Process Control Improvements for Production of Depleted Uranium Hohlraums

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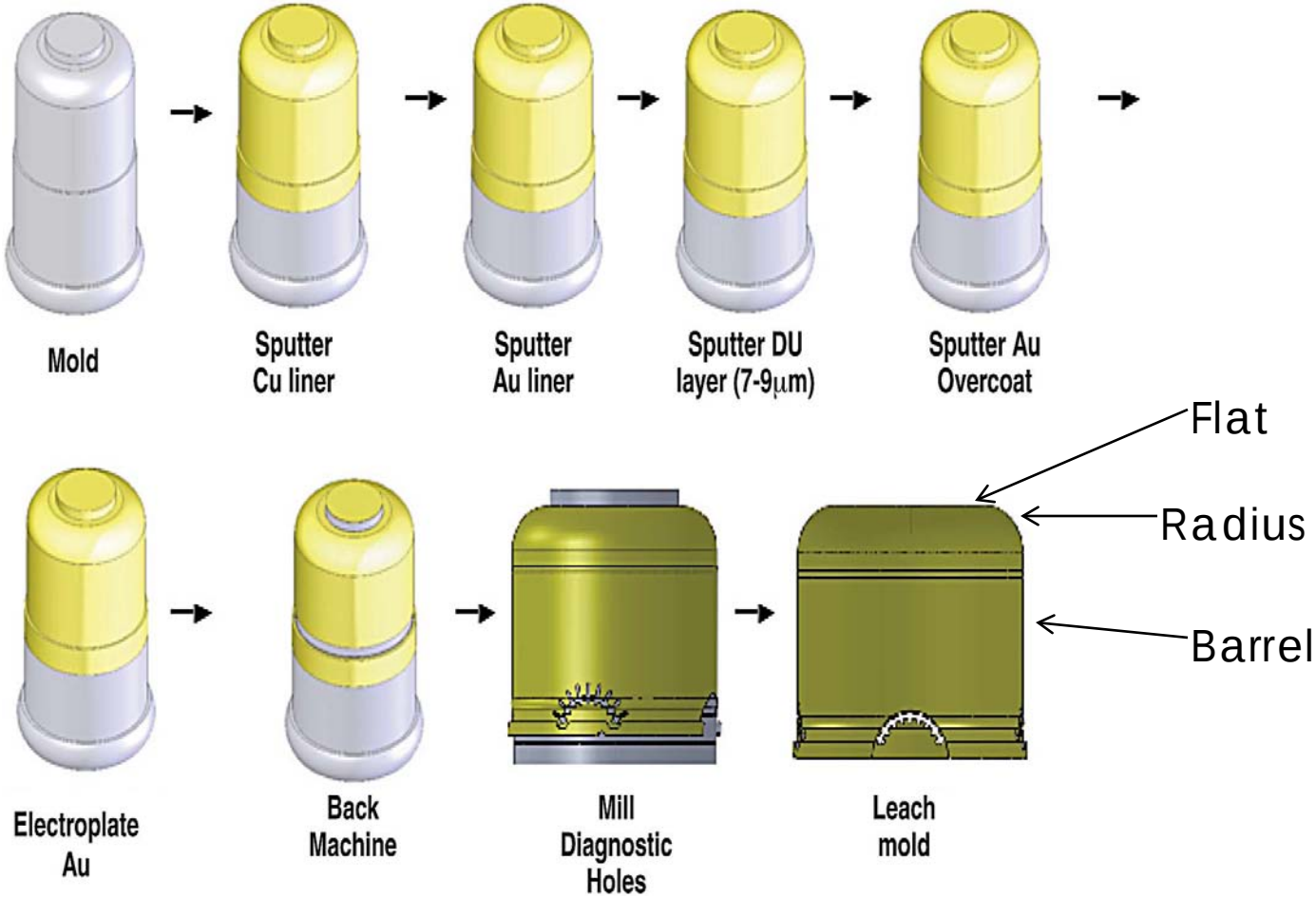
Outline

- Review process steps
- Production of DU hohlraums in early 2011 had low yield – 0%
- Identified problem with mandrel surface quality
- Major issue was process drift related to ion gun
- Mandrel surface quality improvements
- Changed DU coating procedure to further increase yield
- Additional experiments to identify problems and increase yield in progress

GENERAL ATOMICS

DU hohlraum fabrication process

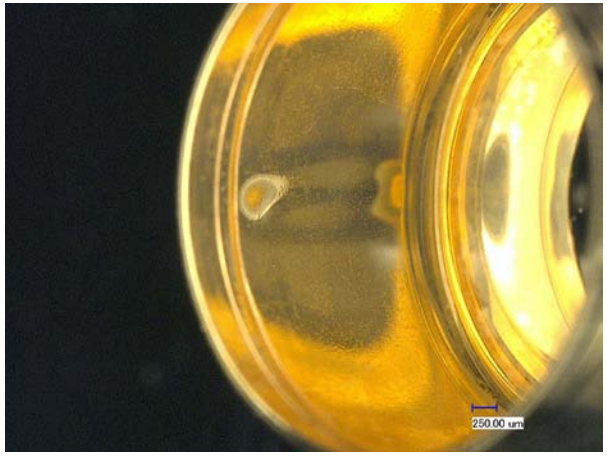


GENERAL ATOMICS

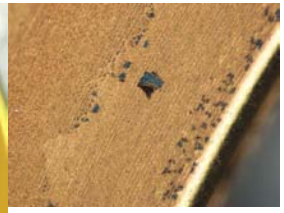
Examples of DU hohlraums with asperities

