Beryllium Capsule Processing Improvements – Polishing and Mandrel Removal

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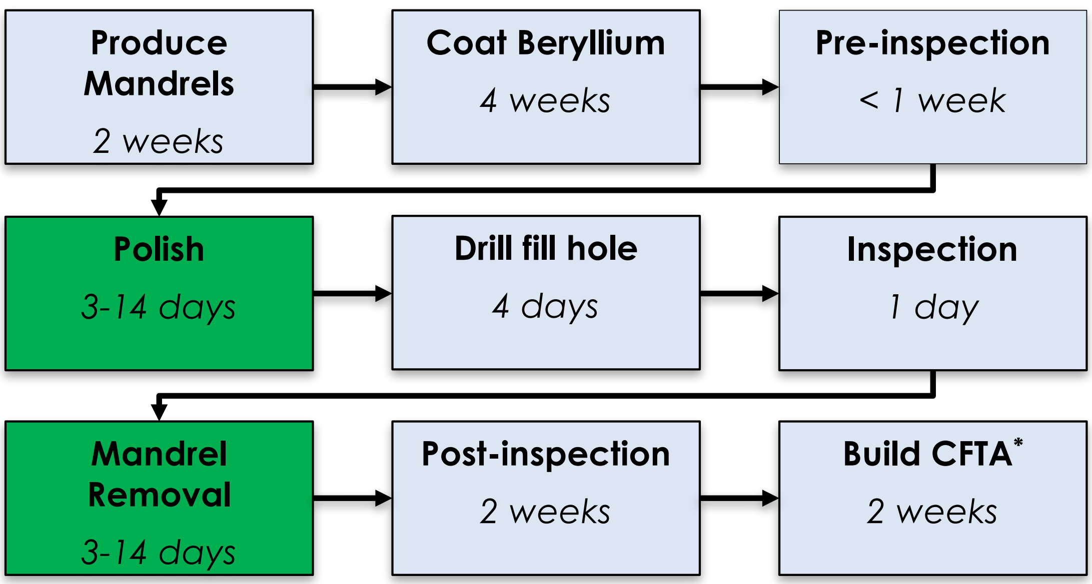
GENERAL ATOMICS

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

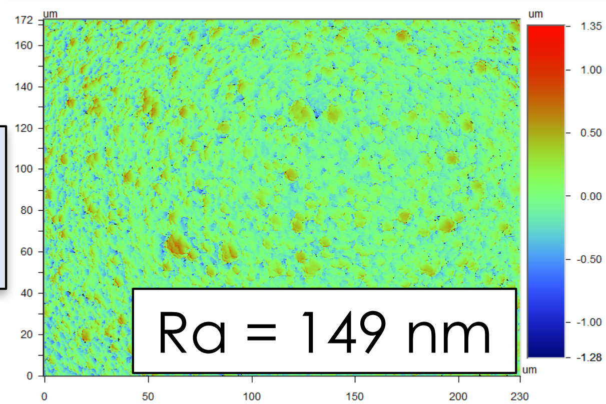
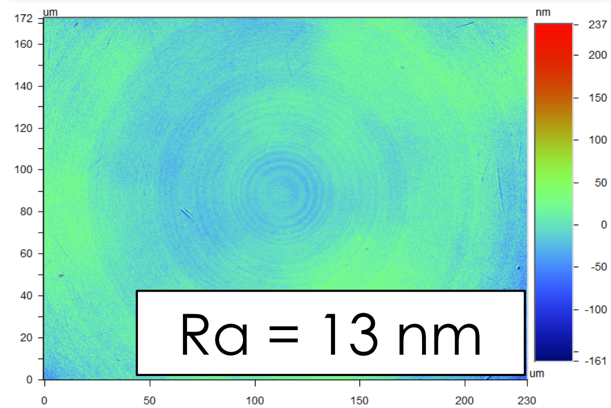
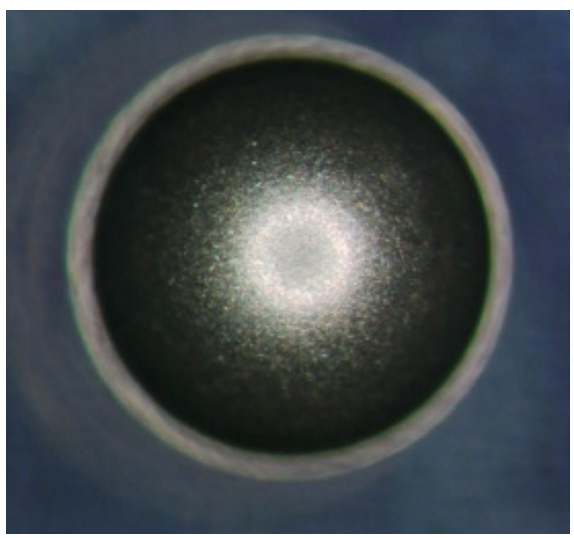
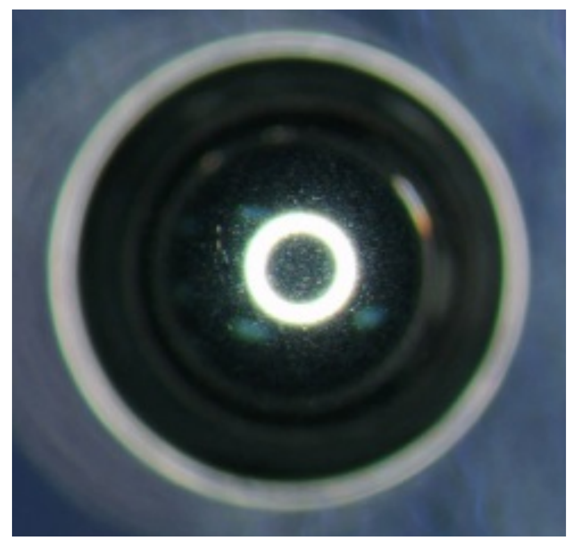
- **Beryllium is a promising ablator material due to its low x-ray opacity, high tensile strength, and high thermal conductivity**
- **Beryllium capsule quality currently lags behind other ablators due to inner surface roughness, sphericity, argon content, crystallinity, etc.**



