US Development of Tungsten “Brush” Armor

*presented by Richard Nygren, Sandia*

- Brief review of Sandia’s PMTF
- Brief review of previous testing of mockups
- Recent mockup tests in FY1999

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W brush armor mockups

“Development of Tungsten Brush Structures for PFC Armor Applications” SOFE97 paper by Slattery, Odegard Jr, McKechnie, Watson
Methods for embedding W rods

**Plasma spray method** is being used by Plasma Processes, Inc. to make mockups for HHF tests. Joining of armor to heat sink by e-beam seam weld and by HIPping is being studied.

**Casting method** - EU and RF produced W/Cu mock-ups and tested them. US introduced tapered rods, honeycomb fixture, reinforced Cu matrix, HIP. With radiant heating in a hydrogen atmosphere in vacuum, Cu wetted W well but wetted the full length of the rods. Work has been suspended because other joining methods seem to be successful.

**Hot pressing method** - Bench tests indicated promise for this very direct method. Good bonding was achieved. Work has been suspended because other joining methods seem to be successful.
**Methods for Embedding W Rods**

1) Fixture Pointed W Rods in Honeycomb
2) Plasma Spray Cu to Tips of Rods
3) HIP Diffusion Bond to CuCrZr Heat Sink at 450°C-550°C/200MPa/180min

**Plasma Spray**

1) Fixture Rods with PVD-coated tips in Honeycomb
2) at 450°C/200MPa/180min,
   2a) HIP Diffusion Bond to CuCrZr Heat Sink, and
   2b) Driving Rods into OFHC Cladding

**OFHC Cladding**

**Hot Pressing**

1) Fixture Tapered W Rods in Honeycomb
2) Cast Cu to Tips of Rods
3) HIP Diffusion Bond to CuCrZr Heat Sink at 450°C/200MPa/180min

**Casting**

1) Cast Cu Between W Rods and Honeycomb
Mechanical “pull out” test of W rods

Bundle of 19 Rods:
18 are 27mm long
1 is 55mm long
All are 3.16mm dia.

55mm W Rod
Protruding up
for Tensile Test

(UTS)
Machine Grips

Cu Grip

Retaining Cap

Plasma Sprayed
Coating on End
Sandia National Laboratories

++>WHVWVRI:EUXVKDUPRUPRFNXSV

PW-4 mockup:  W rods 1.5mm dia., cone end (45°) with 25-50mm Ni coat, plasma sprayed Cu bed; vacuum baked 600 & 900°C; PVD Ni plate; HIP

PW-7 sample:  rods/tooling as PW-4; 5mm thick bed; W/Cu functional gradient layer applied to bond-coated W rods. (Fracture of several rods during manufacturing, and blistering of the PVD Ni coating.)

PW-9 mockup:  Based on previous results, PW-9 was made with 150nm of PVD Nb on the W, followed by 150nm of Ni. Plasma Processing Inc. is preparing additional HHF mockups.

PW-4 and PW-9 were tested in FY98; rod tips on PW-4 melted without adverse effect during subsequent testing.

Additional testing on PW-4 and PW-9 was done in FY1999.

melted rod tips

8 mm
HHF tests of W brush armor mockups in FY1999

PW-7 and PW-9 retested successfully for 500 cycles at 30MW/m².

**PW10 Mockup** (made by Plasma Processes through DOE’s Small Business Innovative Research Program) has W "brush" embedded in plasma sprayed copper and survived 500 cycles at 30MW/m².

The rods splayed slightly during testing. In the last 30 cycles (pattern off center), some rods received >30MW/m² and melted.

Loss from evaporation is evident.