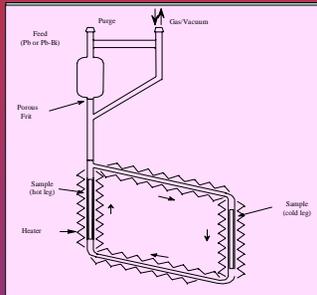


Corrosion of Structural Materials in Lead and Lead-Bismuth Eutectic Coolants

Laurel A. Barnes, Leonard Leibowitz, and Karthick Gourishankar
 Chemical Engineering Division, Argonne National Laboratory

Lead-Cooled Fast Reactor (LFR) Development

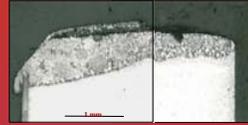
- Part of Generation IV Nuclear Energy Systems Plan
 - Small factory-built turnkey plant
 - 15- to 30-year refueling interval
 - Sealed replaceable reactor module
- Significant Coolant Technology Challenges
 - Long cladding lifetime required
 - High-temperature performance needed
 - Current study designed to evaluate corrosion issues



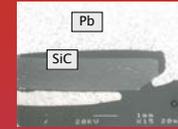
Test Material	Liquid Metal	Time (h)	Hot Leg (°C)	Cold Leg (°C)
HT9	Pb-Bi	4500	550	400
AISI-S5	Pb-Bi	4500	550	400
Kanthal A	Pb-Bi	4500	550	400
HT9	Pb	1000	700	525
Kanthal A	Pb-Bi	4500	550	400
HT9	Pb-Bi	4500	550	400
SiC	Pb	1000	800	650
V-4-Cr-4Ti	Pb	1000	800	650
SiC/SiC-Nicalon Composite	Pb	1000	800	650
MA 957	Pb	1000	650	500
MA 957	Pb-Bi	1000	650	650

Surface Film Found on HT-9 Identified as Cr-Rich Spinel

- Low-angle X-ray patterns contained diffraction lines that matched those of a FeCr_2O_4 -type (spinel) structure
- Raman Spectroscopy showed that oxide film is of the type $\text{Fe}_{3-x}\text{Cr}_x\text{O}_4$ ($1 \leq x \leq 2$)



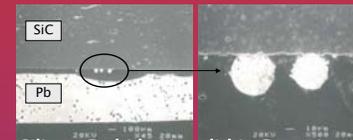
HT-9
 550°C, Pb-Bi, 4500 h
 Intergranular penetration at ends



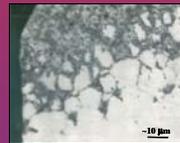
Silicon Carbide Monolithic Ceramic
 800°C, Pb, 1000 h
 No evidence of lead interaction with SiC



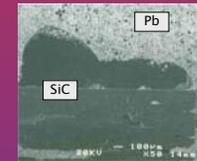
AISI S5
 • No intergranular attack by lead-bismuth eutectic
 • Two diffusion fronts
 – (A) high Cr
 – (B) high Mn



Silicon Carbide Monolithic Ceramic
 Pb droplets show negligible wetting of SiC

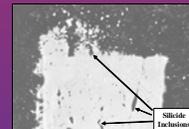


Kanthal A
 550°C, Pb-Bi, 4500 h
 Significant attack shown



Silicon Carbide-Silicon Carbide Fiber (Nicalon®) Reinforced Composite
 800°C, Pb, 1000 h

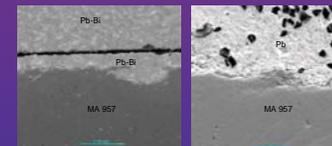
- Nicalon® fiber was first developed by Yajima in Japan
- The fiber contains significant amounts of SiO_2 and free carbon
- Lead wets and intrudes the composite structure



Vanadium 4-Chromium-4-Titanium Alloy
 800°C, Pb, 1000 h
 Significant attack shown

MA 957
 600°C, Pb and Pb-Bi, 1000 h

Comparison of exposure of the ODS ferritic alloy MA 957 to Pb (far right) and Pb-Bi (near left). Note significant intrusion of Pb-Bi into the alloy. No significant attack by Pb. Irregular dark spots in Pb are polishing compound.



Conclusions

- Level of attack depends on coolant and base metal chemistry, microstructure, and impurities
- All metal samples tested showed some degradation
- Pb-Bi eutectic more corrosive than Pb
- SiC appears very promising