficult.
• Entrance gap losses may explain much of the variation in these measurements.

• A suitable emissivity standard is still needed for proper calibration and monitoring of instruments.
Acknowledgements

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