Characterization of multifunctional ceramic coating on steel pipe fabricated by metal organic decomposition

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Aiming to reduce tritium permeation through structural materials as well as realize the advanced fusion blanket, zirconium oxide coatings were fabricated on 316L type stainless steel pipes by the metal organic decomposition method.

Keywords: tritium, permeation, pipe, corrosion, zirconium oxide

1. Introduction

In fusion reactor blankets, multifunctional coatings have been investigated for tritium permeation reduction, electrical insulation, and corrosion protection. In terms of practical use, it is critical to establish a ceramic coating technique on the inner wall of complicated components in liquid metal blankets. In this research, we initially achieved to form homogeneous zirconium oxide (ZrO_2) coatings on the inner wall of 316L type stainless steel (SS316L) pipes of half an inch in outer diameter and up to 250 mm in length by metal organic decomposition (MOD) method.

2. Experiment

The ZrO_2 coating was fabricated on the outer and inner surfaces of SS316L pipes. To form a homogenous coating on the long pipe, the processes of dipping, drying, and pre-heating were repeated eight times, and the heat treatment was processed in an argon and hydrogen atmosphere [1]. The whole coating process was repeated twice to increase the coating thickness. The electrical insulation of the coating was determined from electrical resistivity measurements up to 550 ºC. The compatibility with the liquid metal was examined by liquid lithium-lead exposure at 600 ºC for 100 h and 550 ºC for 500 h and 1000 h. In addition, deuterium permeation tests were conducted to examine the permeation reduction performance. Microstructural analyses, such as the field-emission scanning electron microscopy (FE-SEM) and the dispersive electron X-ray spectroscopy (EDX) were performed on the samples before and after tests.

3. Results and discussion

By FE-SEM observation and EDX analysis, ZrO_2 coating homogeneously formed on the inner wall of the coated pipe with a coating thickness of approximately 400 nm. The coating satisfied the electrical resistivity of $>10^2$ Ω m and dielectric strength of >1 kV/mm required for the MHD coating in a liquid Li-cooled blanket system [2]. After liquid Li-Pb immersion, all samples remained with the coating on the entire surface and had no degradation, such as cracks and peelings. At the test of 600 ºC for 100 h, the coating thickness increase due to including the corrosion layer. However, at the test of 550 ºC for 500 h, the coating thickness slightly decreased, and Zr spread to liquid Li-Pb from EDX analysis. It indicated that the corrosion layer and the outermost coating layer have dissolved in the liquid Li-Pb. The deuterium permeation performance will be released and discussed in the presentation.

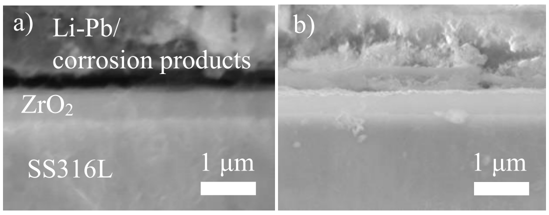

Figure. Cross-sectional FE-SEM images of the samples exposed to liquid Li-Pb for a) 100 h at 600 ºC and b) 500 h at 550 ºC.

References

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