§26. Control of Heat and Hydrogen Transfer by Improvement of Interface Structure in Heat Exchanger of Fusion Blanket

Kondo, M. (Tokyo Institute of Technology),
Suzuki, N., Matusmura, Y. (Tokai Univ.),
Tanaka, T., Hishinuma, Y., Muroga, T., Sagara, A.

1. Introduction

The control of heat and tritium transfer in the liquid breeder blanket system is one of the critical issues for the development of fusion reactors. The interface for heat and tritium transfer of the heat exchanger in the blanket system should be designed to achieve a large coefficient of heat transfer and a small permeability of tritium at the same time. The tritium permeability can be improved by the application of ceramic coatings, which work as a tritium permeation barrier (TPB) in the heat exchanger. The ceramic coatings of Y_2O_3, Er_2O_3 and ZrO_2, which have high chemical stability, can be used as the TPB in the liquid breeder blanket. The function of TPB must be kept during the life time of the heat exchanger. The compatibility of these functional layers with liquid breeders should be improved.

In the current research project, the function sharing type multiple interface structure has been developed to keep the function as the TPB for long term without the maintenance. The outer layer is fabricated by a thermal spraying method, and the inner layer is fabricated by the MOD method. The outer thick layer works as an anti-corrosion barrier, and the inner thin layer works as the TPB. The interface structure having the self-healing function based on the formation and the growth of a compact oxide layer has also been developed. The in-situ monitoring system for the corrosion and the damage of these layers in liquid metals has been developed based on the electrochemical spectroscopy method (EIS).

2. Development of function sharing type interface structure by multiple-layers

The multiple layer structure was fabricated as the outer layer by the ceramic thermal splaying was laminated on the MOD coating layer, which was fabricated on the SUS316L substrate as shown in Fig. 1 (a). In the current work, the multiple layer structures with the ceramic material of Y_2O_3 and $A_{l2}O_3$ were fabricated. Fig. 1 (b) shows the results of the surface cross sectional observation for Y_2O_3 type multiple layer structure. It was found that thermal splay layer of Y_2O_3 with the thickness of approximately 20μm was successfully fabricated on the Y_2O_3 MOD layer. The corrosion tests for the specimens with the Al_2O_3 type multiple layer coating were performed in liquid Pb at 773K. The test duration is 567 hours. Though the outer layer by the thermal spray was chemically stable in the liquid Pb, the layer was partially peeled off from the MOD layer according to the penetration of Pb through the crack of the layer as shown in Fig. 1 (c).

3. Development of interface structure having self-healing function

It is known that the compact oxide layers of Y_2O_3 and ZrO_2 form on the surfaces of Y metal and Zr metal. These oxide layers were fabricated by the pre-oxidation treatment for the rod type specimens at 773K for 350 hours in air environment. Then, the specimens were immersed in the liquid metals at the temperature between 773K and 873K.

4. Electrochemical impedance spectroscopy for interface structure exposed to liquid metal

The EIS analysis was performed for the Al_2O_3 type multiple layer coating exposed to liquid Pb. The EIS response was not detected, since unintended electrical connection between the liquid Pb and the metal substrate was caused by the penetration of the liquid Pb trough the layer (Fig.1(c)). The EIS response was obtained in the test performed with the pre-oxidized Zr metal in liquid Pb. Fig. 2 shows some examples of EIS response obtained during the test. The Nyquist plots indicate the growth of the single oxide layer in the liquid Pb at the initial stage of the immersion. Then, the growth of the oxide layer stopped, and the oxide layer was kept until the end of the immersion tests.

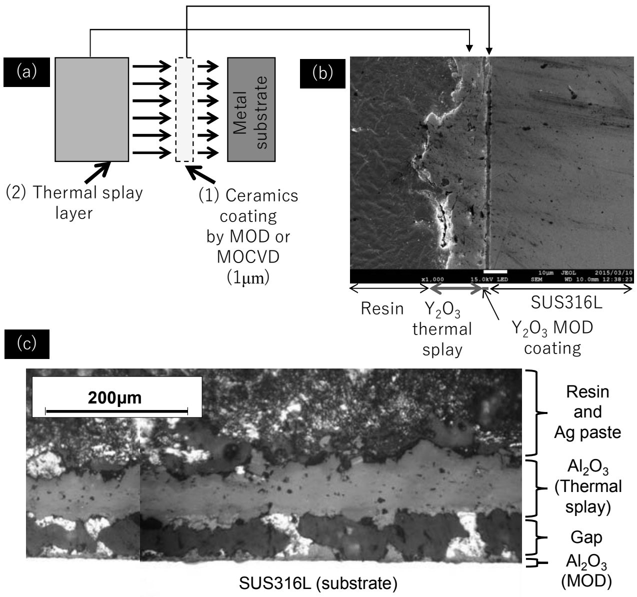

Fig. 1 (a) Multiple layer structure by MOD coating and thermal spray coating, (b) Surface cross section of Y_2O_3 type multiple layer observed by FE-SEM, (c) Peeling off of Al_2O_3 type multiple layer structure observed by optical microscope

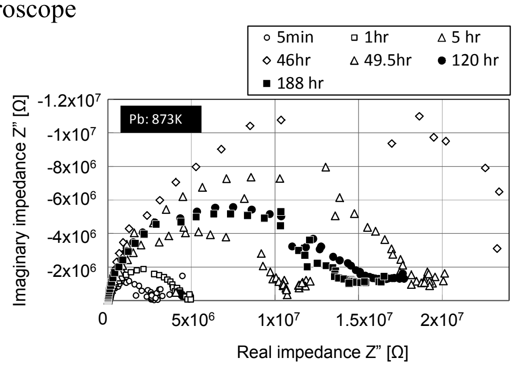

Fig. 2 Result of EIS analysis for pre-oxidized Zr specimen exposed to liquid Pb at 873K