Total production time = ~13 weeks

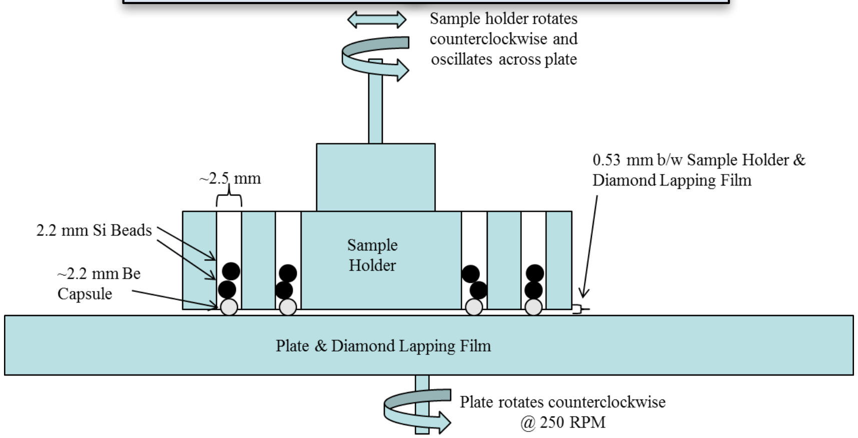
*Capsule fill tube assembly

The coating process produces rough capsules and they must be polished

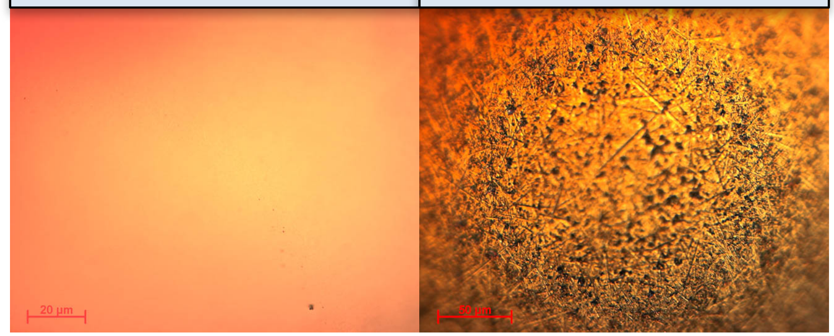
	As-Deposited Capsules	Polished Capsules
White Light Interferometry		
Optical Images		

The current polishing method utilizes a lapper

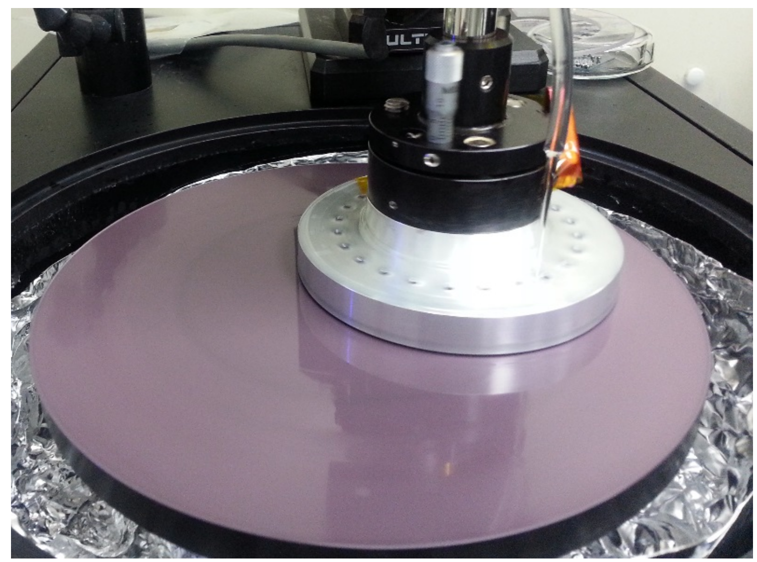
Lapper Polishing Diagram



Fresh Si Bead	Used Si Bead

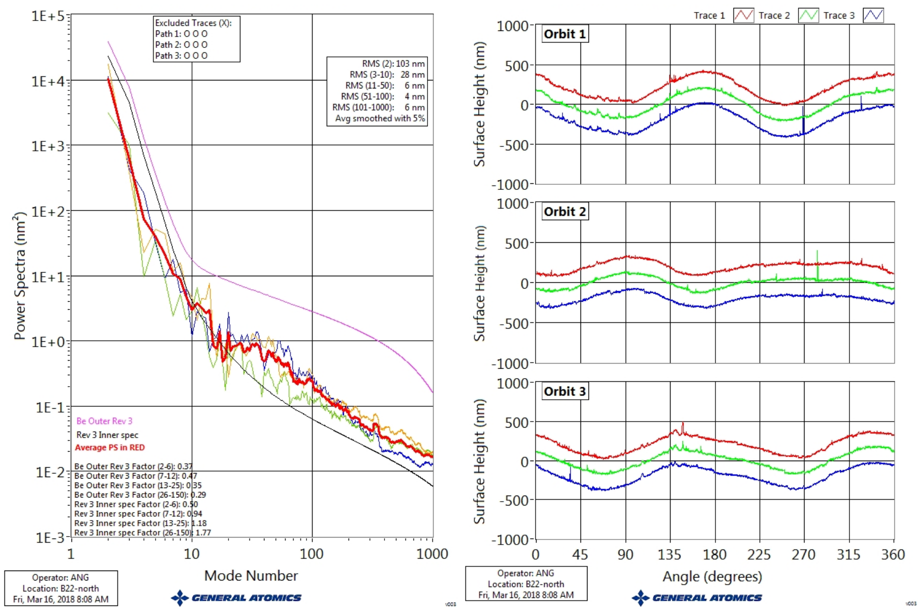


- Quick process (~3 days) but capsules can get stuck, producing facets
- Yield was ~50%
- Process has been improved by using different fixture/capsule slots as they wear down

