Thin Oxides as a Cu Diffusion Barrier for NIF Be Ablator Capsules

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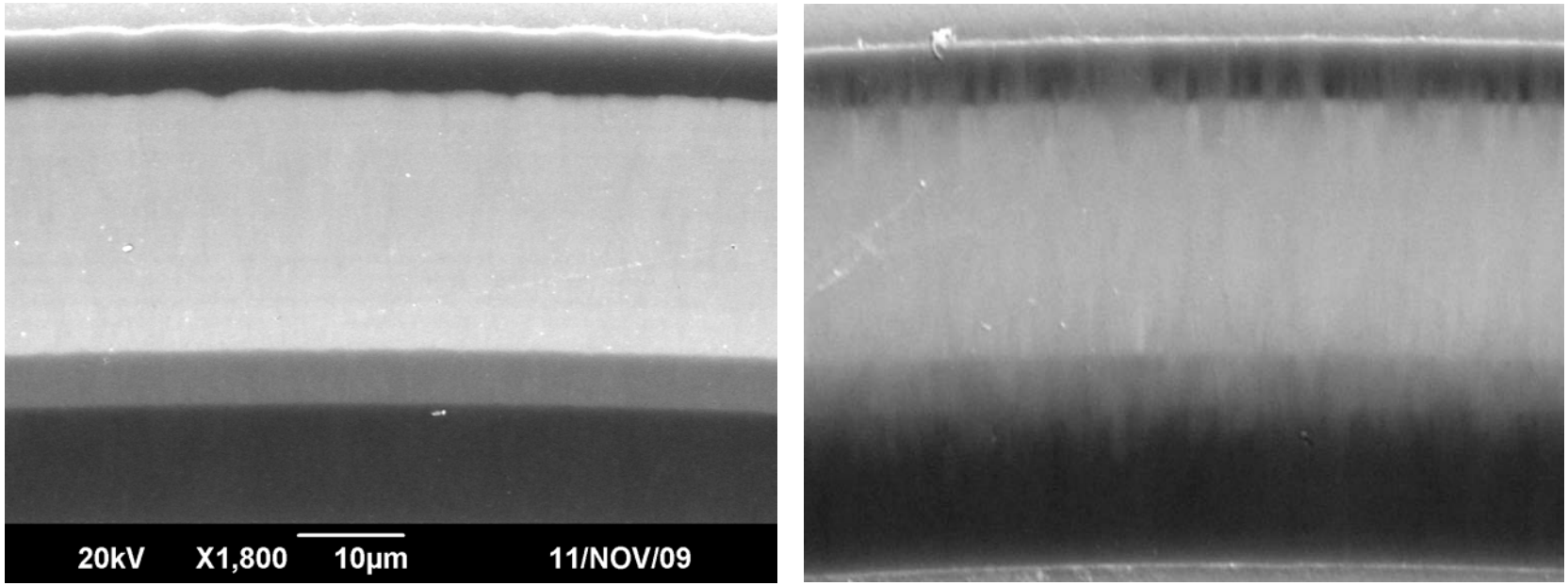
NIF capsules require stepped, doped copper layers to optimize shock timing

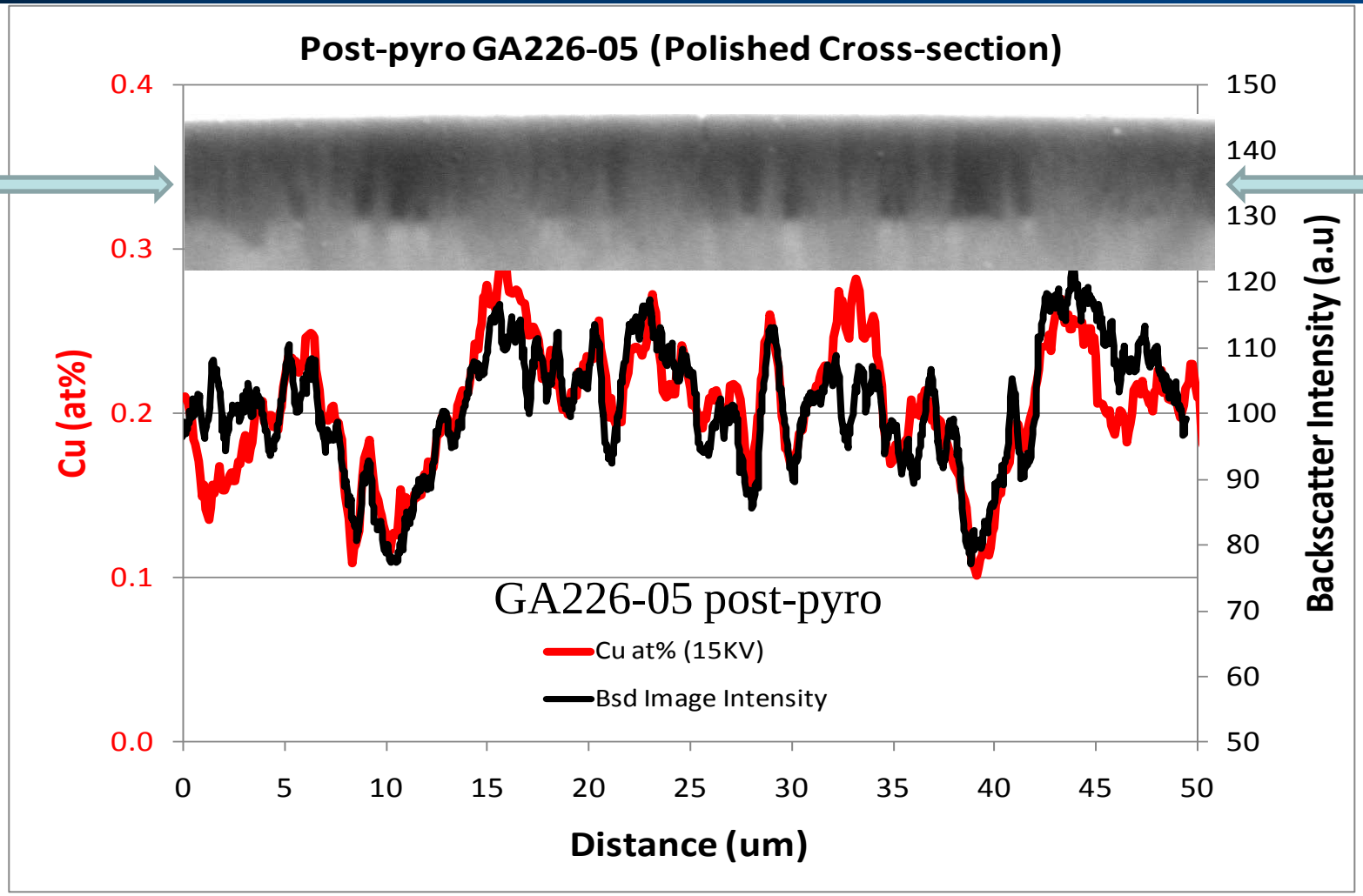
- A variety of measurements have confirmed that after pyrolysis, azimuthal Cu diffusion is inhomogeneous.
- This will not meet the specifications for the NIF target design.



BSE Images Pre and Post Pyro, Cu doped Be capsule

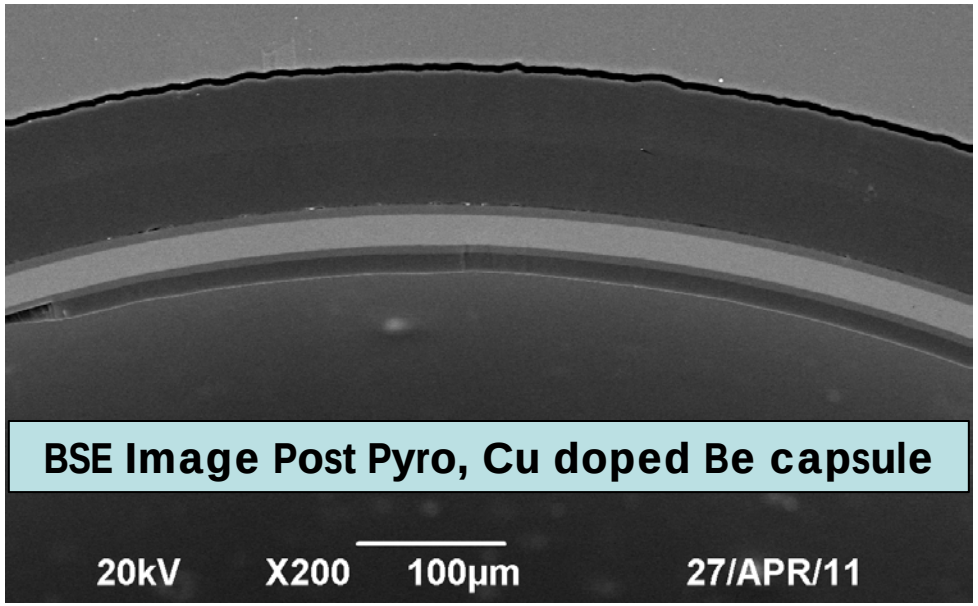
BSE contrast correlates with EDS Cu concentration on polished post pyrolysis cross-section

