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SiC/SiC LiPb Compatibility

S. Malang

A) Tests at FZK (H. Kleykamp)

a) Static test at 600 deg C, 4 weeks :
   - estimated wall thinning 1.7 micro meter

b) Static test at 800 deg C, 4 weeks :
   - estimated wall thinning 3.6 micro meter

c) Static test at 1000deg C, 4 weeks :
   - Test successful, however
     probe still not yet analyzed

A) Tests at CEA (A. Terlain)

a) Static test at 800deg C, 3000 hours:
   - no reaction observed

b) Static test at 1000deg C, 3000 hours:
   - test will be completed by end of dec. 2001

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Isothermal compatibility studies were performed between a Pb-17 at. % Li melt and hexagonal α-SiC (the stable modification) at 600°C, 800°C and 1000°C for four weeks in each case. For this purpose, liquid Pb-Li was filled under argon atmosphere in a SiC crucible with > 98 % th. d. and 2 r_i = 12 mm inner diameter up to 6 mm height which was inserted in an Al_2O_3 crucible. This arrangement was vertically positioned in a steel and Ni-alloy crucible, resp., which was closed with a lid by electron-beam welding. An Al_2O_3 crucible was necessary to avoid SiC-steel and SiC-Ni incompatibilities (silicide formation). The containers were opened after the air atmosphere annealing experiments. The 600°C and 800°C tests revealed a loose contact of the SiC crucibles with the cylindrical Pb-Li ingots, the latter were embedded and prepared as metallic cuts and were polished by diamond emery down to 0.3 µm. X-ray microanalysis was done on Si (Kα line); C analysis was not possible due to diamond polishing and interference of the C Kα line with Pb N-N transitions in the wavelength region 4.2 to 4.5 nm. Si step scans were made from the ingot cylinder surfaces to the ingot centers with about 6 mm distance.

Results: The 600°C experiment resulted in an average Si concentration in the solidified melt of 0.017 mass %, which increased to 0.04 mass % in the outer surface near 60 µm thick region. 0.017 mass % Si corresponds to 0.0073 mass % C as SiC dissolution is assumed yielding c_{SiC} = 0.000243 mass fraction in Li-Pb. Geometrical considerations result in SiC inner crucible wall thinning d_{SiC} = 1.7 µm. An ingot averaged Si concentration of 0.035 mass %, a surface near concentration increase up to 0.3 mass % and a SiC wall thinning of d_{SiC} = 3.6 µm was obtained at 800°C under the same experimental and analytical conditions. The steel containers were not scaling-resistant during the 1000°C annealing in air atmosphere. Therefore, a Ni-base alloy container was used in a second experiment at 1000°C. An appreciable Li-Pb fraction evaporated from the SiC crucible and condensated on the Al_2O_3 crucible wall and inner bottom of the container. Metallography and X-ray microanalysis of the remaining Li-Pb and the condensate are in progress.

COMPATIBILITY WITH Pb-17Li OF MATERIALS FOR FUSION REACTORS

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Liquid metals are often considered in nuclear applications. However corrosion by liquid metals is a concern when solids are exposed to this environment. It can manifest itself by dissolution, formation of reaction products, liquid metal penetration,...and it depends on different factors such as temperature, thermal gradient, hydrodynamics, liquid and solid compositions,...In a fusion reactor, Pb-17Li eutectic liquid is considered as a liquid coolant due to its high thermal conductivity but also as tritium breeding material of the blanket.

The plasma-facing region is submitted to a high particles flux generated in the plasma and thus High Heat Flux Components (HHFC) operate in conditions of high thermal stresses, high neutron flux and high heat flux. Solutions must be found to extract these high heat fluxes, especially on the divertor. Liquid metal-cooled divertors are attractive because of their high thermal conductivity. W-alloys appear to be the best choice as armor material: they will therefore be in contact with the coolant. Thus R&D is required to assess the corrosion behavior of W-alloys exposed to liquid Pb-17Li.

Moreover, the TAURO blanket developed in the European Community by CEA is a self cooled breeder blanket using the SiC_f/SiC ceramic matrix composite as structural material and liquid Pb-17Li as coolant, breeder and neutron multiplier. Among the most significant design issues on the TAURO blanket, the assessment of the compatibility between Pb-17Li and SiC_f/SiC (including the brazing material) has been identified.

In this paper, we report the results of corrosion tests of SiC_f/SiC composite and W materials in stagnant Pb-17Li.

The corrosion behavior of a W alloy has been studied by immersion tests in static liquid Pb-17Li in the temperature range 450-800 °C and for exposure times up to 1500 h. The amount of tungsten found in Pb-17Li at the end of the isothermal tests was very small indicating that the dissolution of this element was likely very limited. The interaction with the molten alloy did not lead to the formation of reaction products on the tungsten surface. No composition change was found at the solid-liquid interface. The observations did not exhibit any liquid metal penetration in the tungsten.

The SiC_f/SiC composite Cerasep® N3-1 was exposed to liquid Pb-17Li at 800 °C up to 3000 h. These experiments indicate that the material has not reacted with the liquid alloy. Therefore, it should be stable and compatible with this environment. Penetration of Pb-17Li was only observed into the free space (porosity) as the composite is not highly densified. The open porosity was mainly due to the cutting of the specimen after manufacturing.