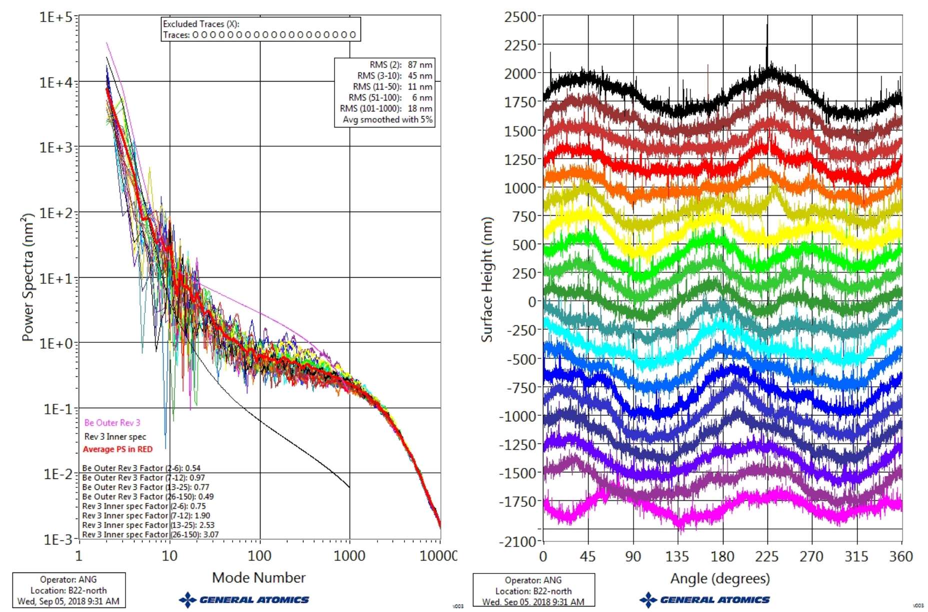


The polishing process may introduce mid-mode roughening

Typical AFM Data of GDP Mandrel



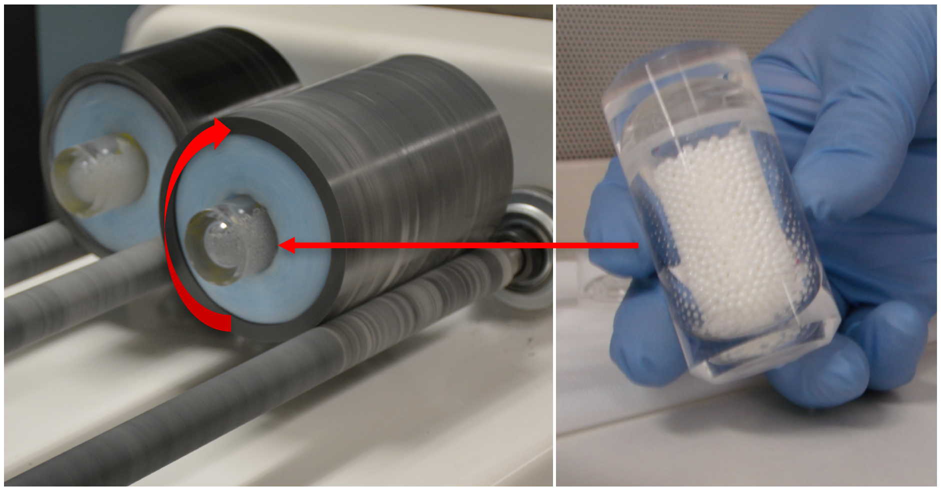
Typical AFM Data of Polished Be Capsule

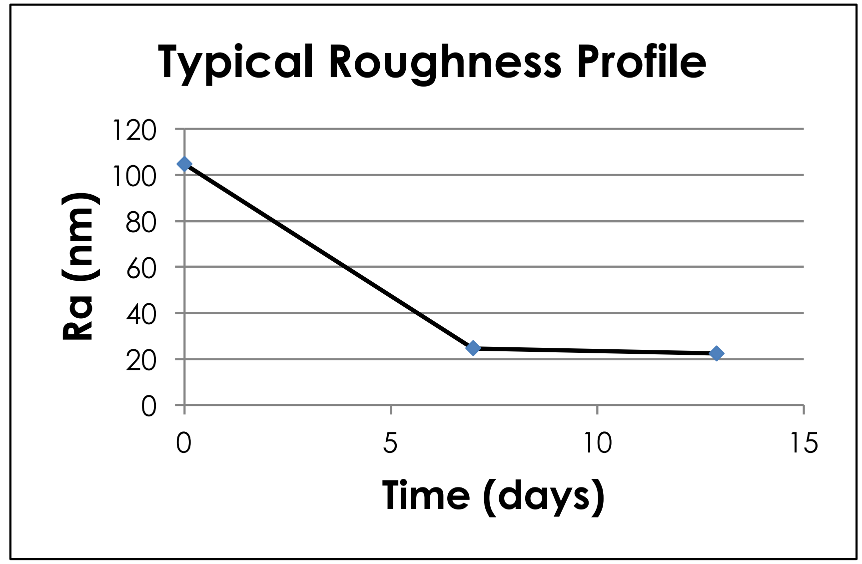


- Coating and polishing affect mid- and high-modes
- As-deposited capsules cannot be characterized with AFM due to high roughness