Line scan location



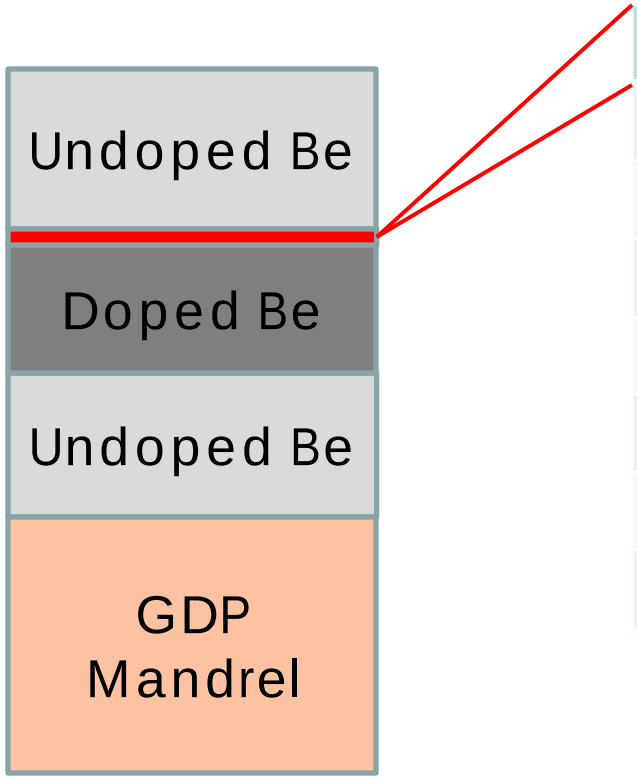
Skipping to the end: we can halt the diffusion of Cu using an oxide layer

- **Cu diffusion in beryllium can be halted by the application of an oxide layer.**
- **An in-situ oxide layer applied using a 3 minute cycle of 20%O2/Ar gas blend will result in a BeO layer which is ~7nm thick.**



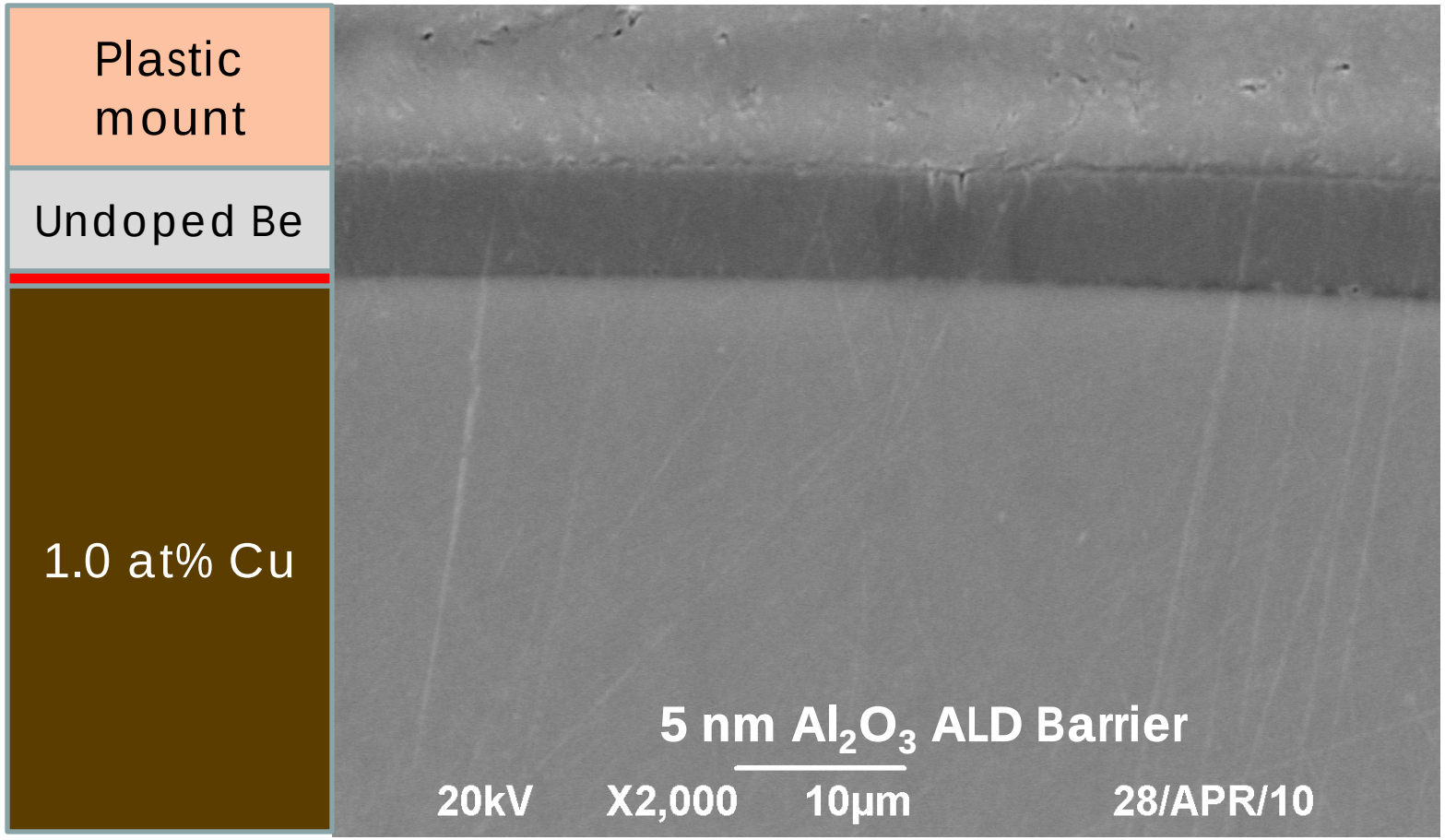
We tested Alumina barrier layers to halt copper diffusion

- **ALD coatings (Alumina) of various thicknesses**
- **Various control samples with heat induced BeO interfaces**

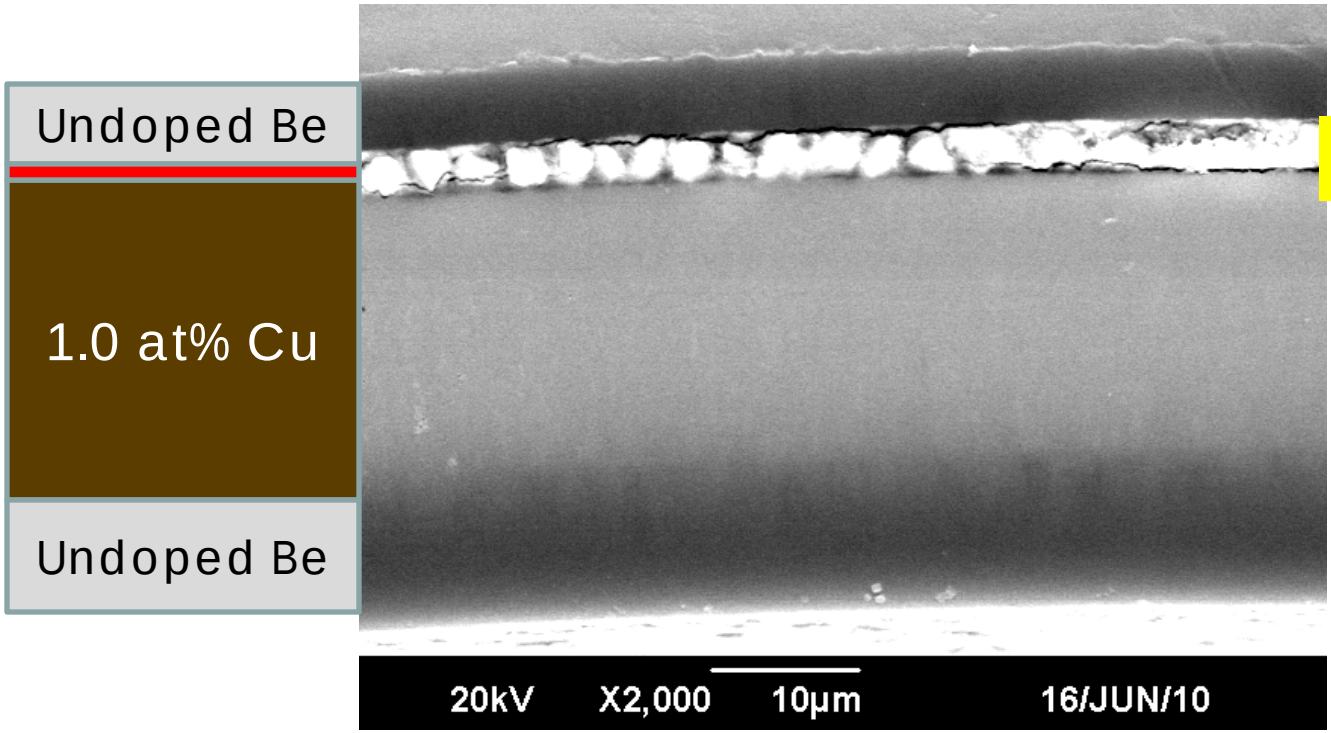


Barrier Layer
ALD 1nm
ALD 2nm
ALD 4nm
ALD 8nm
Control, no ALD (native oxide)
Control, 200C 1 day pyro
Control, 430C 2 day pyro

