COMPATIBILITY OF SILICON CARBIDE COATED GRAPHITE WITH LEAD-BISMUTH EUTECTIC AT 900°C

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INTRODUCTION

Bhabha Atomic Research Centre (BARC) is developing a prototype Compact High Temperature Reactor (CHTR), which aims at the production of industrially usable hydrogen by splitting of water [1]. The CHTR uses U-233 and thorium-based carbide as fuel compacted in a graphite matrix (TRISO coated particle). Cylindrical fuel compacts are packed in fuel bores located at the walls of each graphite fuel tube. The core heat is removed by natural circulation of lead-bismuth eutectic alloy [44.5 wt. % Pb + 55.5 wt.% Bi], which enters the graphite fuel tube at 900°C leaves the tube at 1000°C. Lead-bismuth eutectic is found to be substantially corrosive towards various structural materials like austenitic stainless steels and graphite [2-3]. Considering this aspect, a protective coating of silicon carbide material (SiC) has been proposed over the graphite fuel tubes. Nevertheless, obtaining a uniform and continuous SiC coating over graphite material is a major challenge. Although SiC is a relatively hard and inert material, compatibility of the same with lead-bismuth eutectic at the working temperature is another important area of investigation. With this view, a layer of SiC was formed on a graphite pellet through slurry based silicon coating followed by high temperature in-situ reaction. Later, the corrosion behaviour of the coated pellet with molten Pb-Bi was studied in static condition at 900°C for a duration of 200 h.

EXPERIMENTAL DETAILS

A graphite pellet of 17 mm diameter having a density of 1.8 gm/cc was coated with silicon slurry prepared in-house. The coating was carried out by simple brush painting method. The silicon coated sample was subsequently heat treated at 1600°C to form a uniform SiC coating on the graphite surface. For compatibility study, a test retort having online sample removal mechanism was fabricated out of a one end closed pipe made of Inconel 625 material (Figure 1). A graphite crucible containing the requisite amount of solid of Pb-Bi chunks was placed inside the retort.

Fig 1: Schematic of the static corrosion test facility with online sample removal mechanism

Fig 2. XRD plot of the SiC coated graphite material before exposure to LBE
The sample (pellet) was placed inside a molybdenum sample holder which could be dipped in and out of molten Pb-Bi with the help of an Inconel 625 rod. After assembly, the temperature of the Pb-Bi was raised to 900°C under inert argon atmosphere and the sample was completely dipped inside the liquid Pb-Bi. The experiment was conducted for 200 hrs and sample was analysed through weight loss measurement, X Ray Diffraction (XRD) and Secondary Electron Microscopy-Energy Dispersive Spectroscopy (SEM-EDS).

RESULTS AND DISCUSSION

Figure 2 shows the XRD plot of the SiC coated graphite pellet before exposure to Pb-Bi. The conversion of Si in the slurry to SiC during heat treatment was confirmed by the presence of β-SiC. The peak of pure silicon indicated the presence of un-transformed Si possibly towards the outer surface of SiC layer. The SEM micrograph of the cross section of the SiC coated graphite pellet before exposure to LBE showed satisfactory adherence between the graphite and SiC material (Figure 3). The pellet suffered a weight loss of 17 mg after exposure which corresponds to 0.78 % of the initial weight. Individual peaks of LBE and Si along with prominent peaks of graphite (C) and β-SiC was noted in the XRD analysis of the in the unwashed exposed pellet whereas the XRD plot of the exposed and cleaned pellet showed the presence of graphite and SiC only. This indicated that cleaning of the exposed pellet might have caused removal of the outer Si layer and was the possible reason for weight loss. Figure 4 shows the SEM micrograph of the the cross section of a SiC coated graphite pellet after exposure to LBE. The SiC layer over the graphite material was found to remain intact even after exposure. EDS results confirmed the effectiveness of the SiC coating since no penetration of Pb or Bi could be observed into the SiC or graphite matrix.

CONCLUSION

An adherent coating of β-silicon carbide (SiC) was formed over a graphite pellet through slurry based silicon coating technique followed by in-situ reaction at 1600°C. The SiC coated graphite pellet was exposed to LBE at 900°C in a static corrosion test facility equipped with online sample removal mechanism for 200 h. A weight loss of 0.78% of the original weight was recorded for the exposed pellet possibly due to the removal of residual silicon during cleaning of the adherent LBE layer. The SiC coating was found effective in preventing molten LBE from attacking the inner graphite substrate at 900 °C for a duration of 200 h.

REFERENCES