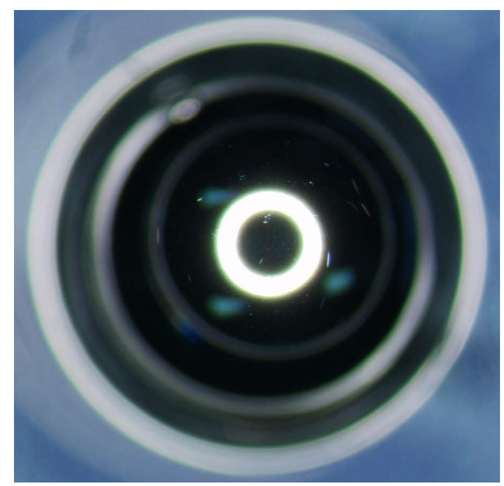
GENERAL ATOMICS

Wet tumble polishing is being explored as an alternative



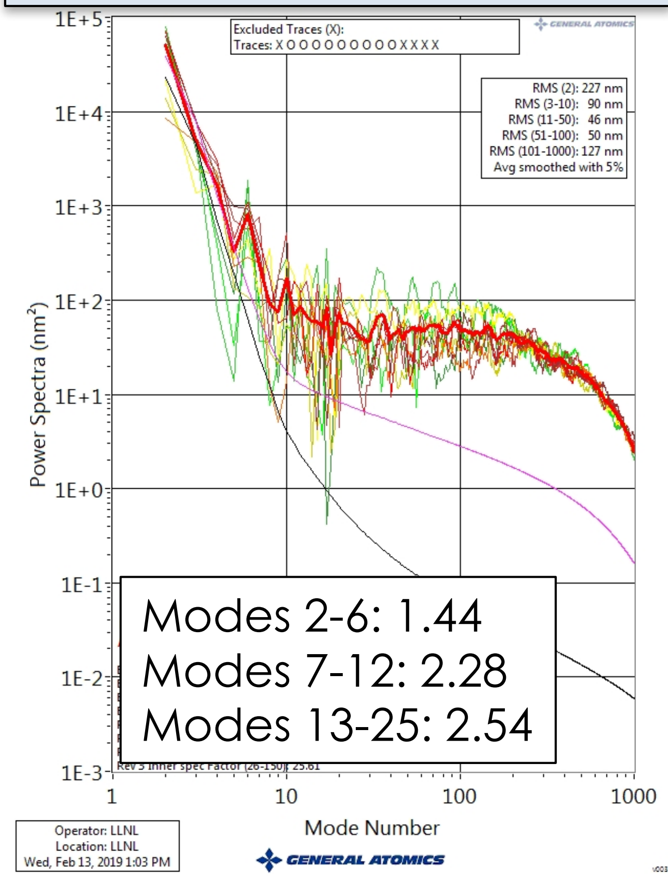


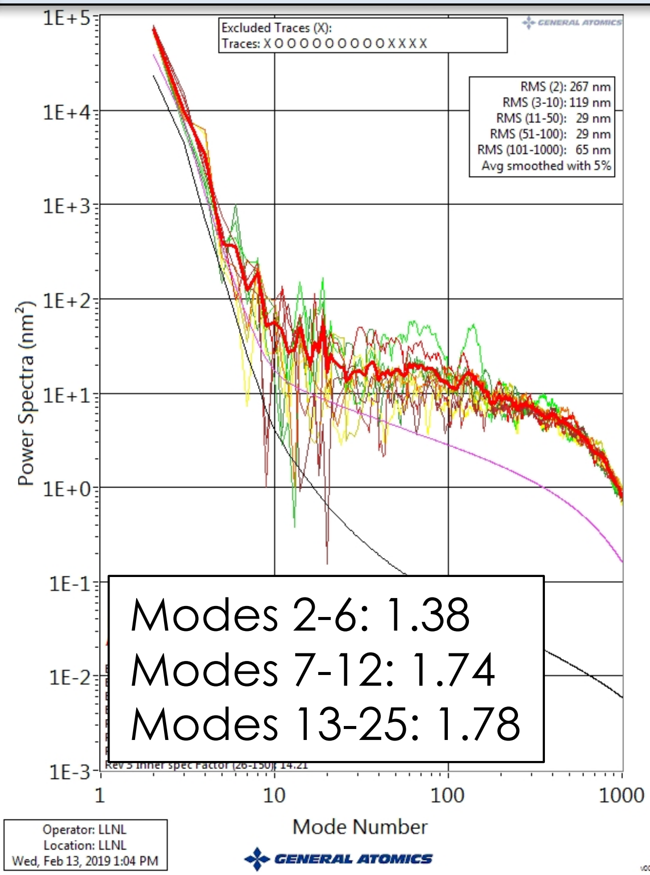
- Two diamond slurries are used: 3-5 μm and 0-0.2 μm finishing slurry
- Can achieve <15 nm Ra surface roughness
- Shells cannot get stuck
- Ready for production qualification

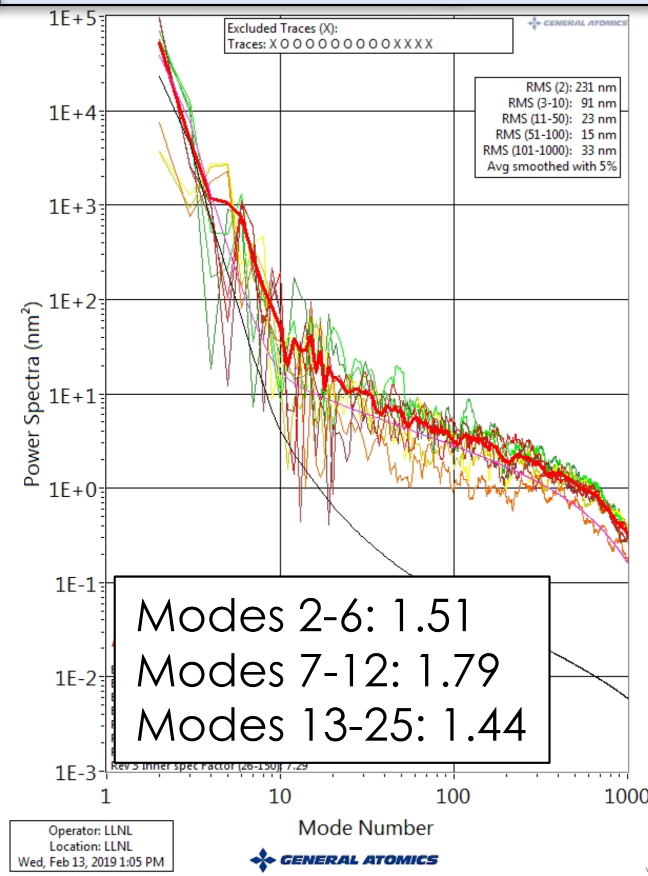


Power spectra of test capsules do not change significantly in the mid-mode region