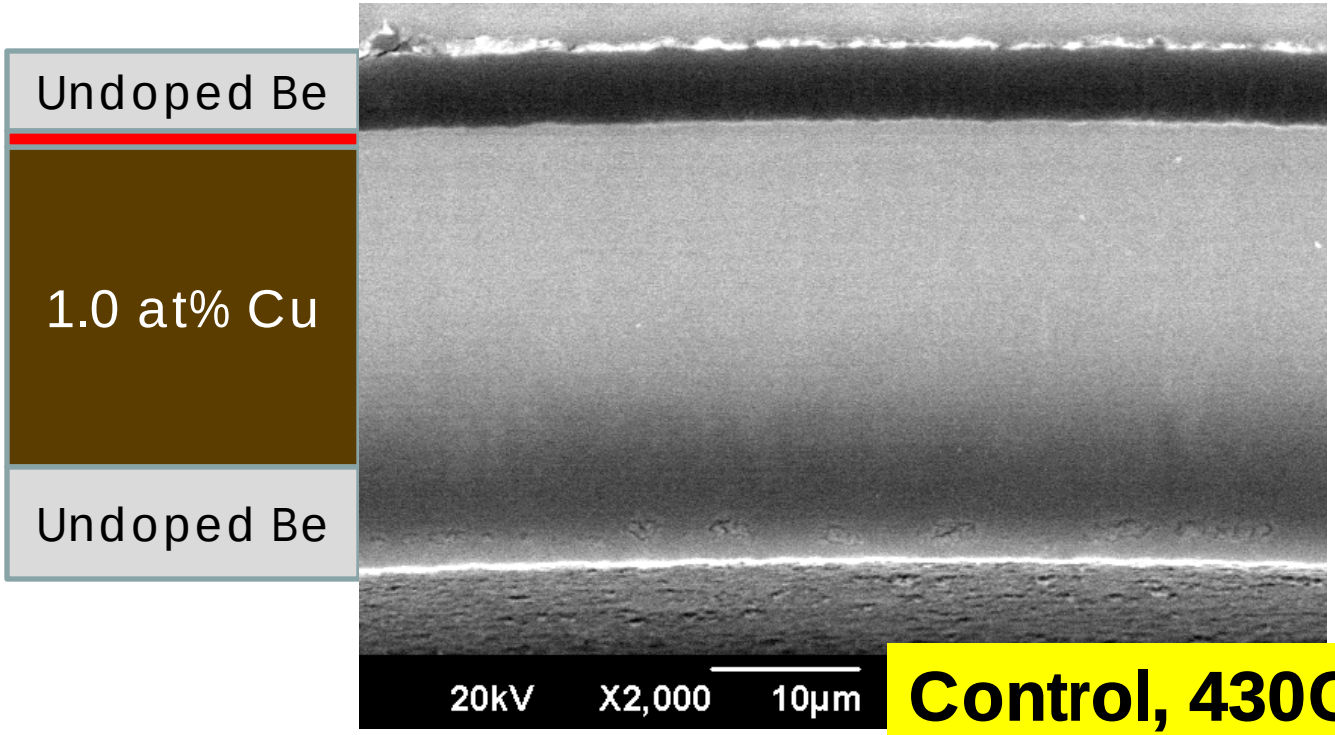
All Al_2O_3 and BeO control layers halted Cu diffusion



Many polished cross sections showed delamination at the interface



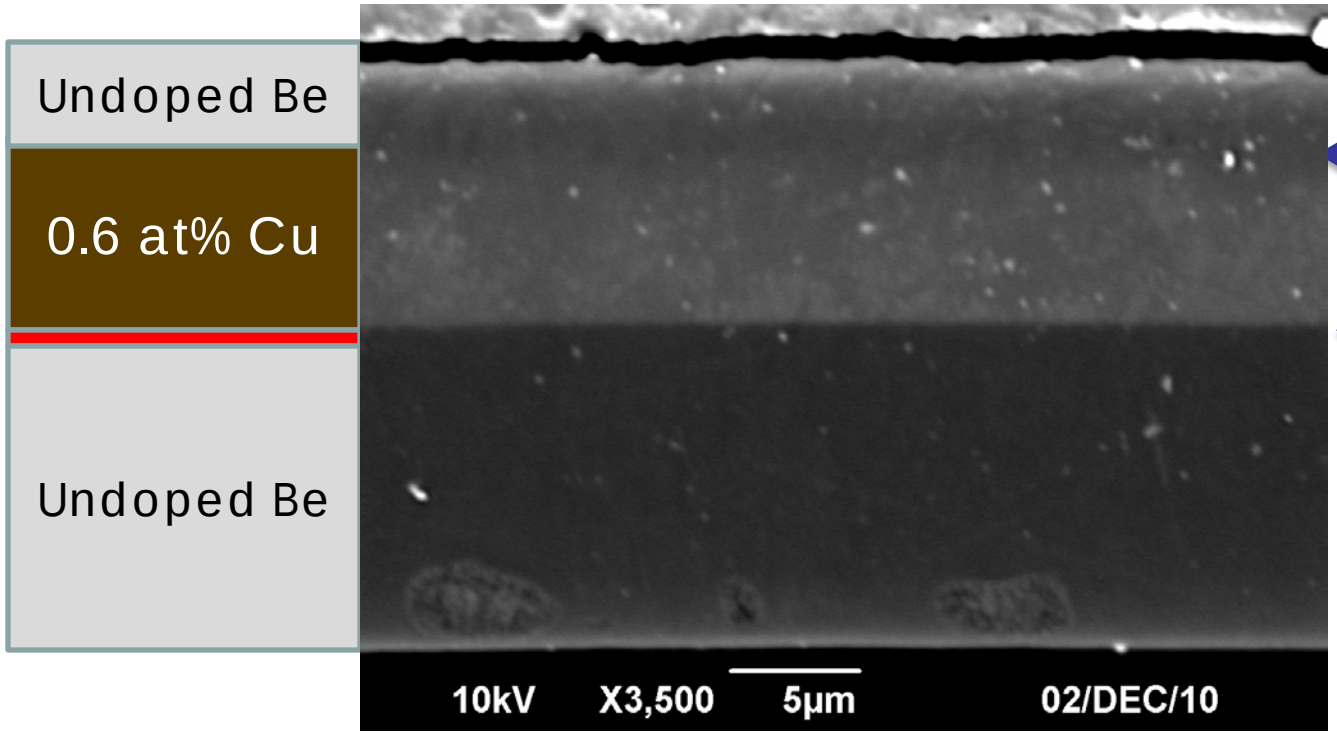
A thermally grown oxide layer didn't delaminate or diffuse



Control, 430C 2 day pyro

- **We hypothesized that a thermally grown beryllium oxide might halt diffusion without delaminating, and take less time than ALD.**
- **Could not exceed 250C without affecting the GDP mandrel**