Large blisters in radius

Exposed DU on exterior barrel



Medium blister on interior barrel

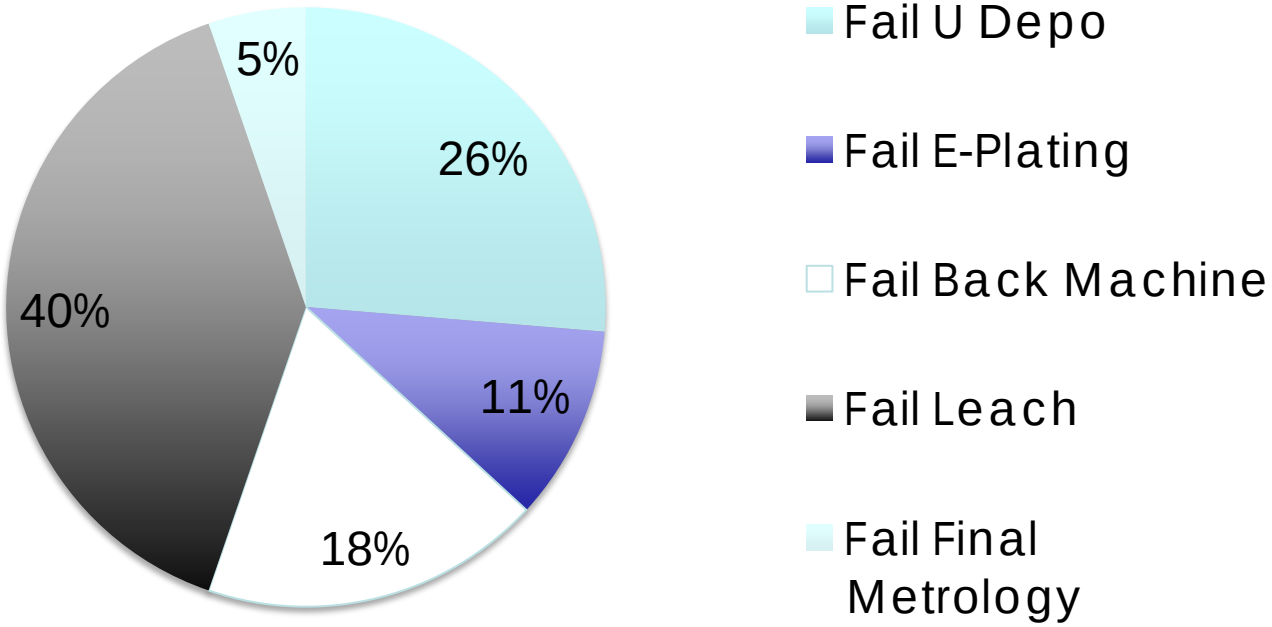


Residual Cu in flat

GENERAL ATOMICS

0 % yield for DU hohlraum production in early 2011

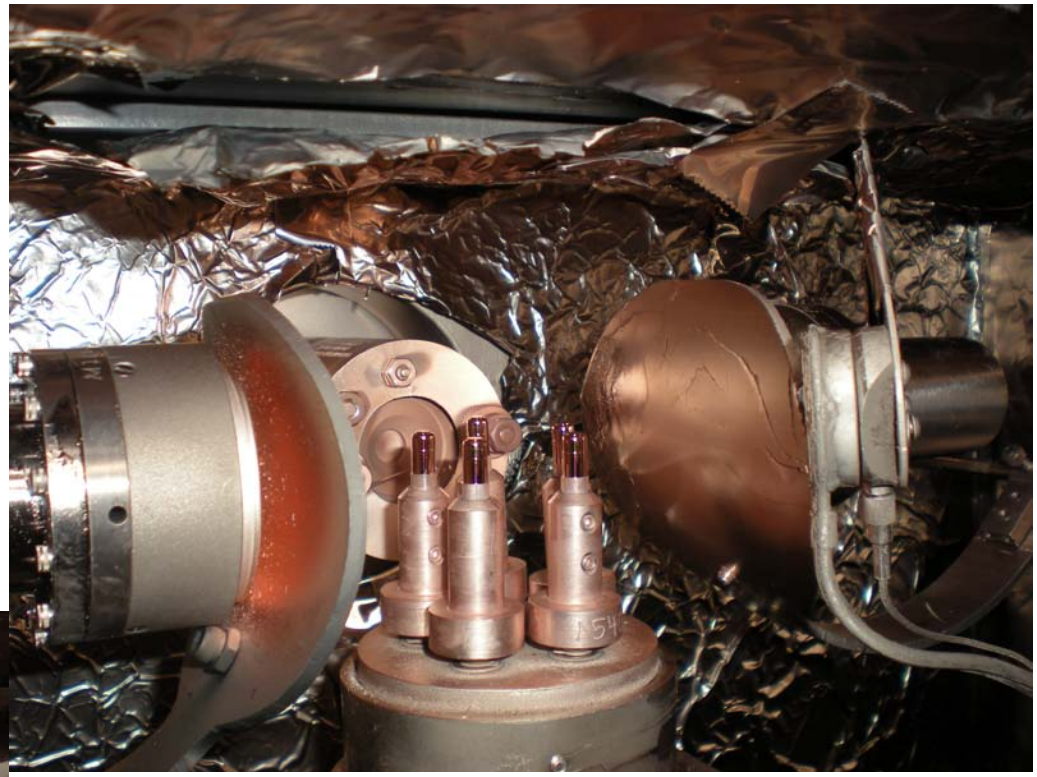
Failures categorized according to process step