As-Deposited	5 Days of Polishing	2 Weeks of Polishing

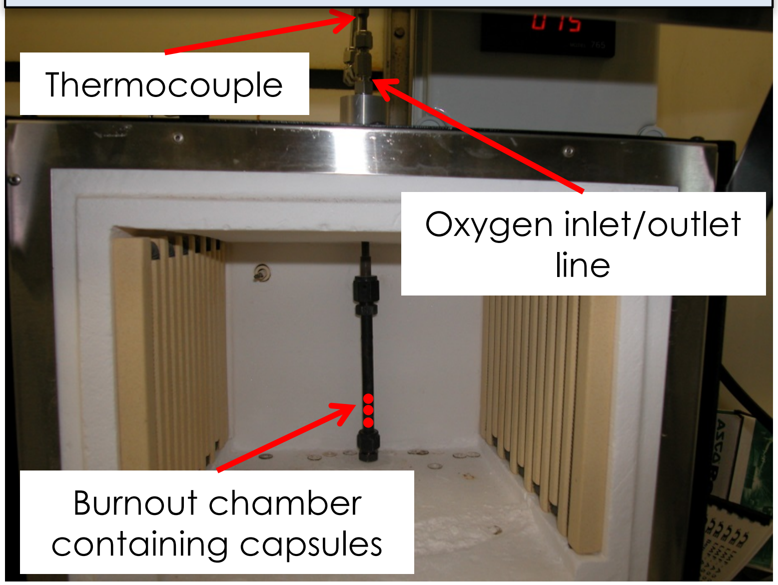




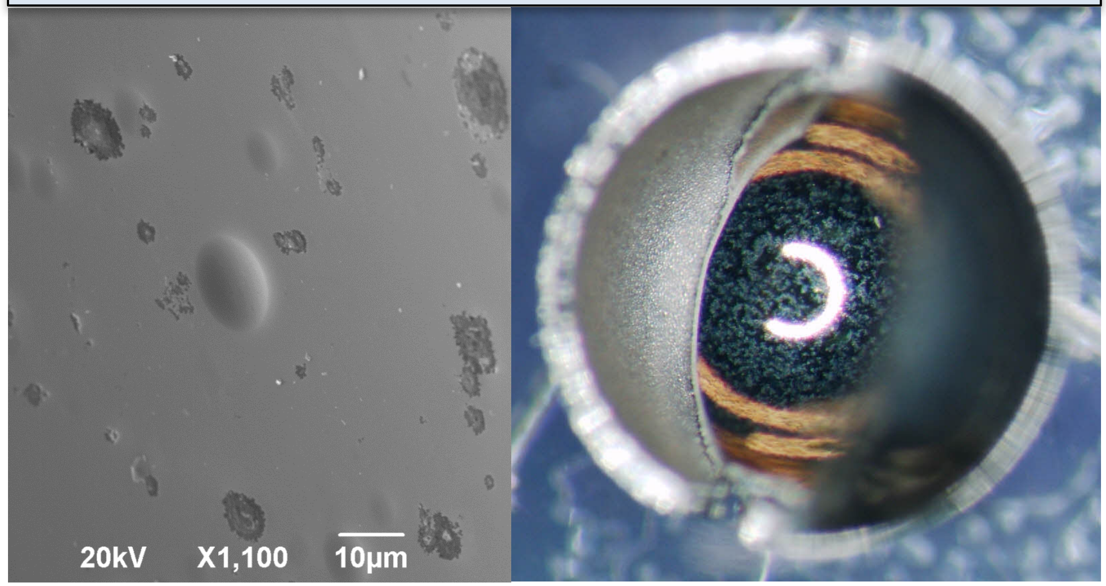


Current oxygen mandrel burnout causes inner surface defects

Oxygen Mandrel Removal Setup



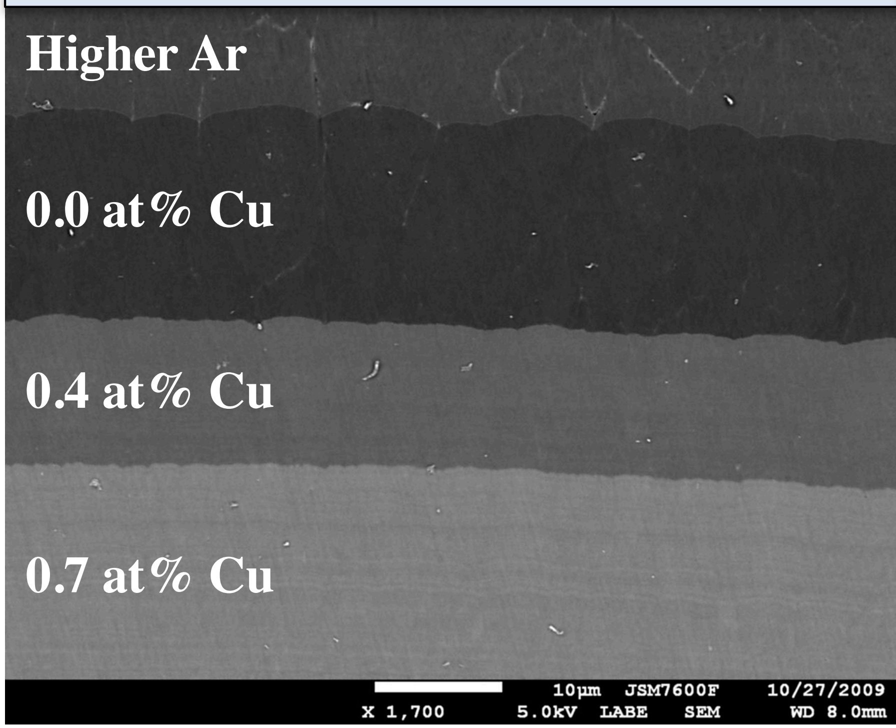
SEM/Optical Image of Capsule That Underwent Oxygen Mandrel Removal



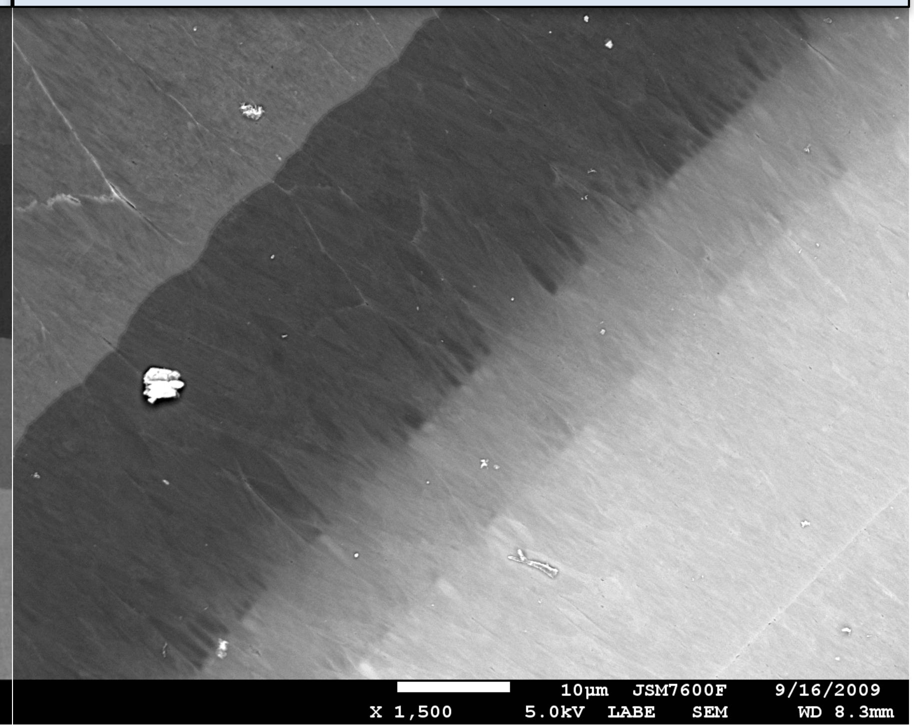
- **Mandrels removed with oxygen at 380˚C over 2-3 days**
- **Prior studies have shown temperature to be a strong driver for surface roughness**

Concentration gradients can diffuse at oxygen mandrel removal conditions

As-Deposited Be Capsule With Stepped Cu Dopant Profile



Dopant Diffusion After Mandrel Burnout

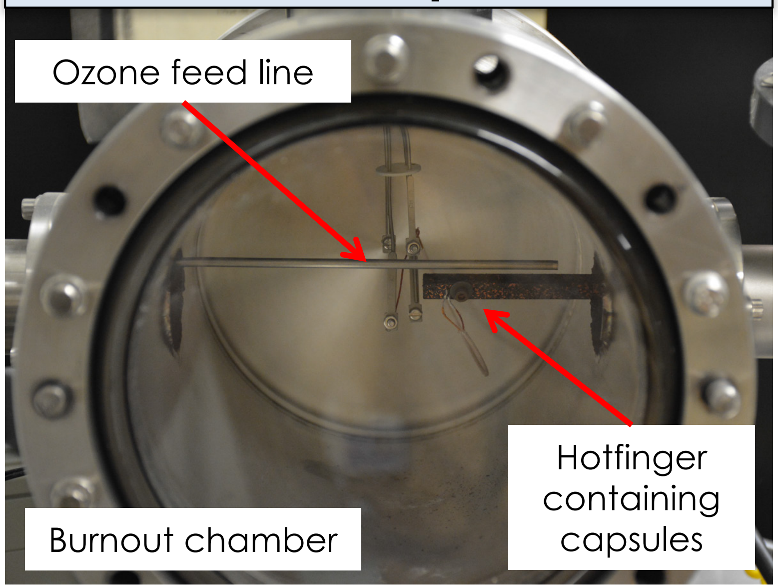


- **Problem has been solved for stepped dopant profiles but still relevant for concentration gradients**