We further tested thermally grown oxide layers



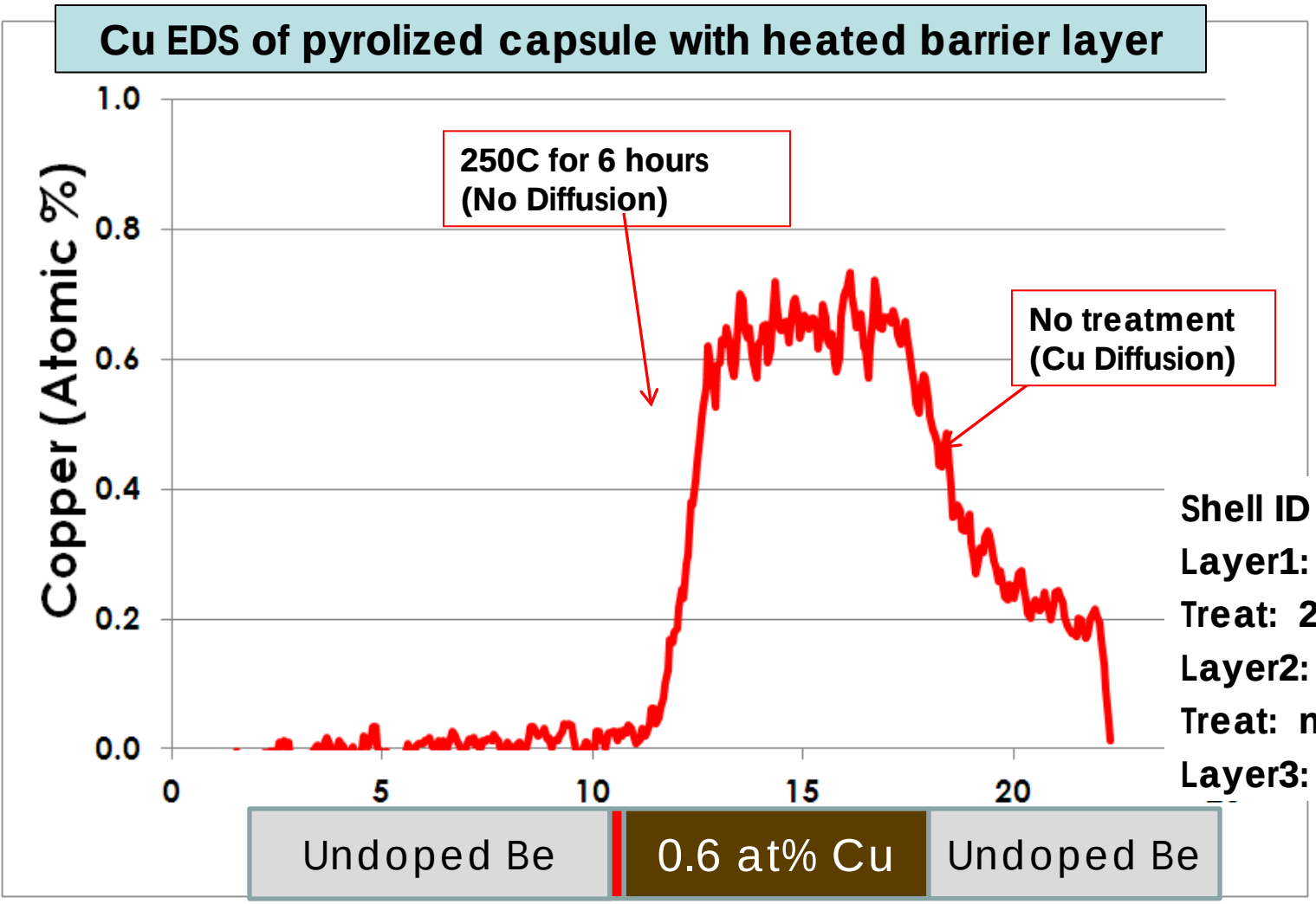
Cu diffused where there is no oxide

No diffusion across oxide

S6NIF244-01

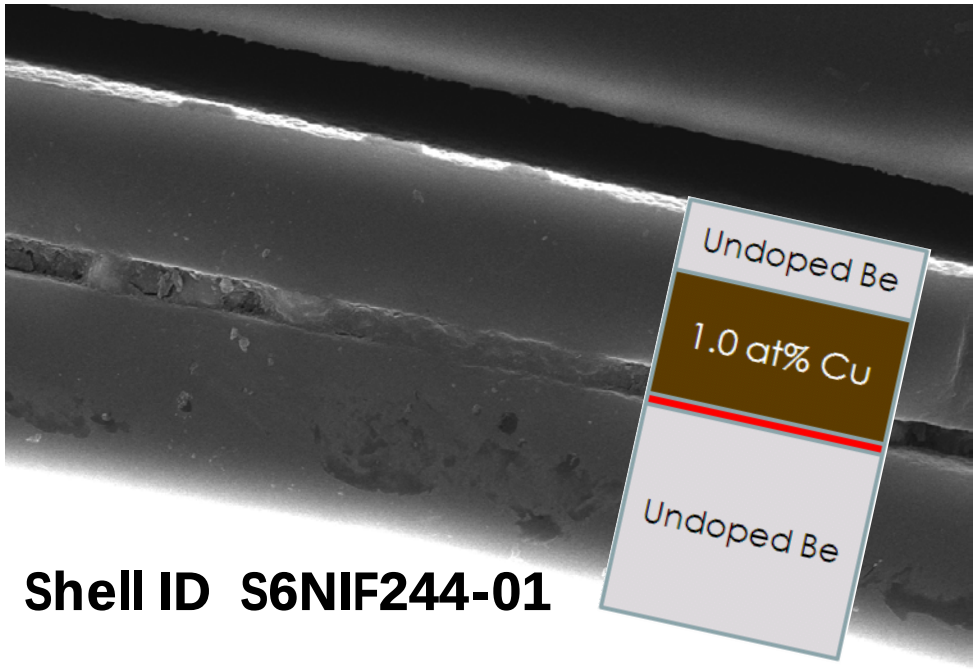
Thermal treatment at 250C for 6 hours

Thermal beryllium oxide layer halted Cu diffusion



Shell ID S6NIF244-01
Layer1: 14um pure Be
Treat: 250C for 6 hours
Layer2: 5um 0.6 at% Cu
Treat: none
Layer3: 3um pure Be

Some of the thermally grown oxide layers delaminated in polished cross section

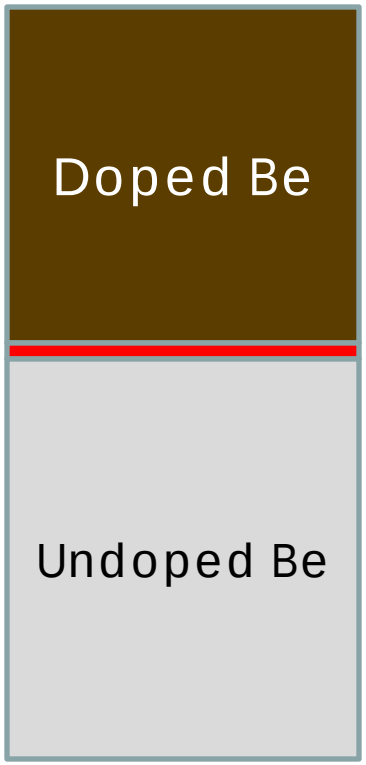


Shell ID S6NIF244-01

- **Stresses from polish cross section process?**

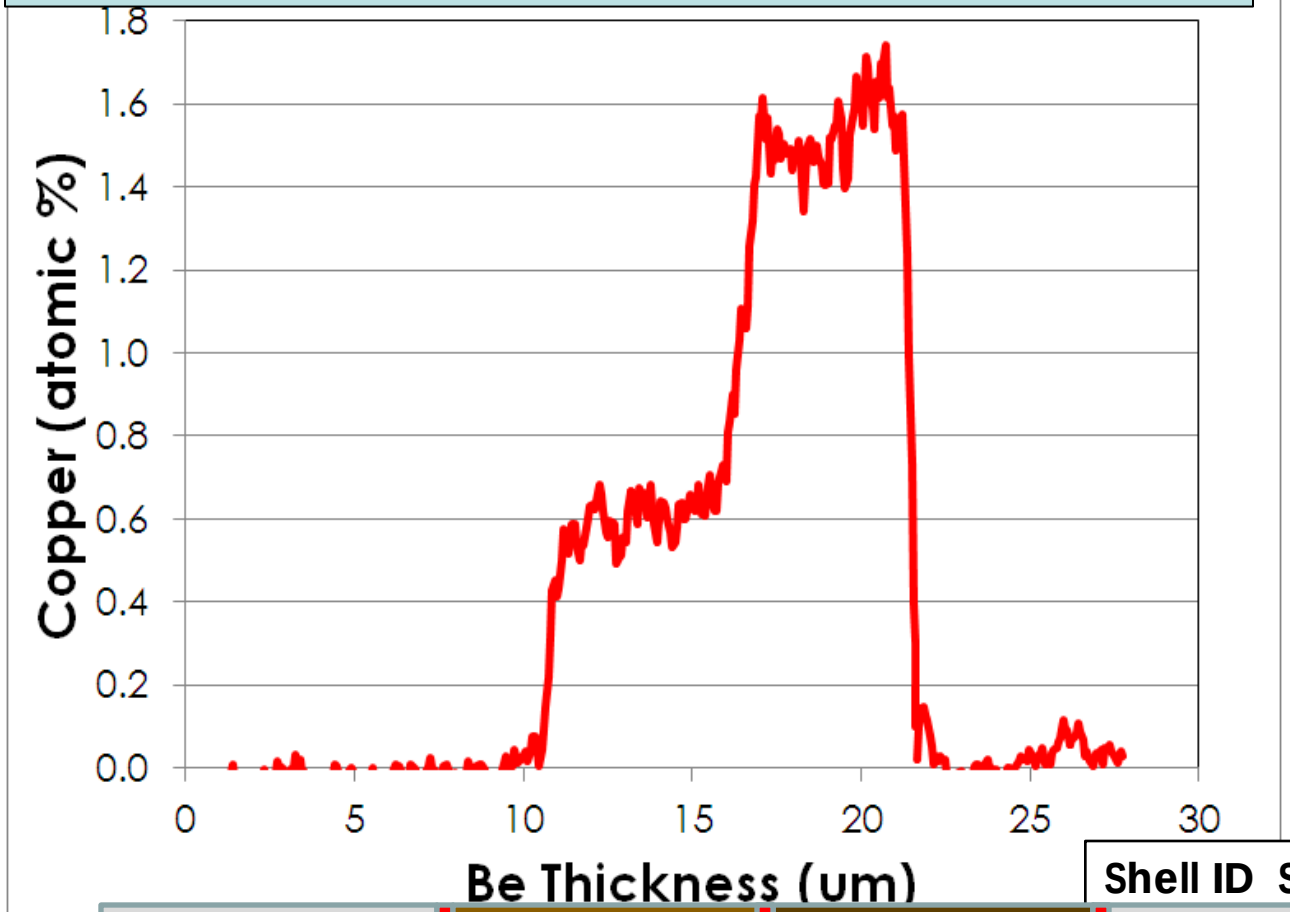
Ex-situ was a time consuming process, developed an in-situ method

- **Added a secondary gas supply of Ar with oxygen, turned on blend between doped and undoped layers.**
- **We tested a wide variety of parameters and conditions.**
- **Our final recipe is a blend of Ar with 20% O2, turned on for 3 minutes between the different layers.**



In situ oxide layer halted Cu diffusion

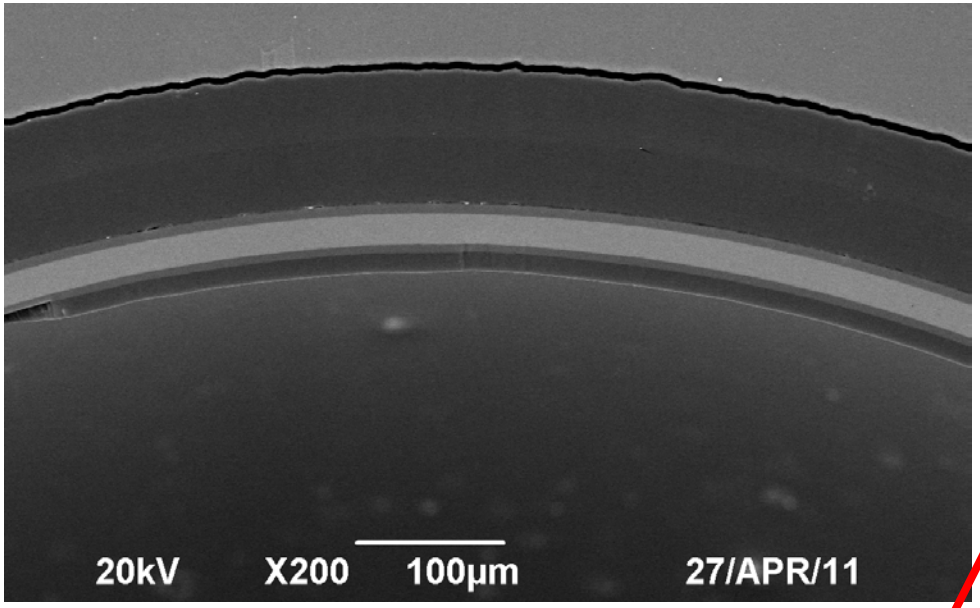
Cu EDS of pyrolized capsule with in situ layer