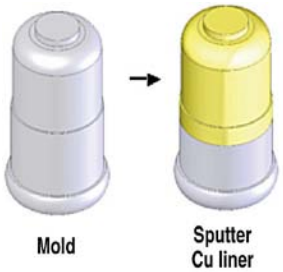


- **Most failures became apparent at leach step**
- **Primary failure mode was blisters and delaminations**
- **Adhesion problem, particularly inside layers**

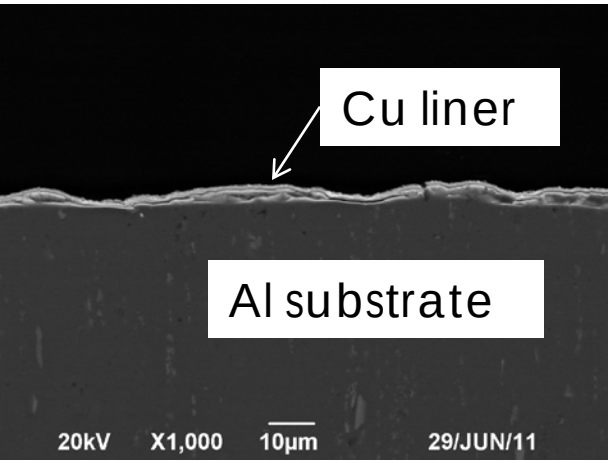
GENERAL ATOMICS

M1 Sputter coater with ion gun for cleaning Al mandrel

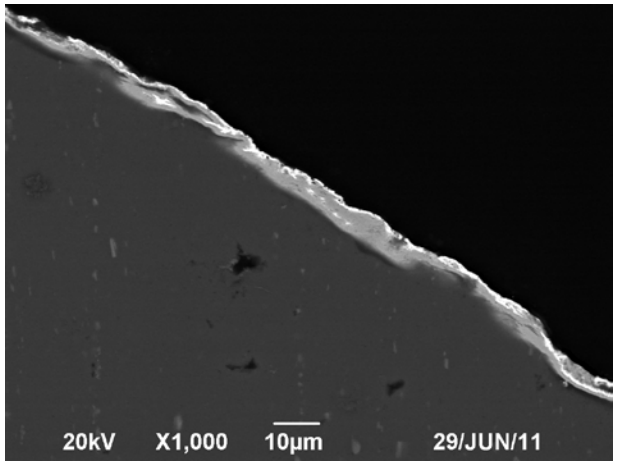




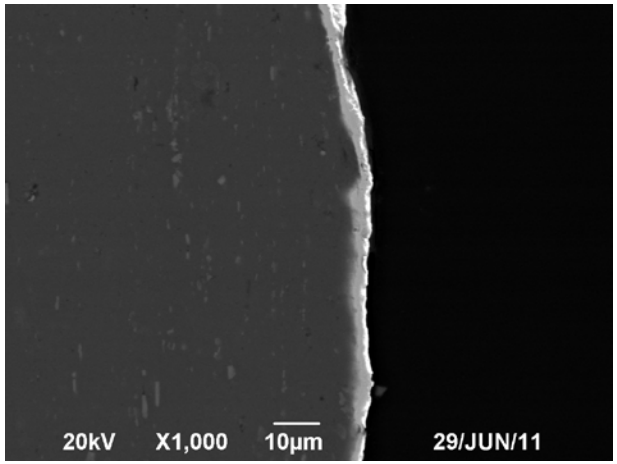
Scanning Electron Micrographs of Cu coated Al mandrel show poor surface quality



