Beryllium Capsule Processing Improvements – Polishing and Mandrel Removal

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Beryllium has been of interest as an ablator but overall quality needs improvement

- Beryllium is a promising ablator material due to its low x-ray opacity, high tensile strength, and high thermal conductivity.

- Beryllium capsule quality currently lags behind other ablators due to inner surface roughness, sphericity, argon content, crystallinity, etc.

Total production time = ~13 weeks
The coating process produces rough capsules and they must be polished.

**As-Deposited Capsules**

**Polished Capsules**

White Light Interferometry

Ra = 149 nm

Ra = 13 nm

Optical Images
The current polishing method utilizes a lapper

- Quick process (~3 days) but capsules can get stuck, producing facets
- Yield was ~50%
- Process has been improved by using different fixture/capsule slots as they wear down
The polishing process may introduce mid-mode roughening.

- Coating and polishing affect mid- and high-modes.
- As-deposited capsules cannot be characterized with AFM due to high roughness.

Typical AFM Data of GDP Mandrel

Typical AFM Data of Polished Be Capsule
Wet tumble polishing is being explored as an alternative

- Two diamond slurries are used: 3-5 µm and 0-0.2 µm finishing slurry
- Can achieve <15 nm Ra surface roughness
- Shells cannot get stuck
- Ready for production qualification
Power spectra of test capsules do not change significantly in the mid-mode region

As-Deposited

| Modes 2-6: 1.44 | Modes 7-12: 2.28 | Modes 13-25: 2.54 |

5 Days of Polishing

| Modes 2-6: 1.38 | Modes 7-12: 1.74 | Modes 13-25: 1.78 |

2 Weeks of Polishing

| Modes 2-6: 1.51 | Modes 7-12: 1.79 | Modes 13-25: 1.44 |
Current oxygen mandrel burnout causes inner surface defects

- Mandrels removed with oxygen at 380°C over 2-3 days
- Prior studies have shown temperature to be a strong driver for surface roughness
Concentration gradients can diffuse at oxygen mandrel removal conditions

<table>
<thead>
<tr>
<th>As-Deposed Be Capsule With Stepped Cu Dopant Profile</th>
<th>Dopant Diffusion After Mandrel Burnout</th>
</tr>
</thead>
<tbody>
<tr>
<td>Higher Ar</td>
<td></td>
</tr>
<tr>
<td>0.0 at% Cu</td>
<td></td>
</tr>
<tr>
<td>0.4 at% Cu</td>
<td></td>
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<tr>
<td>0.7 at% Cu</td>
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</tbody>
</table>

• Problem has been solved for stepped dopant profiles but still relevant for concentration gradients

*Images taken from H. Huang’s (GA) 54th annual APS DPP presentation*
We are exploring ozone etching as an alternative mandrel removal method.

- **Hotfinger** is held at 300°C while room temperature O₃/O₂ mixture flows over it
  - O₃ λ<sub>RT</sub> = 3 days, λ<sub>300°C</sub> = <1.5 sec
- Slower process – up to 2 weeks processing time
Current mandrel removal process can cause cracking in metal gradient Be capsules
Mass loss is similar between 10 µm and 15 µm drill holes

- Results suggest reaction rate limitation
Outer surface does not roughen with ozone burnout

White Light Interferometry Image of Capsule Before Ozone Burnout

White Light Interferometry Image of Capsule After 1 Week of Ozone Burnout

Ra = 13 nm

Ra = 13 nm
Ozone burnout sometimes leaves residue

Incomplete

Incomplete

Complete
Summary

• **Tumble polishing**
  – Cannot damage shells by introducing facets but processing time increases up to 2 weeks

• **Ozone mandrel removal**
  – Reduces processing temperature and preserves inner/outer surface quality but increases processing time up to 2 weeks

• **Tumble finishing and ozone mandrel removal are promising processing methods that will likely increase yield and quality of capsules**