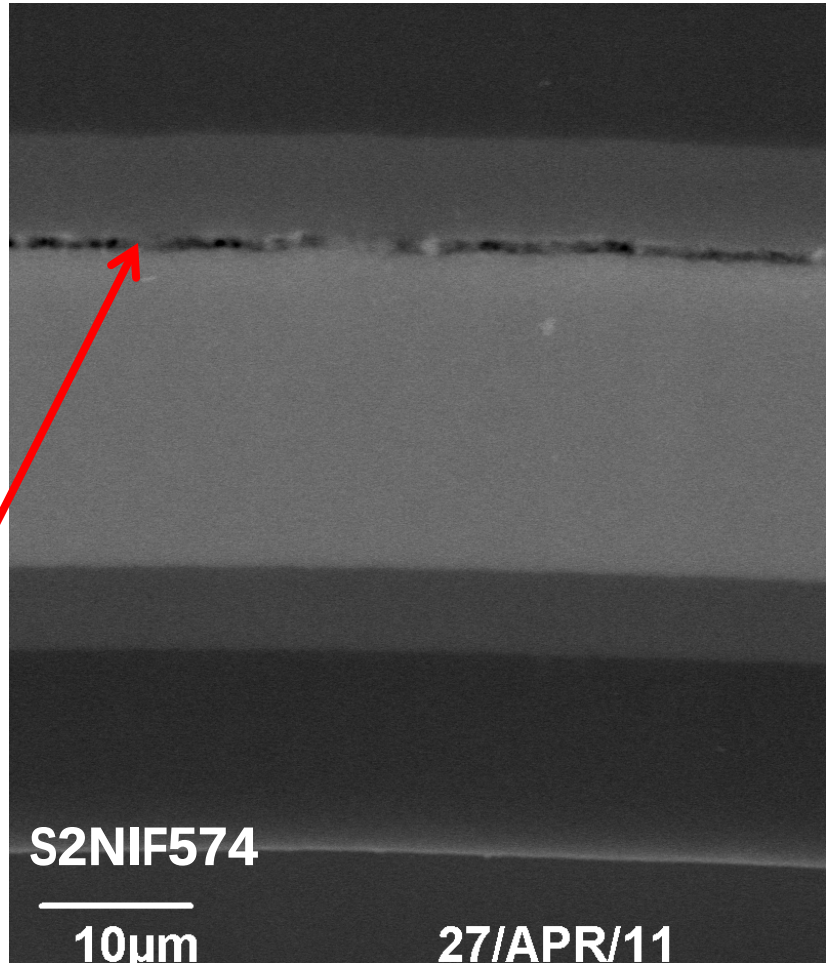


Shell ID S6NIF260-01

Undoped Be	0.6 at% Cu	1.5 at% Cu	Undoped Be

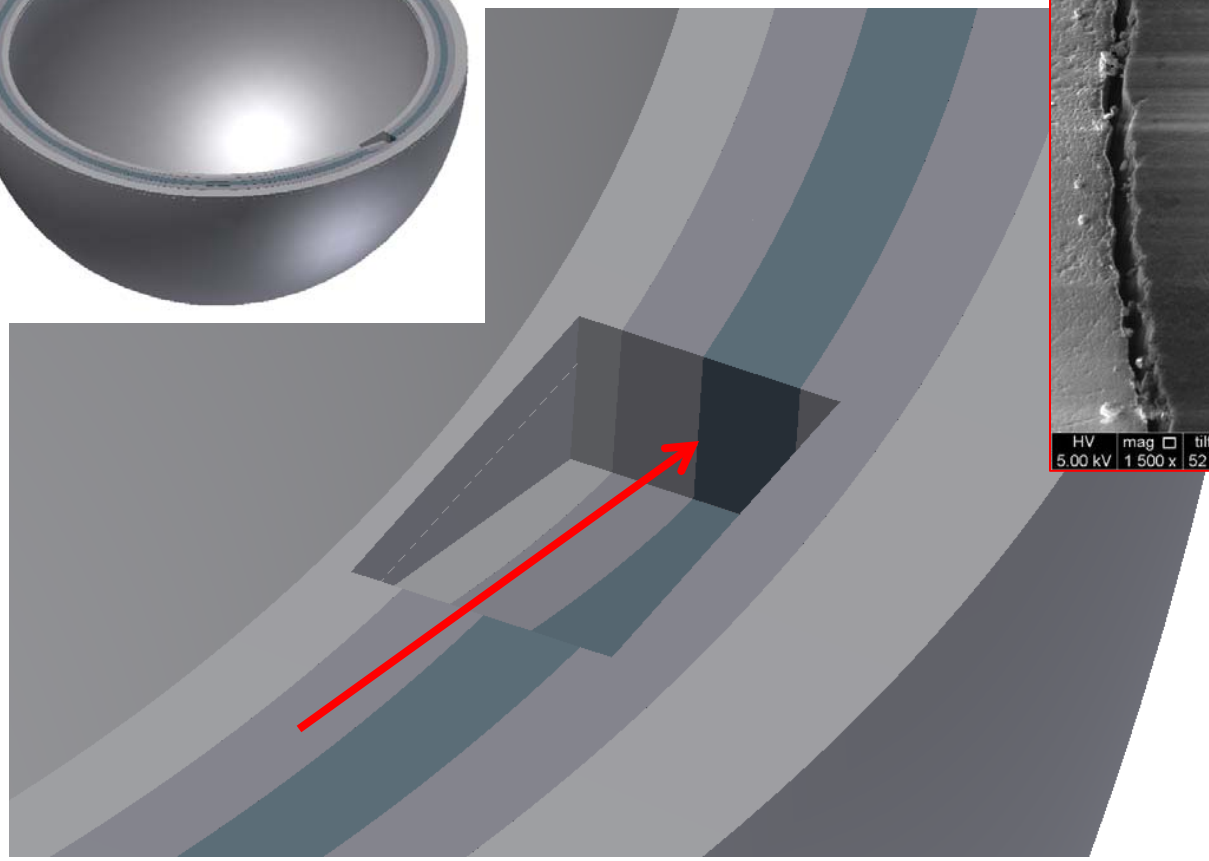
We were able to halt copper diffusion; but we were still concerned about delamination

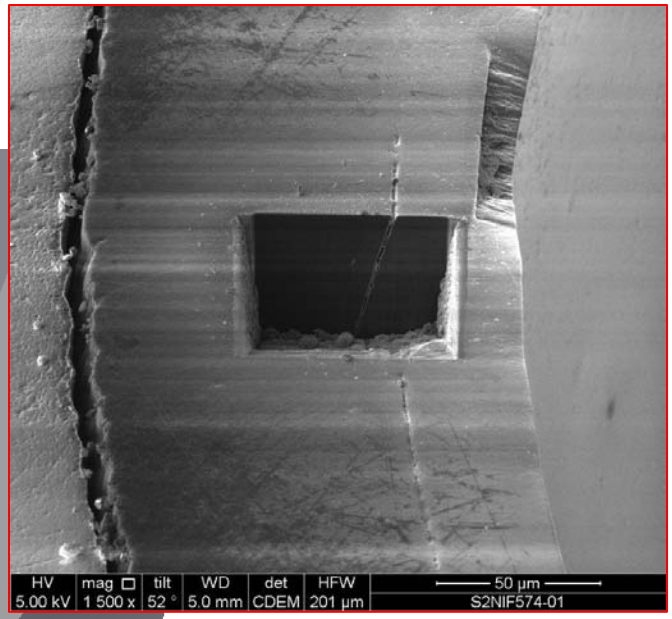




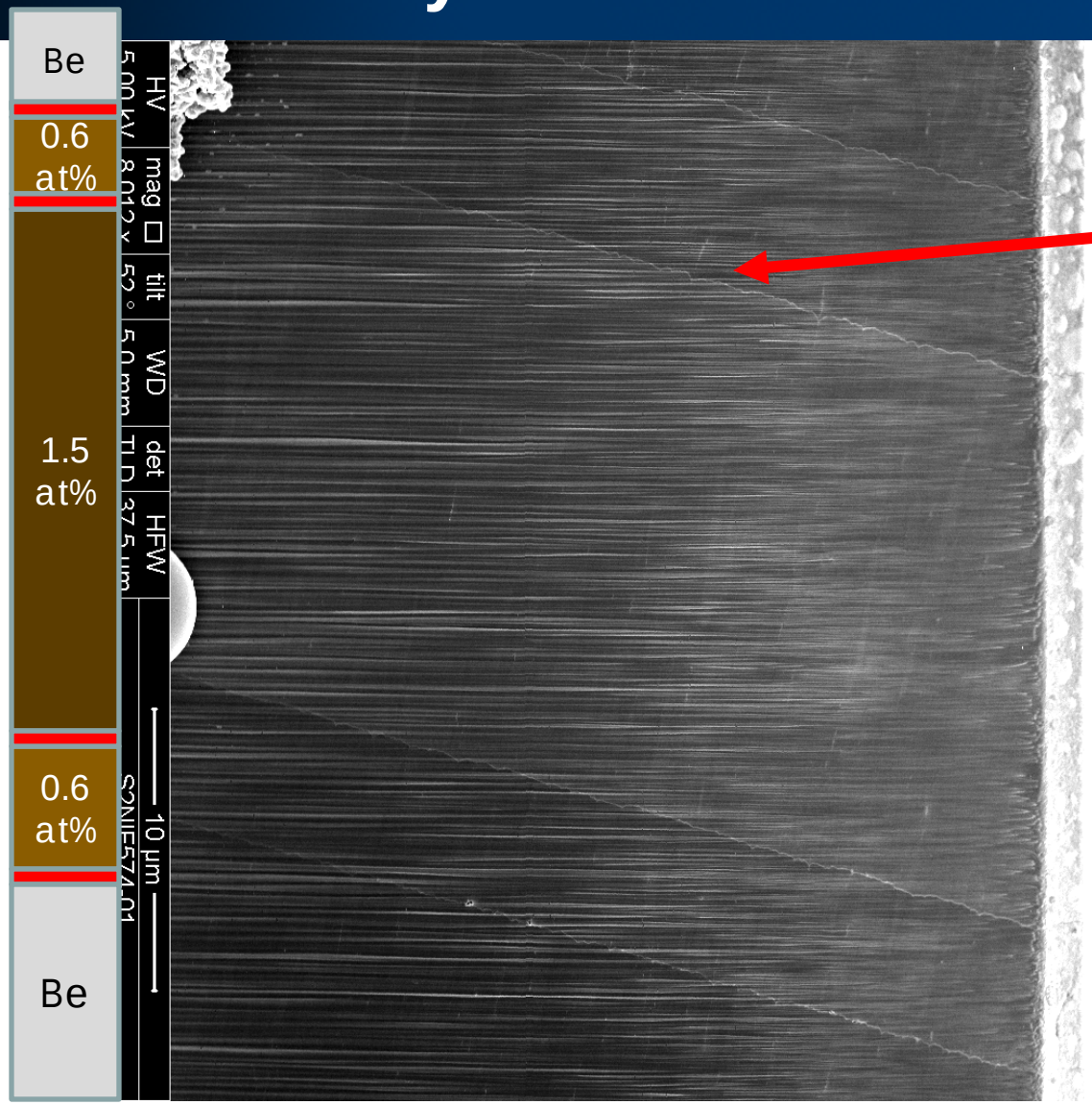
In-Situ Target design capsule at 120µm. Polished cross section shows some delamination.