Flat



Radius

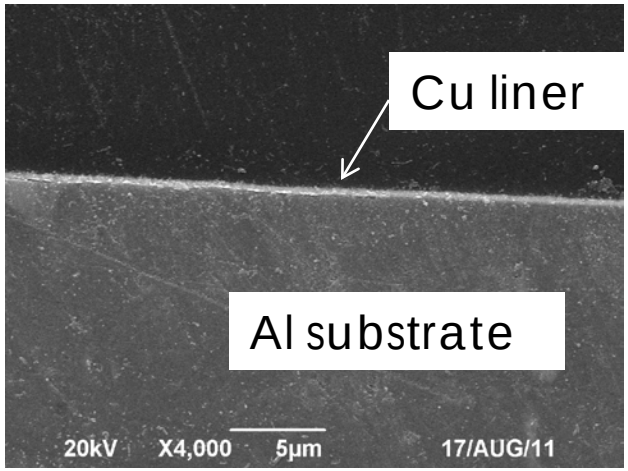


Barrel

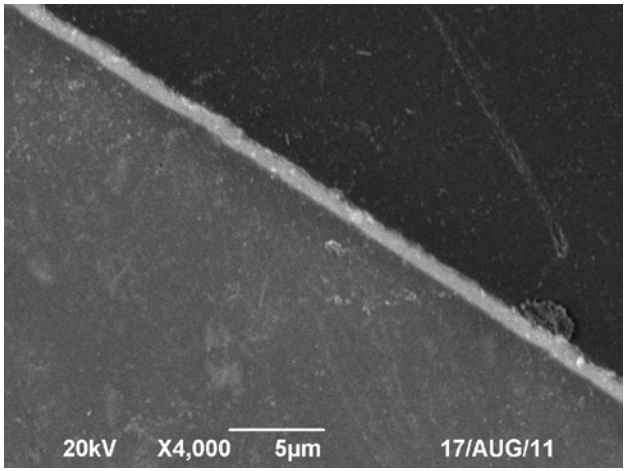
- **Al substrate surface quality is poor independent of location on mandrel**
- **Consequently Cu liner has poor adhesion**
- **Most likely cause is improper surface conditioning through ion etch**
- **Process drift of ion gun (degraded gas distributor plate)**

GENERAL ATOMICS

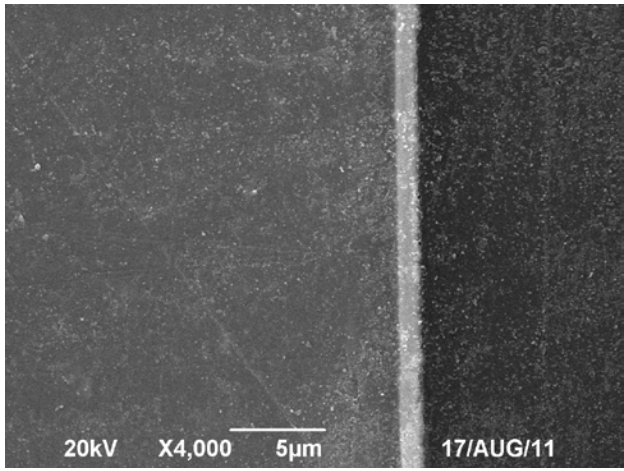
SEMs of Cu coated Al mandrel post maintenance of ion gun show big improvement



Flat



Radius



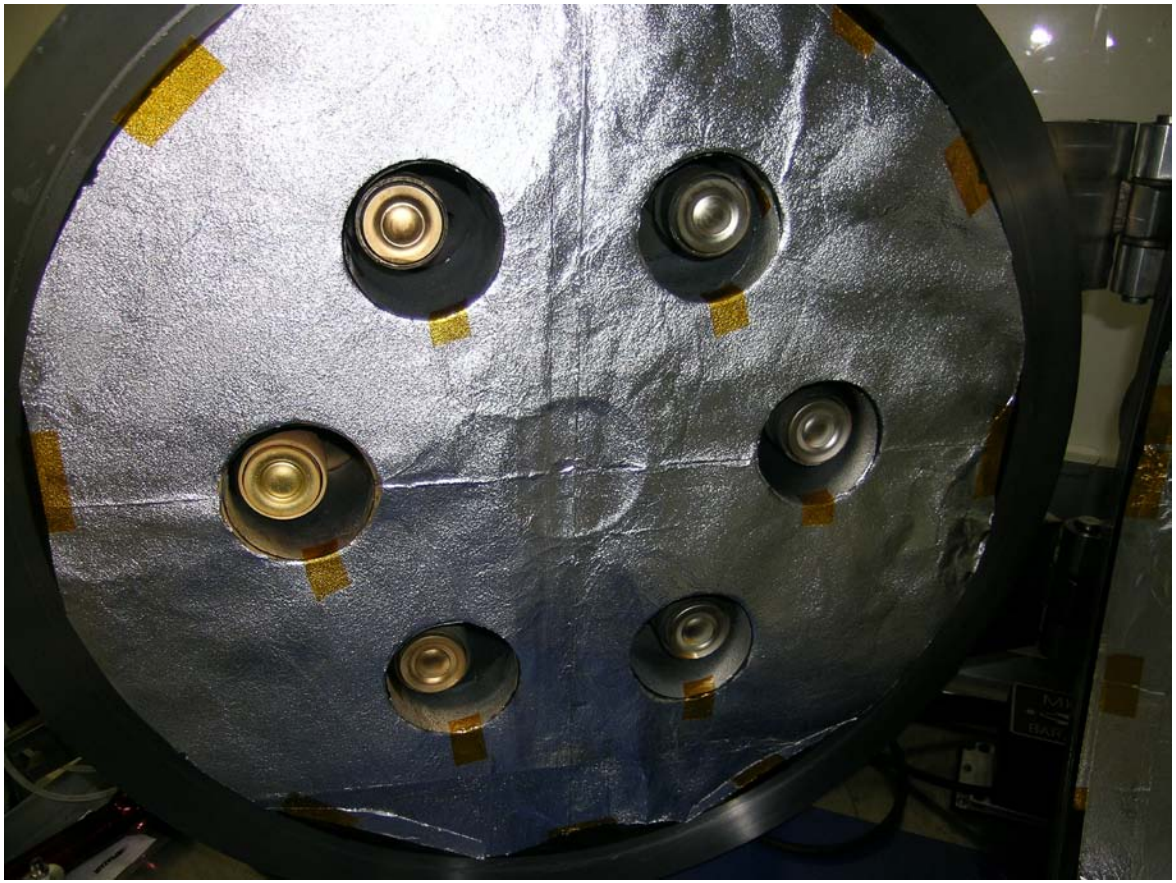
Barrel

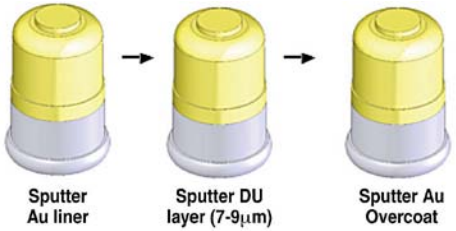
- **Al substrate surface is smooth with no major defects**
- **Cu liner is continuous and well bonded to underlying Al substrate**
- **Tight process control is important**

