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
DU hohlraum fabrication process
Examples of DU hohlraums with asperities

- Large blisters in radius
- Exposed DU on exterior barrel
- Medium blister on interior barrel
- Residual Cu in flat
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
M1 Sputter coater with ion gun for cleaning Al mandrel
Scanning Electron Micrographs of Cu coated Al mandrel show poor surface quality

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

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

1. O 0 at%
   Au 100
   U 0

2. O 21 at%
   Au 71
   U 8

3. O 61 at%
   Au 7
   U 32

20kV  X50  500µm  30/NOV/11
Auger Electron Spectroscopy (AES) depth profile of Au and DU interface

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