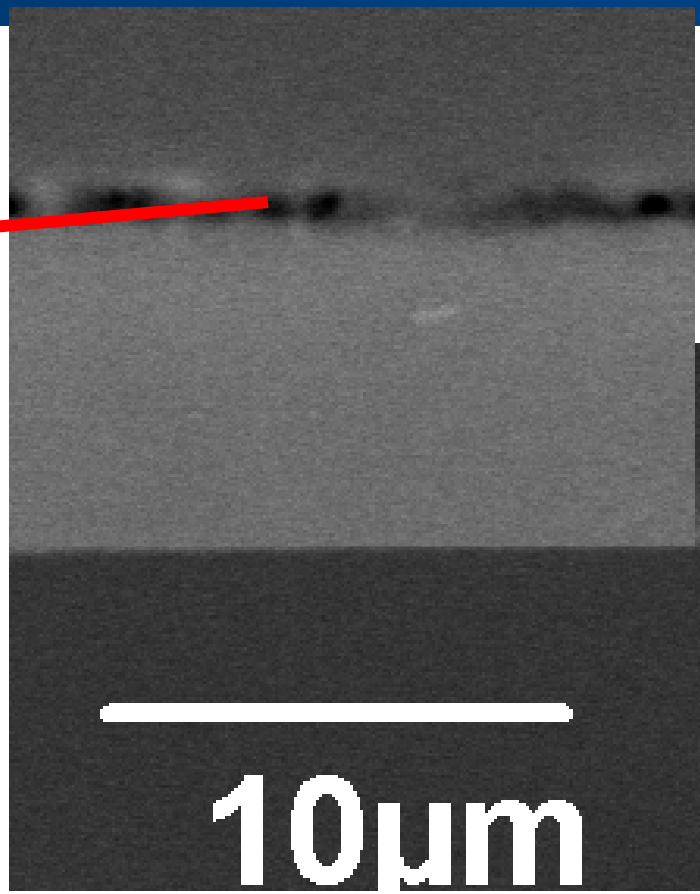
FIB technique adapted to look at 120um thick capsule.





In situ oxide does not show delamination between layers with FIB sectioning

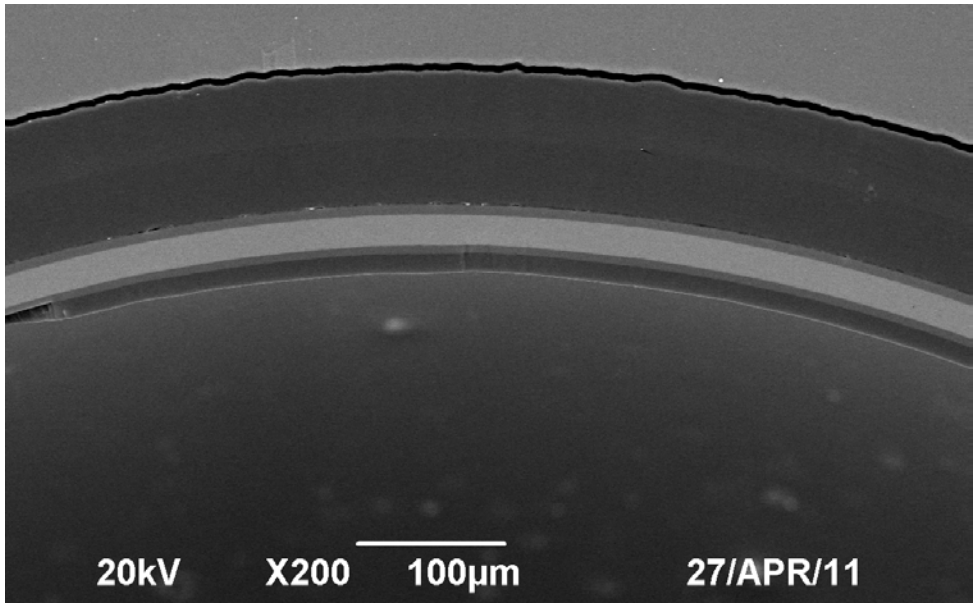




The polishing stresses appear to cause the delamination *in this case*

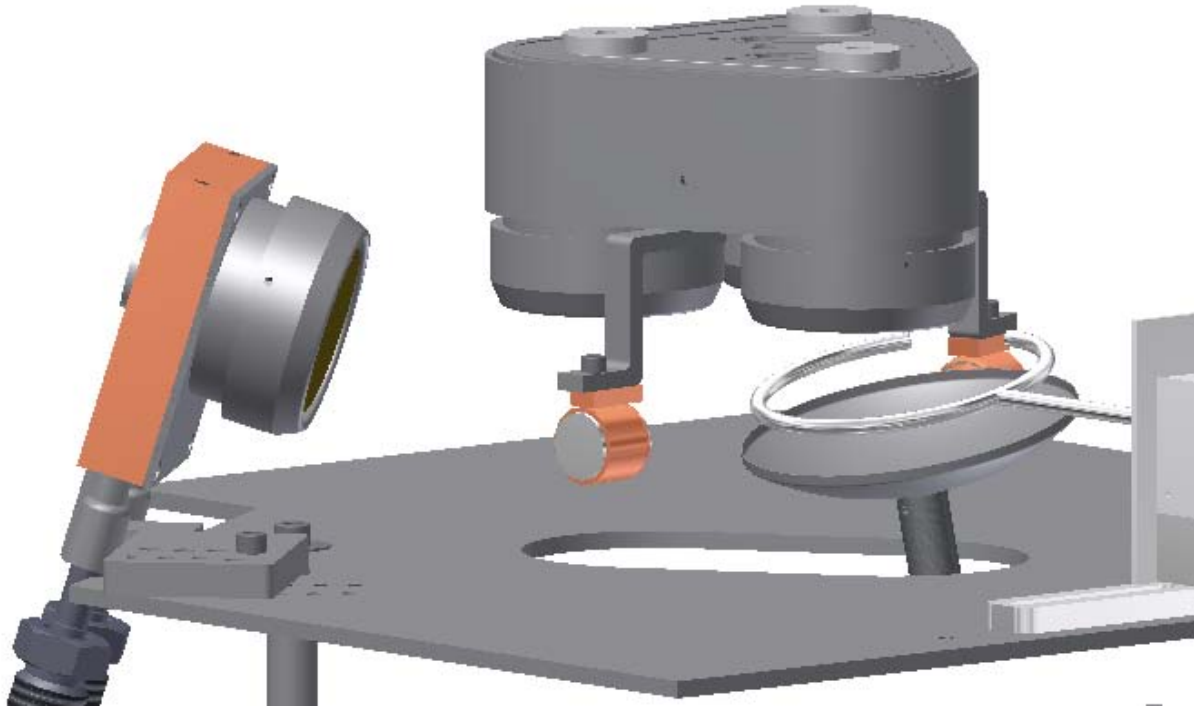
Conclusions

- Cu diffusion in beryllium can be halted by the application of an oxide layer.
- An in-situ oxide layer applied using a 3 minute cycle of 20%O2/Ar gas blend will result in a BeO layer which is ~7nm thick.