Ion gun maintenance improved yield to ~25%

GENERAL ATOMICS

DU coaters have six gun configuration for coating Au and DU without breaking vacuum





Au coating ~20-30 min

DU coating ~4-8 hrs

Therefore use more DU than Au targets

GENERAL ATOMICS

4 part vs 5 part operation increased yield by ~30%

5 parts in coater

- 5 DU targets, 1 Au target
- coat 1 part at a time with Au
- Time between Au and DU coating lengthy (2-3 hrs)
- For Au overcoat the DU targets turned off before Au target turned on
- No chance for co-deposition
- Yield was <50%

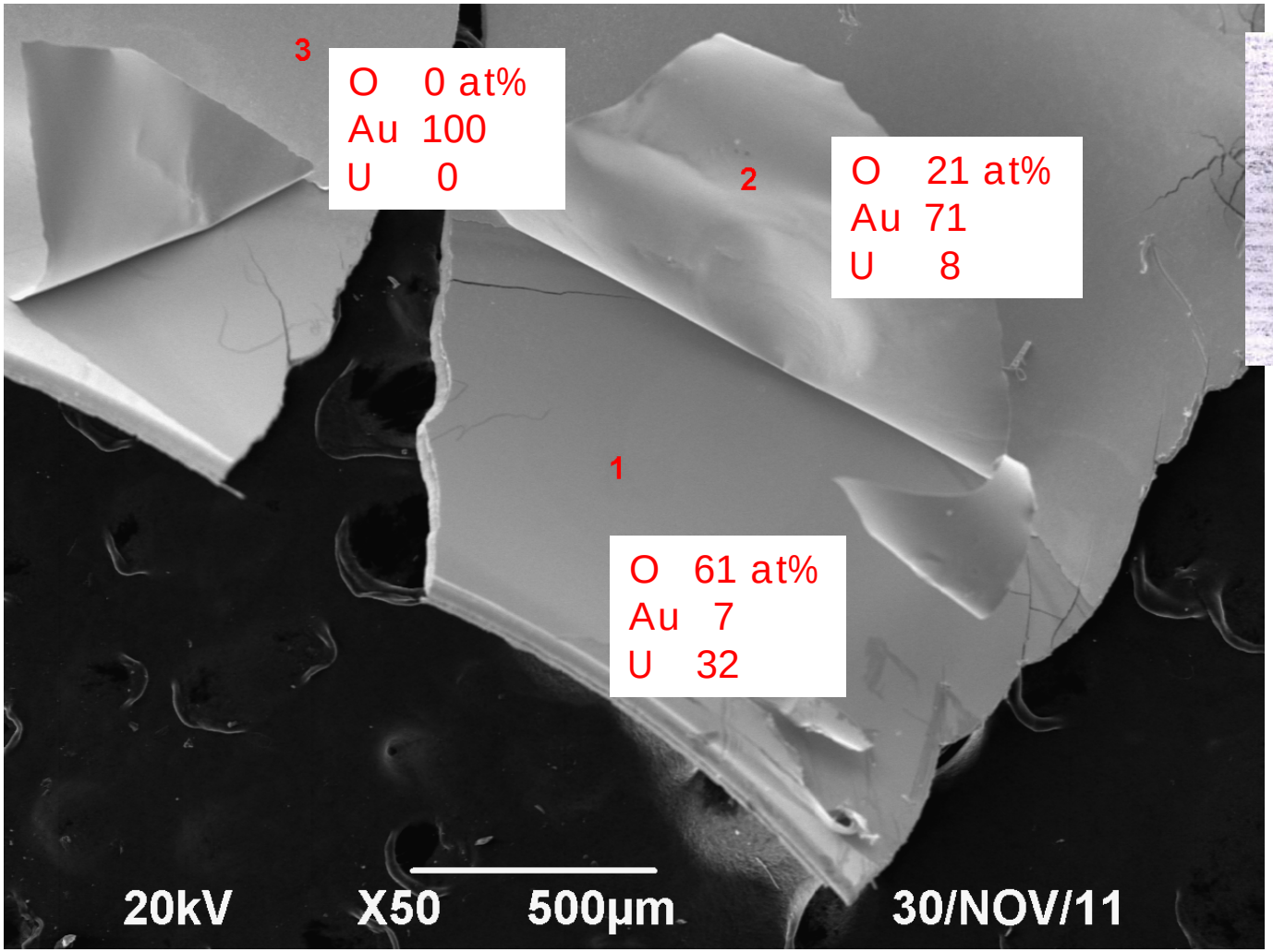
4 parts in coater

- 4 DU targets, 2 Au targets
- Coat 2 parts at a time with Au
- Time between DU and Au coating reduced (~1 hr)
- For Au overcoat the Au targets turned on before DU targets turned off
- Some possibility for co-deposition to promote adhesion
- Yield is >80%