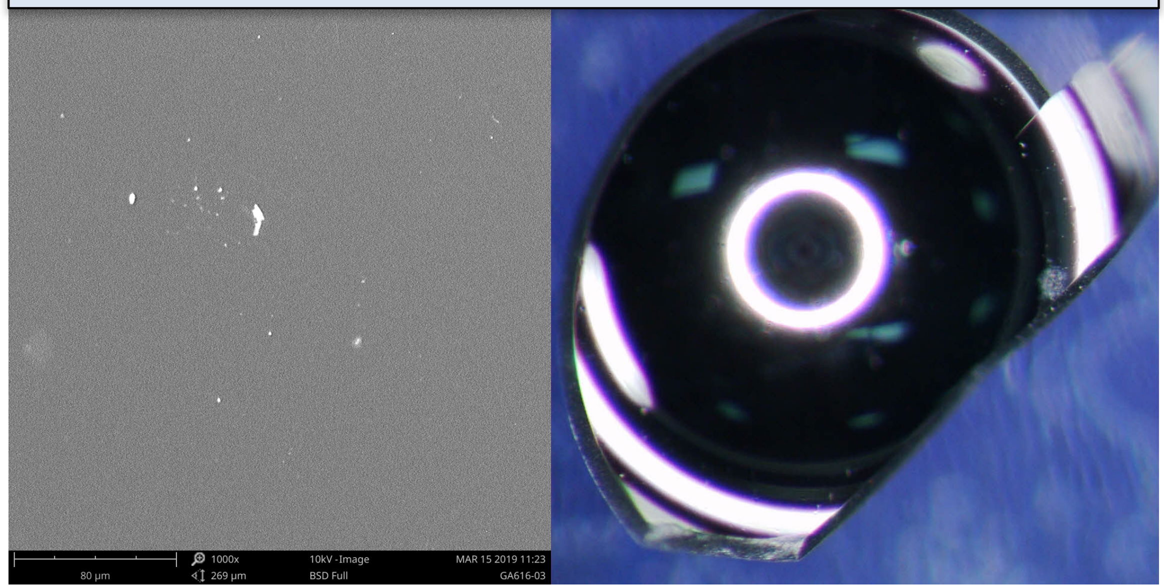
*Images taken from H. Huang's (GA) 54th annual APS DPP presentation

We are exploring ozone etching as an alternative mandrel removal method

Ozone Mandrel Removal Setup



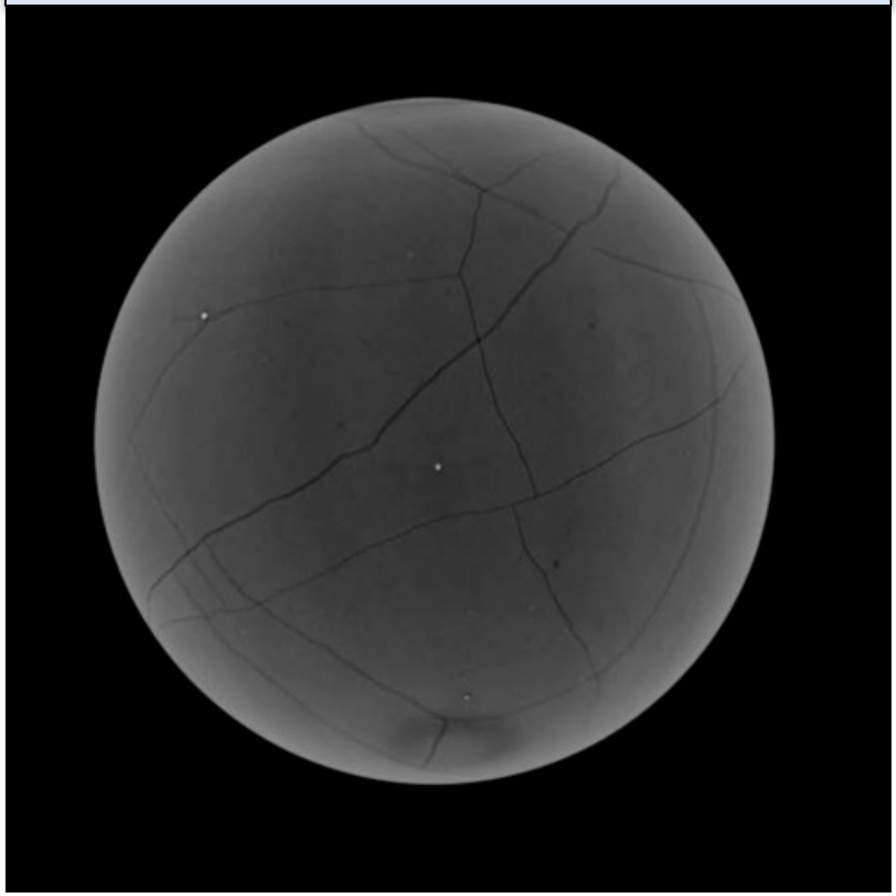
SEM/Optical Image of Capsule That Underwent Ozone Mandrel Removal



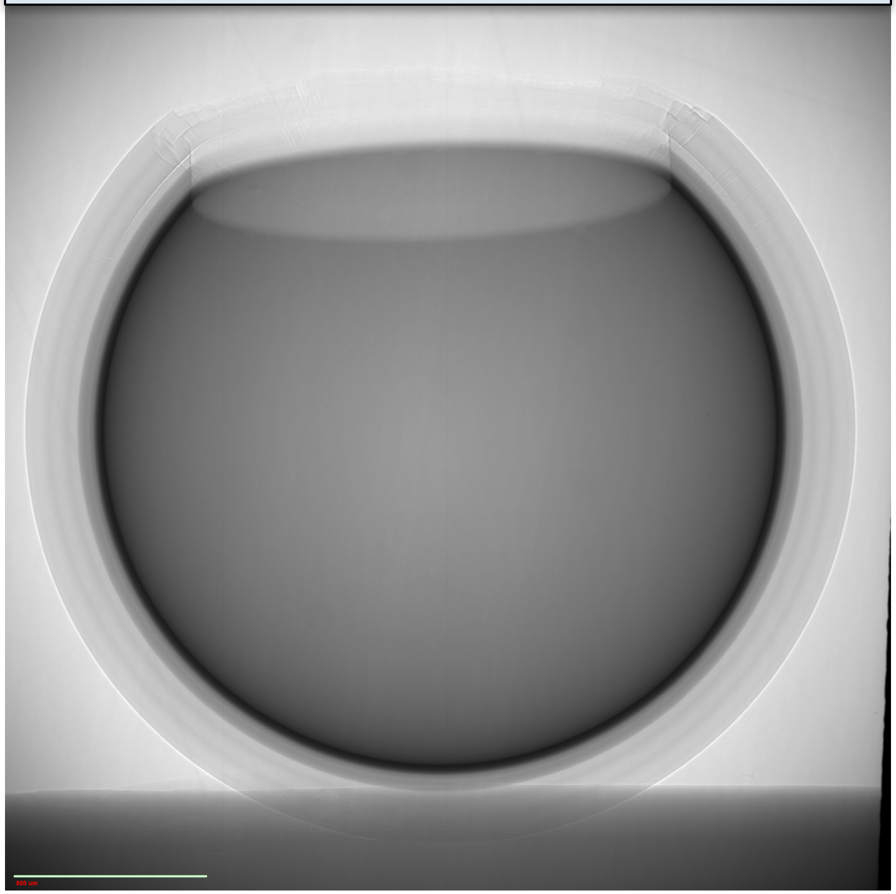
- **Hotfinger is held at 300˚C while room temperature O_3/O_2 mixture flows over it**
  - O_3 λ_{RT} = 3 days, $\lambda_{300^\circ C}$ = <1.5 sec
- **Slower process – up to 2 weeks processing time**