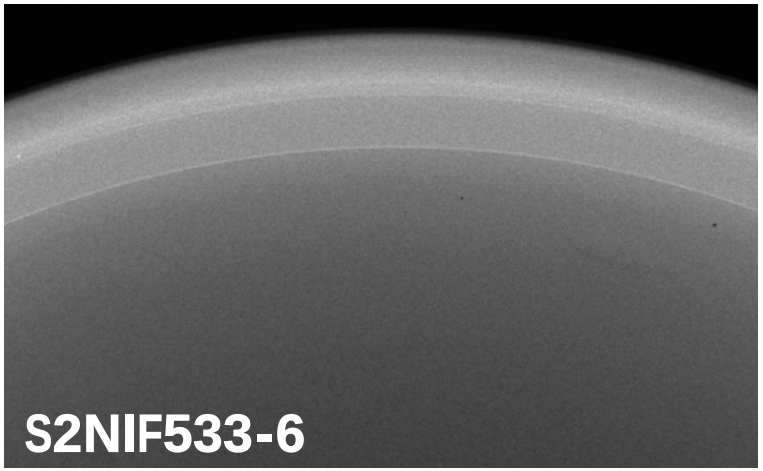
Tuesday Night poster session P28 (Haibo Huang)

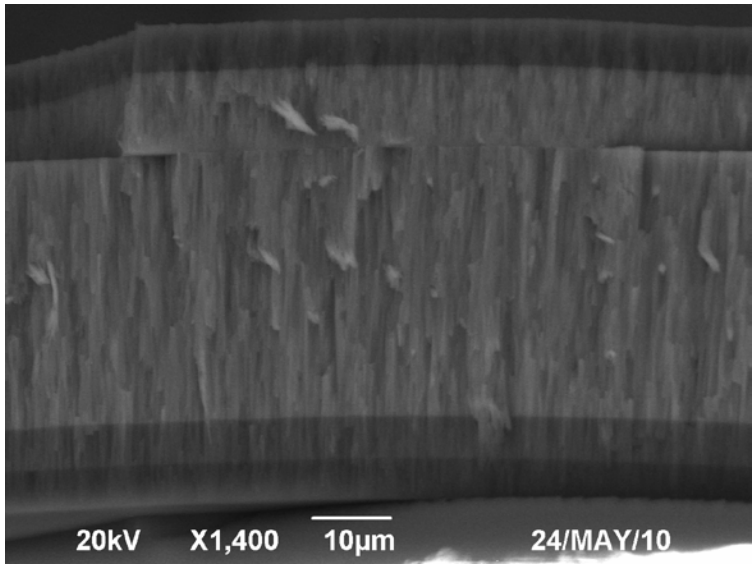
Coater configuration



- 1 gun configuration, 1” away
- 50 Watts
- Ring (45V)and Pan(-80V) bias

Diffusion halted, possible delamination

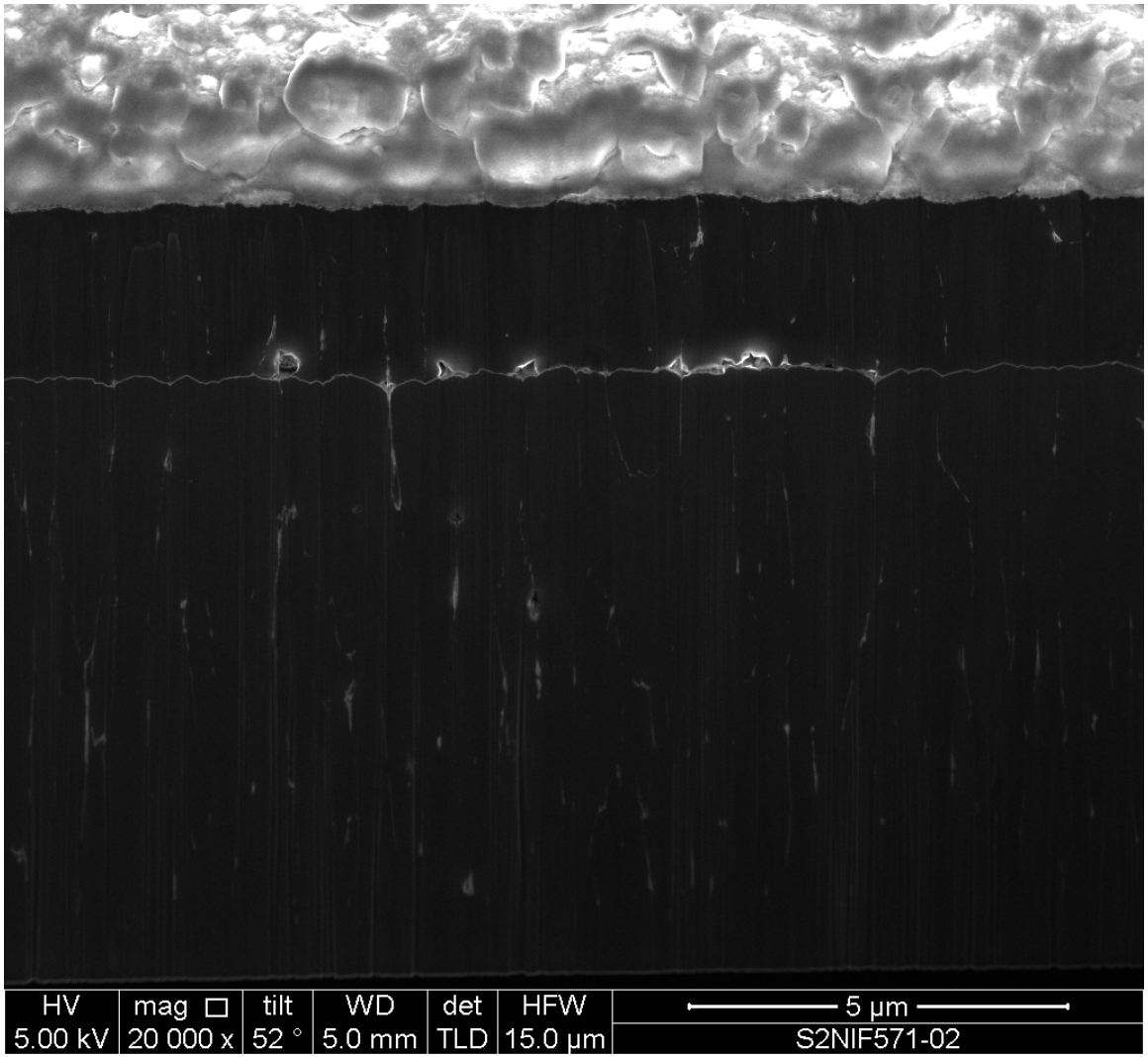




- **No visible delamination in x-radia pictures. Delamination after the shell was fractured for EDS.**
- **It's not clear from this data if the delamination was not visible or if it was introduced by the stress of the fracture process.**