Overall yield increased to ~35 %. Further studies in progress to increase yield and reduce cost

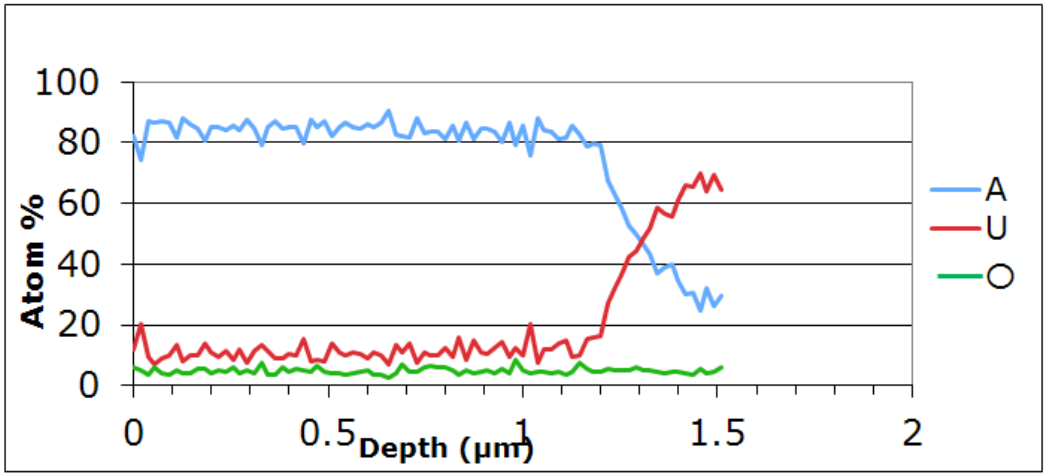
GENERAL ATOMICS

Blisters are main failure mode
SEM & EDX examination of blister region

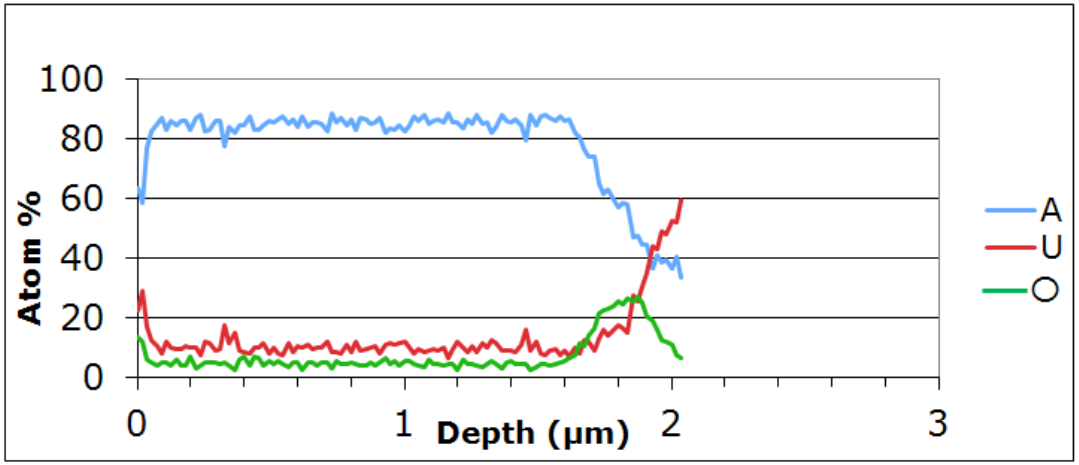


GENERAL ATOMICS

Auger Electron Spectroscopy (AES) depth profile of Au and DU interface



AES through good surface



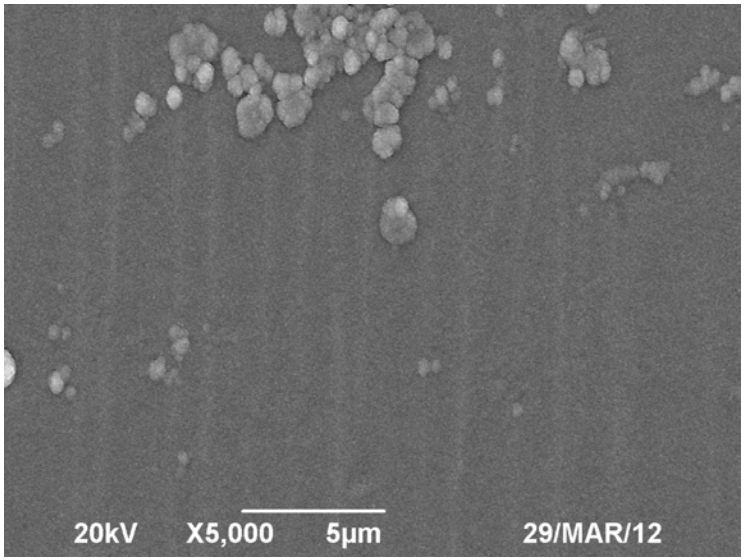
AES through blister

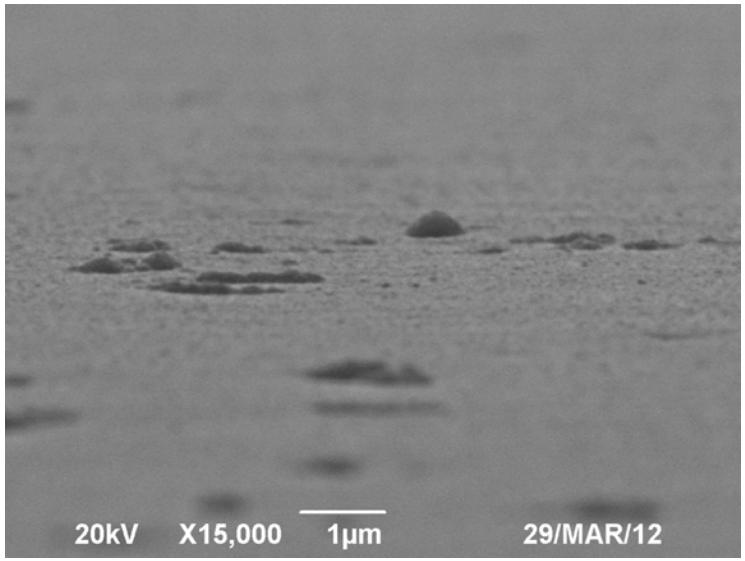