Current mandrel removal process can cause cracking in metal gradient Be capsules

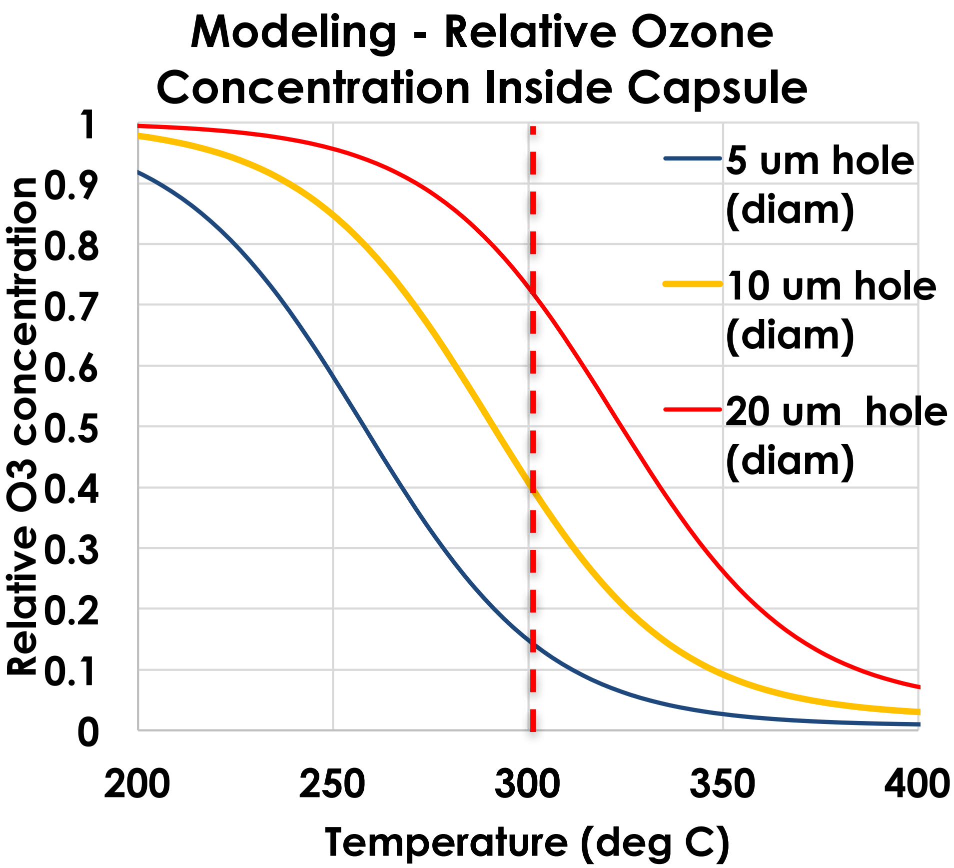
X-Ray Image of Be/Cr Graded Capsule – Oxygen Burnout