Supporting slide: FIB image

- **S2NIF571-02 FIB image**



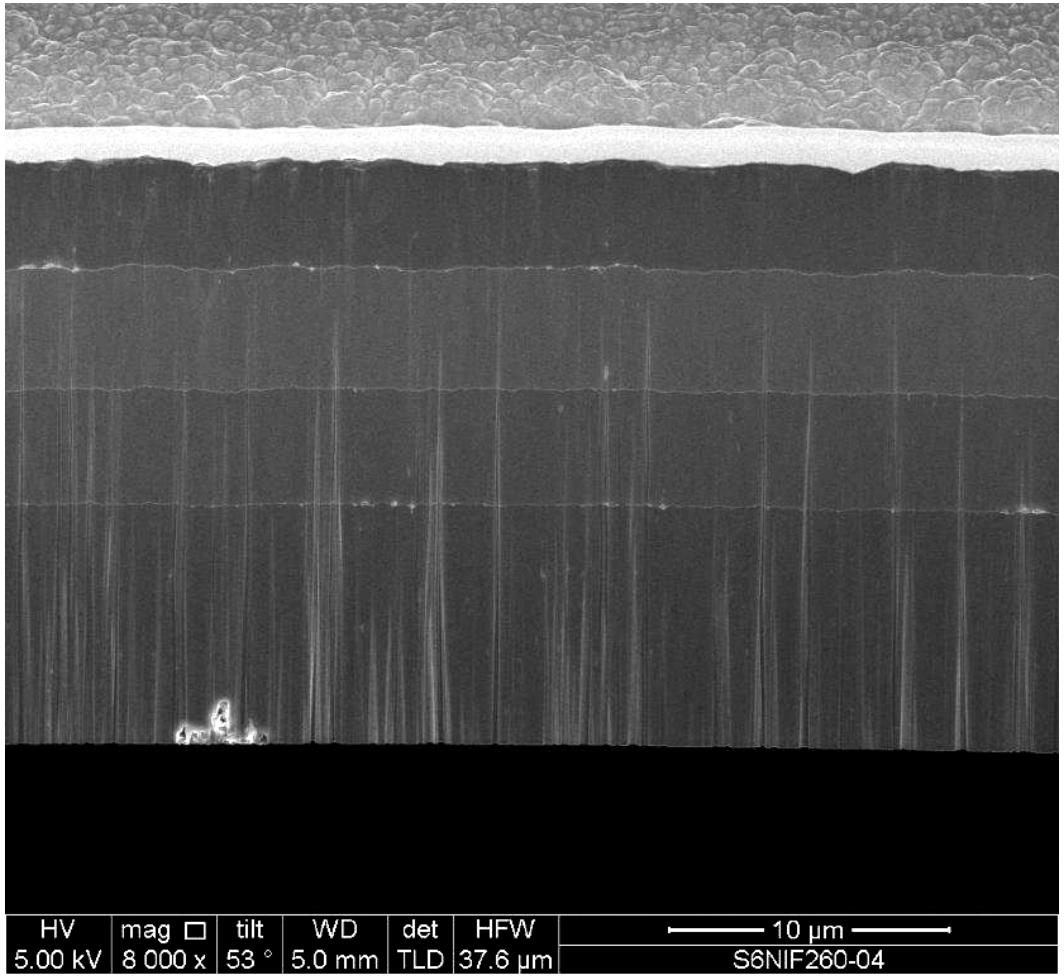
S6NIF260, FIB results

Undoped Be

1.7 at% Cu

0.6 at% Cu

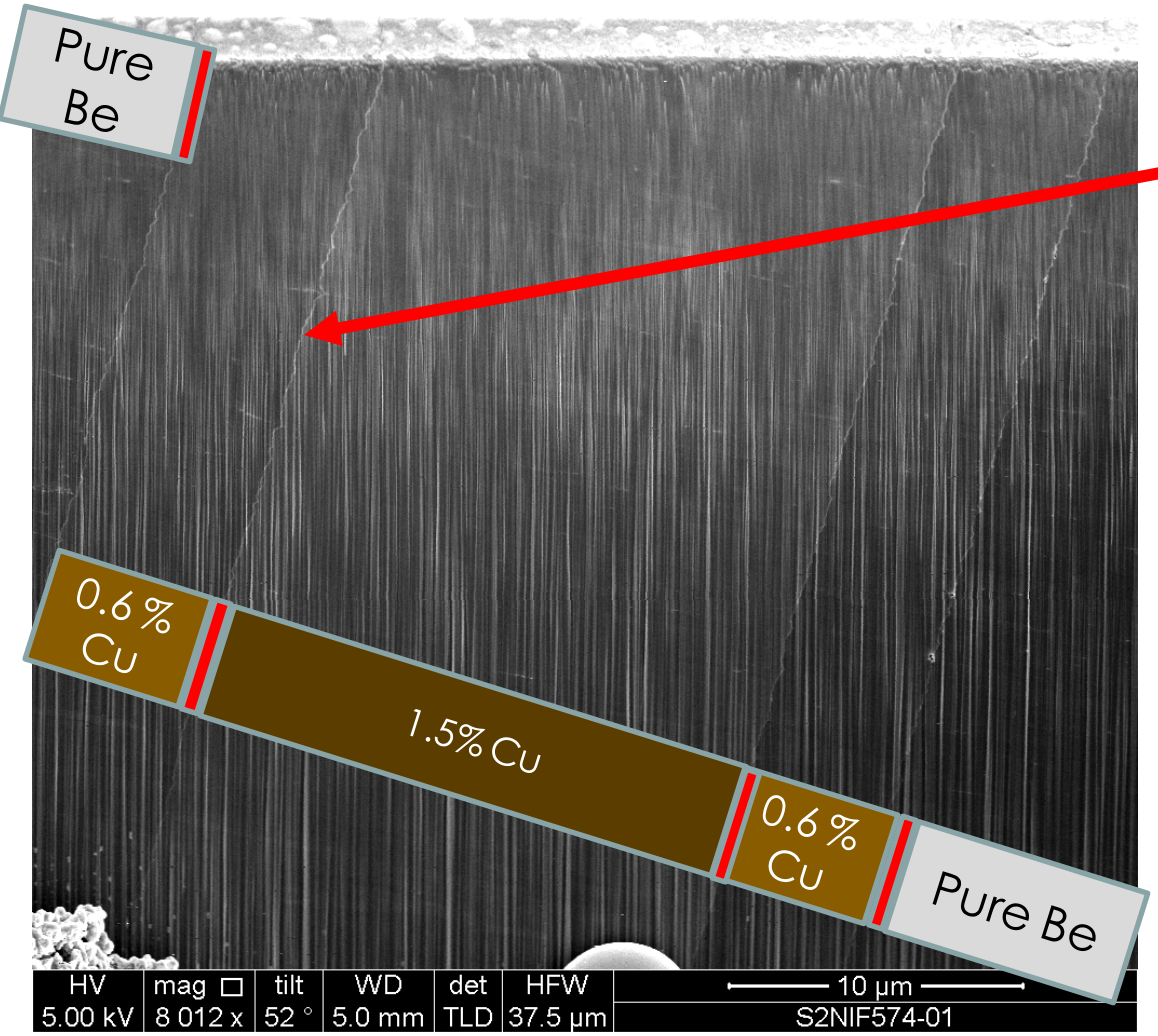
Undoped Be

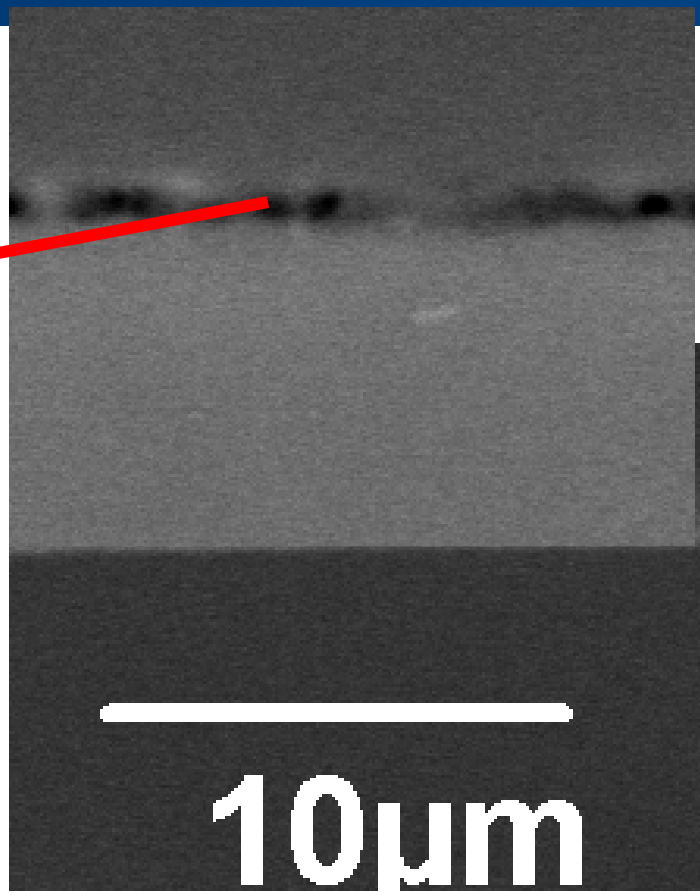


- **10um scale bar**

Shell ID S6NIF260-04

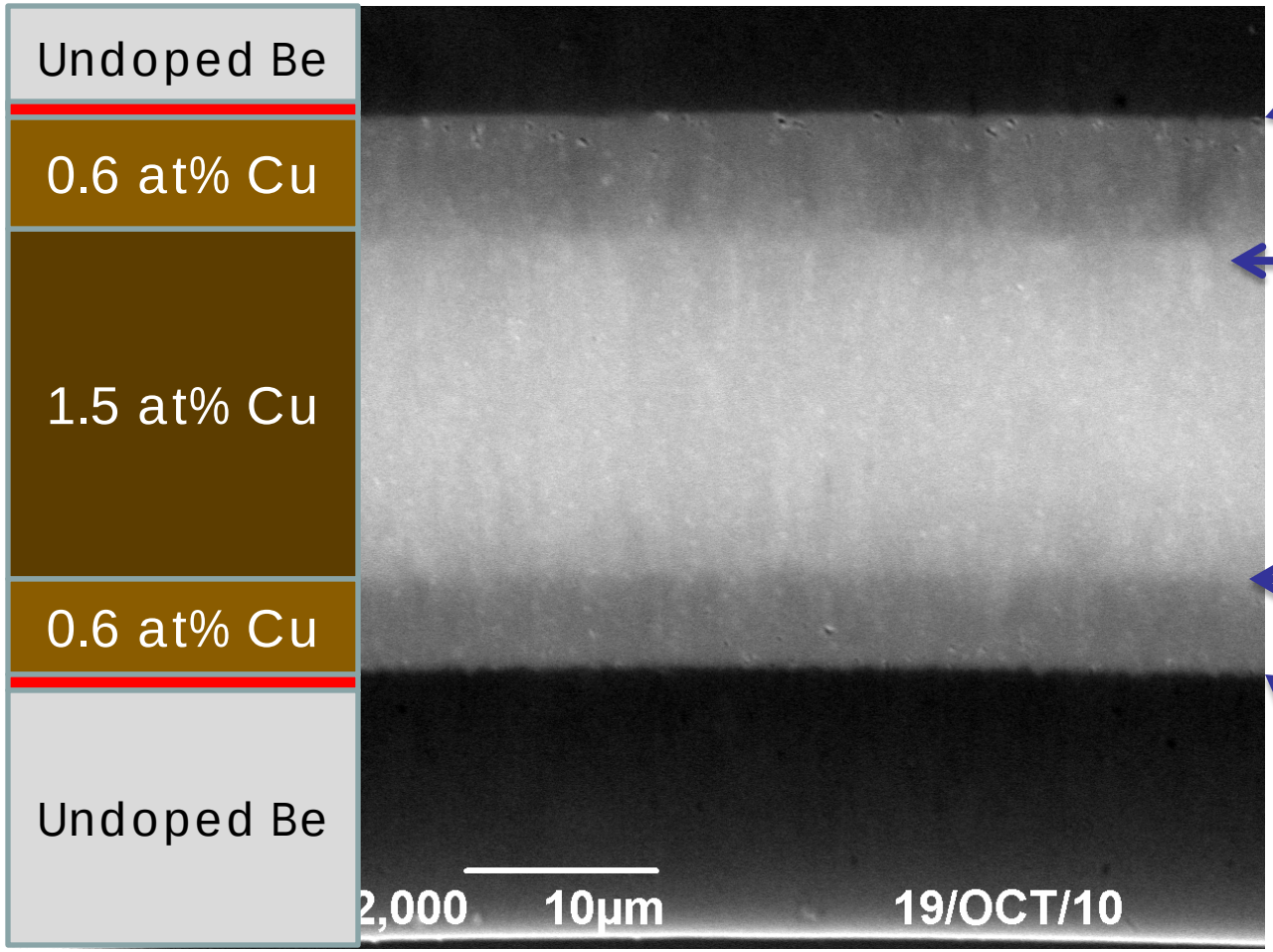
In situ oxide does not show delamination between layers with FIB sectioning





The polishing stresses appear to cause the delamination *in this case*

Supporting slide: Another image of a heat treated oxide capsule



No diffusion across oxide

Cu diffused where there is no oxide

Cu diffused where there is no oxide

No diffusion across oxide

S2NIF552-03