Both EDX and AES show oxygen is present under blister. Does it cause the blister or form after the blister? Are pinholes a problem?

GENERAL ATOMICS

Further mandrel surface experiments in progress

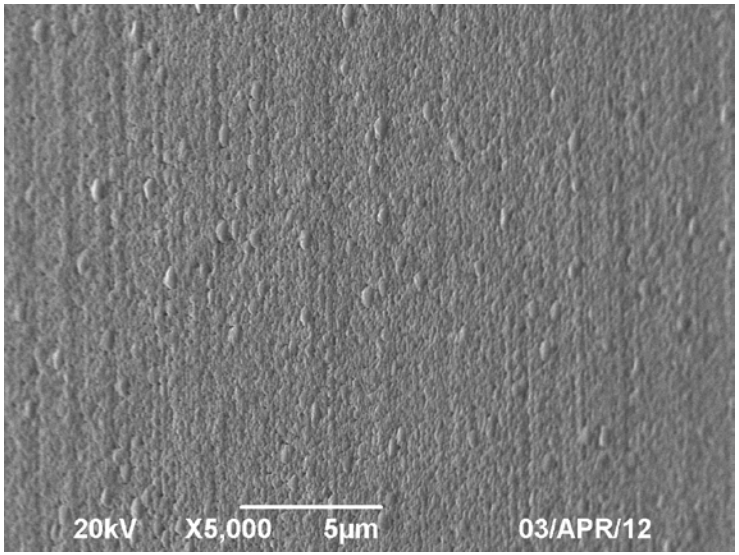
- "Standard" mandrel - 30 min ion etch to clean surface and promote adhesion of Cu
- ~1 µm of sputtered Cu
- Numerous asperities approximately equal in size to Cu coating thickness
- Asperities potential sites for problem areas

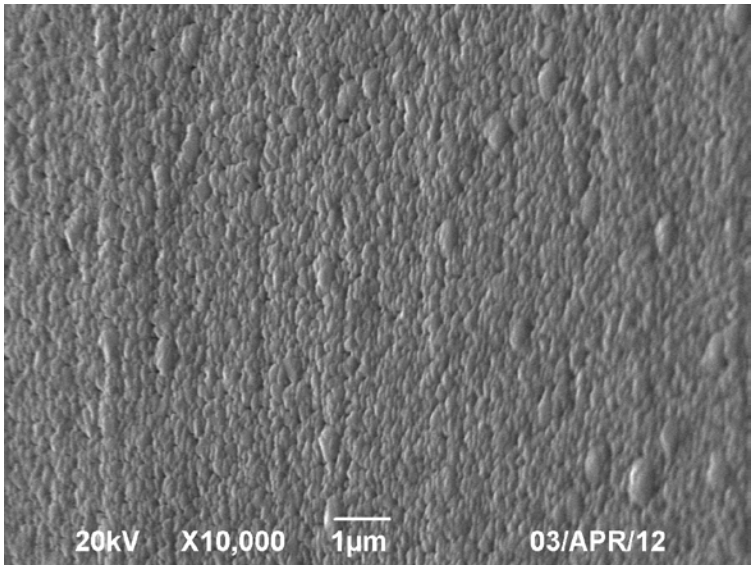




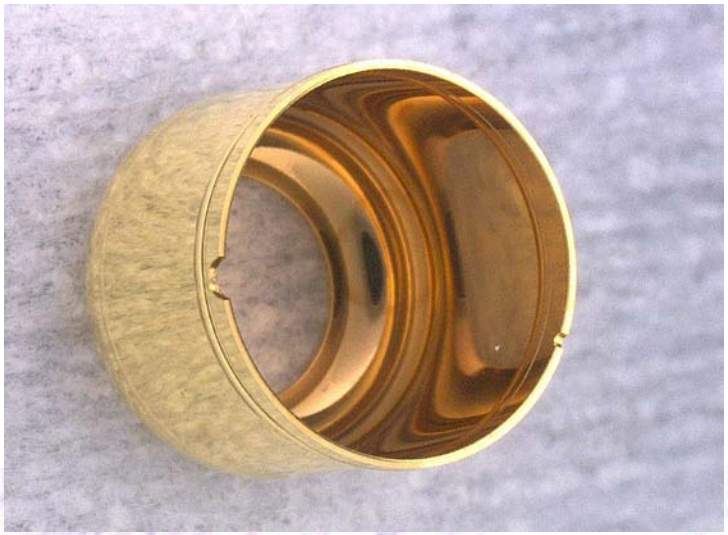
Improved mandrel treatment for higher yield

