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液体リチウム鉛回転流動場における機能性セラミックス被覆の共存性試験

Compatibility tests of functional ceramic coatings with liquid lithium-lead under rotating flow

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1. Introduction

Tritium permeation through structural materials in fusion reactor blanket systems is a critical issue from the perspectives of fuel loss and radiological safety. Ceramic coatings have been investigated as a tritium permeation barrier and shown high permeation reduction performance. In liquid blanket concepts, however, corrosion of the coatings by liquid tritium breeders such as lithium-lead (Li-Pb) is an unavoidable concern. Recently, the Li-Pb corrosion resistance of the single-layer and multi-layer coatings was investigated in static conditions [1,2]; however, a limited number of reports investigating in flowing conditions are available. Therefore, in this study, the Li-Pb exposure tests under rotating flow were conducted using the coatings with various layer structures to investigate the effect of layer structure on the compatibility with flowing Li-Pb.

2. Experimental

Reduced activation ferritic/martensitic steel F82H (Fe-8Cr-2W, F82H-BA07 heat) plates were used as substrates. The coating procedure including formation of chromium oxide (Cr_2O_3) on the substrate, dip-coating of the coating precursors, drying, pre-heat treatment, and heat treatment is described in detail in Ref. [2]. The layer structures of the coatings are summarized in Fig. 1. The heat treatment was performed every time after preparing each layer for crystallization.

Li-Pb exposure tests under rotating flow were performed using a rotating apparatus at 550 ºC for 100-500 h with a rotating speed of 200 rpm. The samples were fixed to the rotating blades by stainless steel wires so that the flow velocity on the samples is calculated to be approximately 0.37 and 0.57 m/s. Surface and cross-sectional observations of the exposed samples were conducted by scanning electron microscopy (SEM) with energy dispersive X-ray spectroscopy.

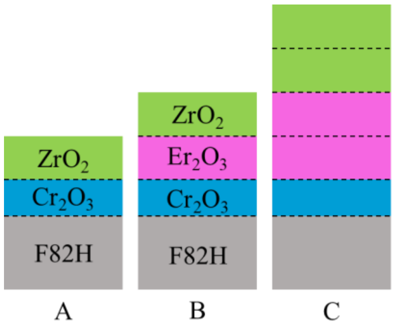

Fig. 1 Layer structure of coating samples.

3. Results and discussion

A difference in surface morphology depending on the flow velocity was confirmed after the exposure test for 100 h, while was not after the test for 500 h. After the test for 500 h, cracks were observed in Samples A and C. In Sample B, swelling of the coating was observed, and iron oxide was detected under the swelled coating. From these results, an acceleration of corrosion caused by Li-Pb flowing was confirmed. Moreover, it was found that the oxygen was supplied to the substrate through the ZrO_2 coating to a certain depth under flowing conditions. To improve Li-Pb compatibility of the coating under flowing conditions, it is necessary to take into consideration oxygen supply to the substrate through the coating in addition to flow-accelerated corrosion.

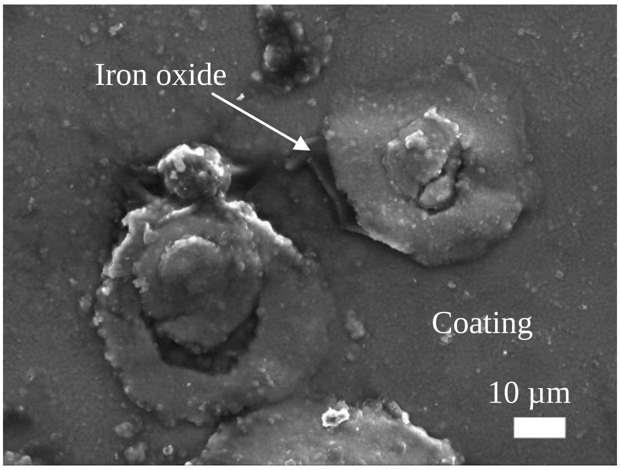

Fig. 2 Surface SEM image of Sample B after Li-Pb exposure test under rotating flow at 550 ºC for 500 h with flow velocity of 0.37 m/s.

Reference

[1] M. Matusnaga et al., J. Nucl. Mater. 511 (2018) 534-543.
[2] E. Akahoshi et al., Fusion Eng. Des. 160 (2020) 111874.