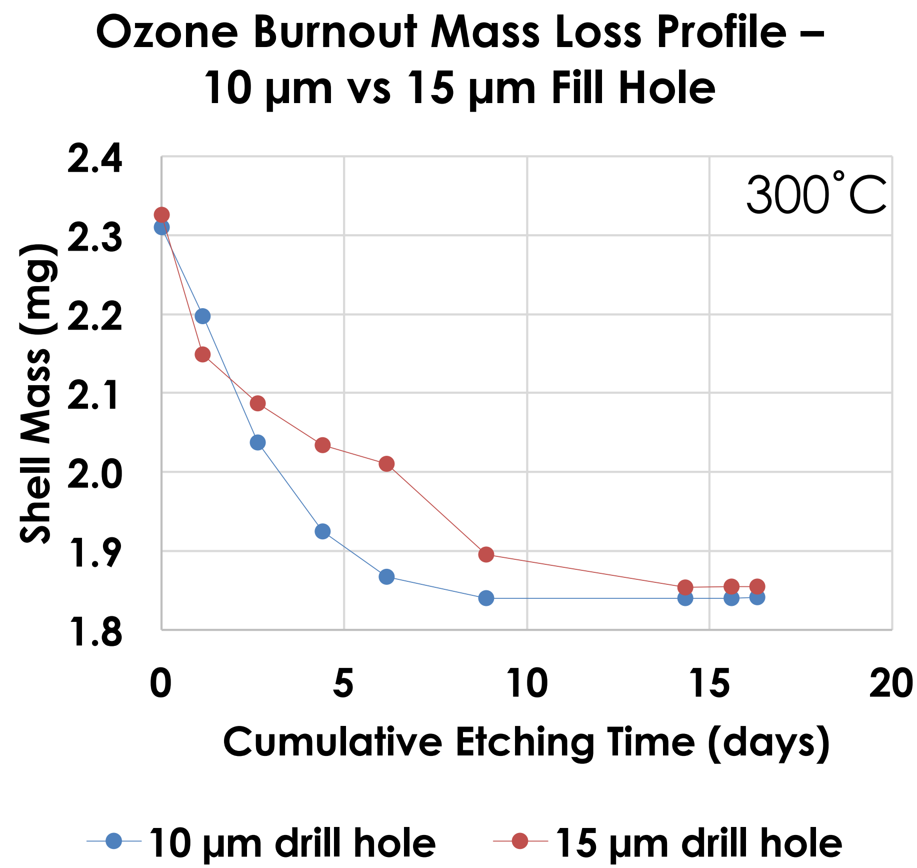


X-Ray Image of Be/Cr Graded Keyhole Capsule – Ozone Burnout



Mass loss is similar between 10 μm and 15 μm drill holes

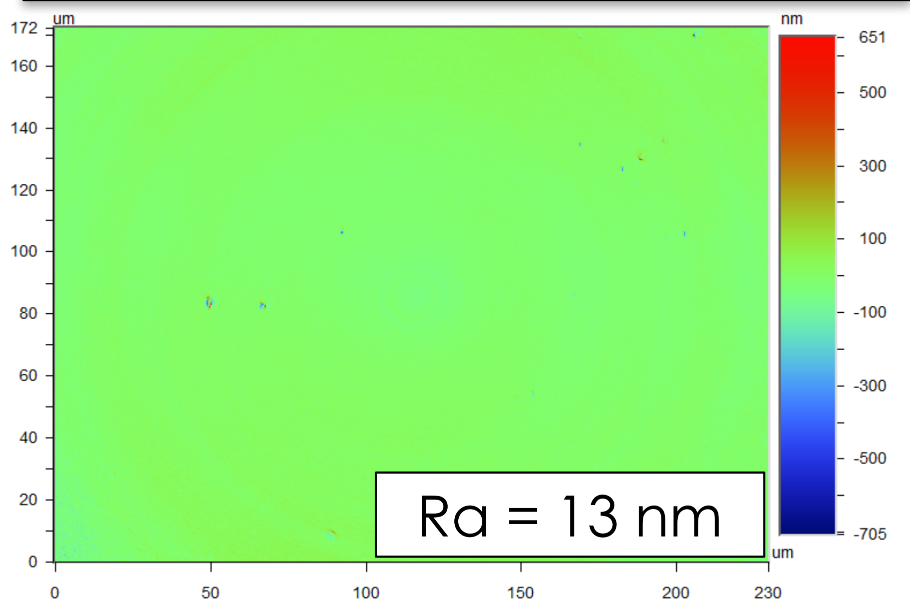




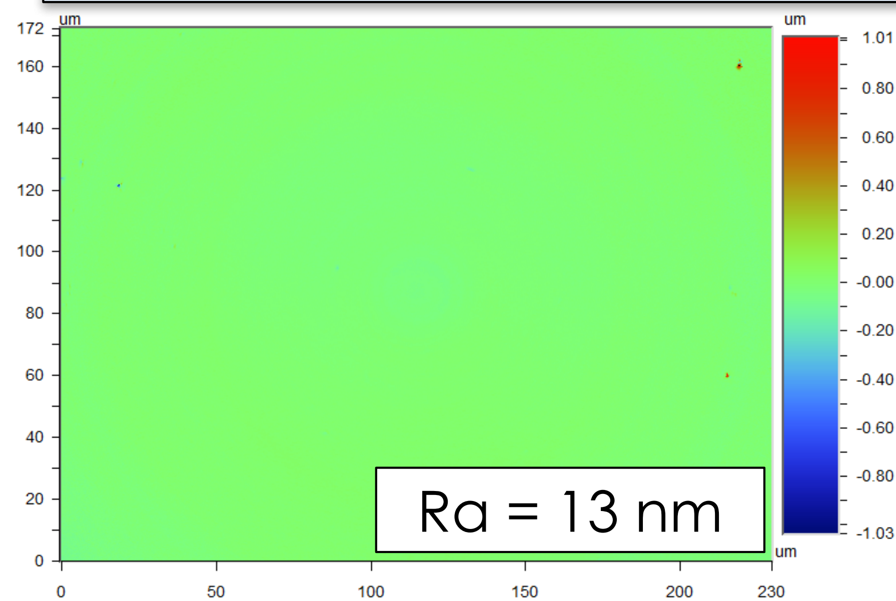
- **Results suggest reaction rate limitation**

Outer surface does not roughen with ozone burnout

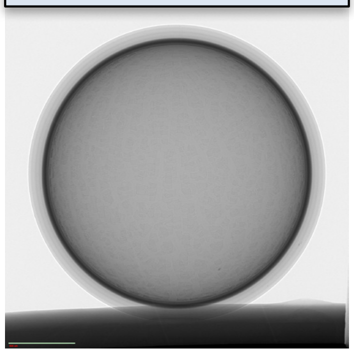
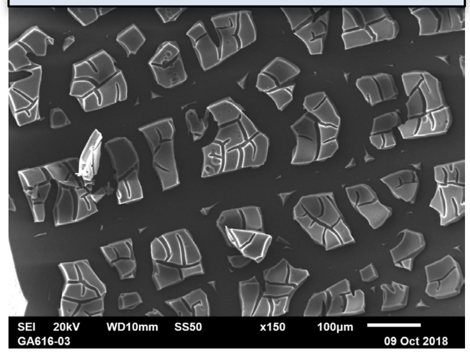
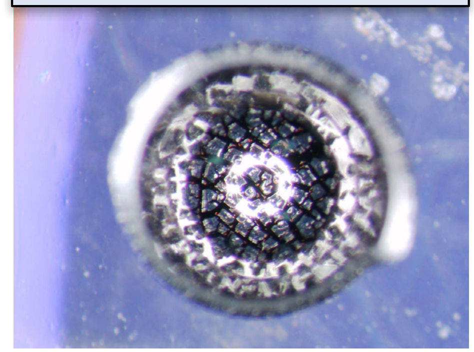
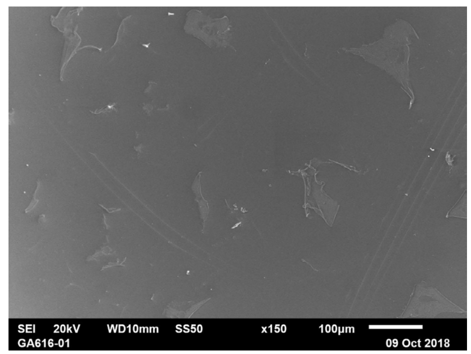
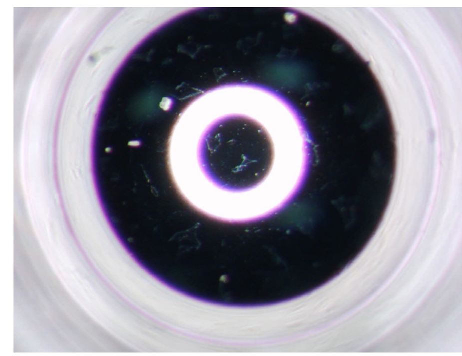
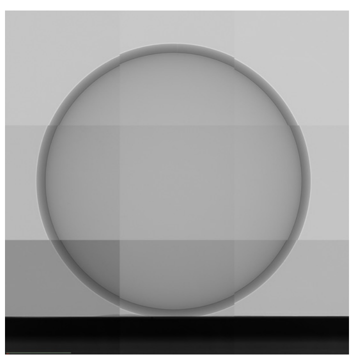
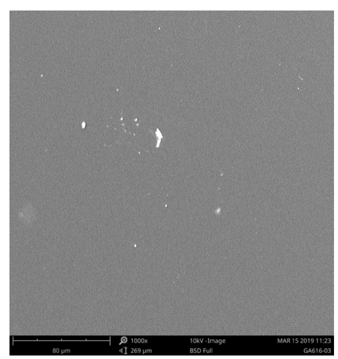
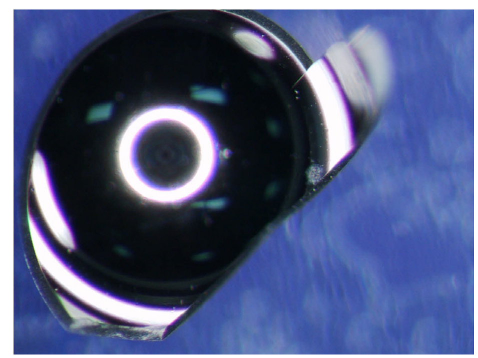
White Light Interferometry Image of Capsule Before Ozone Burnout



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



Ozone burnout sometimes leaves residue

	X-Ray	SEM	Optical
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**