- 7.5 min ion etch, ~1 µm of sputtered Al, ~1 µm of sputtered Cu
- Multiple layers reduces probability of pinholes
- Cu layer is well bonded
- Blemishes are reduced in size
- Preliminary yield results are promising



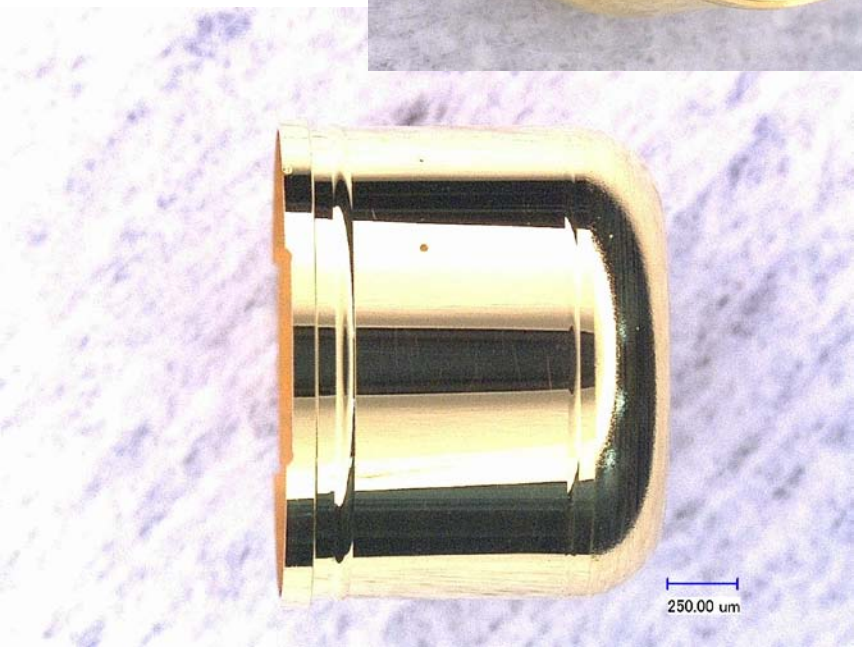


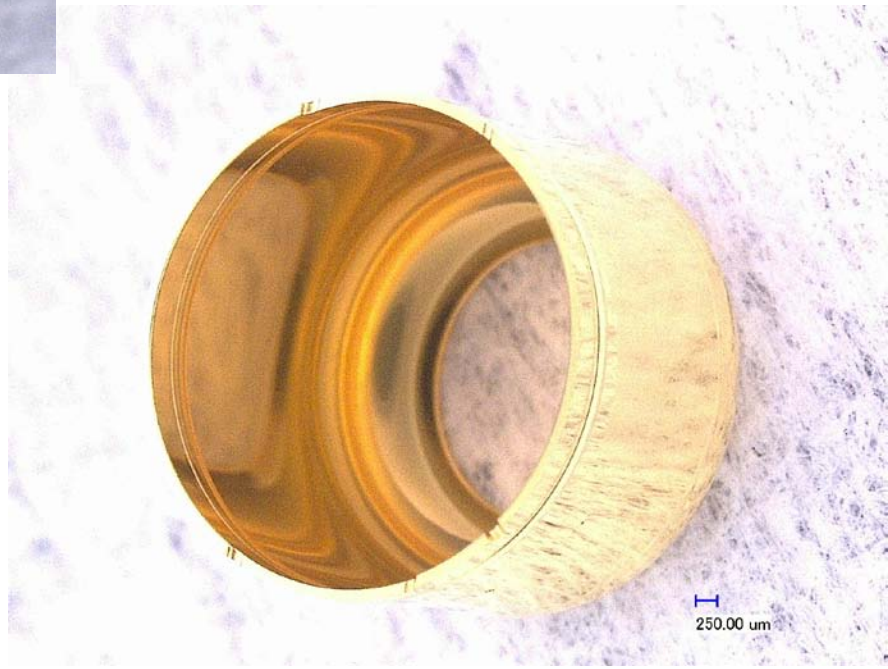
Examples of good DU hohlraums



DU SymCap half hohlraum

ConAw half hohlraum





Summary of Yield Improvements

- Maintain tight control to prevent process drift
- Implement process changes to determine production/yield improvements
- Investigation of failures to determine causes and failure modes (e.g. blisters, coating integrity, pinholes, oxides) and increase yield
- Working closely with LLNL to examine production issues and failure modes
- DU hohlraum production capability at current yields with 2 DU coaters is 8-9 half hohlraums per week
- 3rd DU coater nearly complete and will increase production capability by 50%
- Year to date a total of 93 DU hohlraum halves have been produced and shipped to LLNL

GENERAL ATOMICS