§27. Experimental Study on Self-healing Functional Layer for Liquid Breeder Blanket

Kondo, M., Suzuki, N. (Tokai Univ.),
Tanaka, T., Muroga, T.

The application of functional layers such as Y_2O_3 and Er_2O_3 to the loop piping is necessary to suppress the tritium leaks and the pressure drop of MHD flow in the blanket system. The fabrication of these functional layers was based on two methods. One is the fabrication of the ceramic coating on the tube wall by means of MOD or MOCVD method before the exposure. The other is the in-situ formation due to the oxidation of some metals plated to the steel. The plating of erbium metal to RAFM steel was carried out in our previous study[1)], and the layer can form the Er_2O_3 layer by its oxidation in liquid breeders. Then, the layer has a function of self-healing in the liquid breeders, and enables a longer-term use in fusion blanket system. The corrosion reactions caused on the surface of the ceramic coatings or the oxide layers in the liquid metals were reported in our previous studies[2)]. Then, just the corrosion analysis of the specimen surface after the exposure to the liquid metals does not make clear the corrosion process in detail. An electrochemical impedance spectroscopy (EIS) method must be feasible technique to follow the formation of the functional oxide layer and the degradation of ceramic coating in liquid metals. However, the information on the performance of the EIS in the liquid metals is limited.

The purpose of the present study is to investigate the potential of the EIS method for the self-healing functional layer in the liquid metal system. A series of EIS experiments was performed with various test materials in the liquid metal system as presented in Table 1. Figure 1 shows the experimental apparatus. Approximately 300g of liquid metal was placed in the Al_2O_3 crucible. The temperature condition was controlled by the thermocouple placed at the bottom part of the test container and the heater wound around the container. The impedance measurement on the interface between the specimen surface and the liquid metals by EIS was performed by VERSASTAT 3 manufactured by Princeton applied research. After the exposure, the specimen was picked up from the liquid metals, and the metallurgical analysis on the specimen surface was performed.

The results of the EIS measurement were summarized as Nyquist plot. The impedance due to the formation of oxide layers in liquid metals was detected in some tests. The impedance was not detected in the test with the JLF-1 and Cr specimens because the electro resistivity of the oxide formed on these surfaces was too small to be detected by EIS. The Nyquist plot obtained for the formed oxide layer was evaluated with an equivalent circuit model. The semicircular Nyquist plot with large electro resistance was obtained in Y test due to the formation of Y oxide. The thickness of the oxide layer given by EIS agreed with that by the metallurgical analysis on the surface cross section of the exposed specimen. It was made clear that the EIS was feasible technique to monitor the electrical properties of the oxide layer, which can work as functional layer in the liquid metals.

1) Kondo, M. et al, Plasma Fusion Res. 7 (2012) 2405069.
2) Kondo, M. et al., Fus. Eng. Des. 87 (2012) 1777-1787.

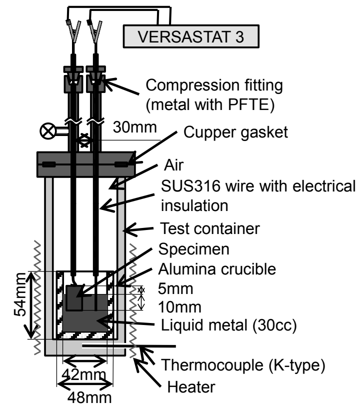

Fig.1 Experimental apparatus

Table 1 Experimental conditions

Specimen	Liquid metal	Cover gas	Exposure time (hour) 375°C	500°C	600°C	700°C	Total	Impedance detection due to oxide layer formation
Fe				986			986	x
Cr				645	312		957	x
JLF-1		Air (1atm)		504	313		817	x
SUS316		(Oxygen saturation in liquid Pb)		764			764	x
Y	Pb		1817	22	1	1	1841	O
Er							1266	x
Al							Ongoing	O
Zr		Ar（0.2ppm O)	26	2	528		556	O
Ti							Ongoing	x
Fe		Air (1atm)		311			311	x
Cr		(Oxygen saturation in liquid Pb-17Li)		790			790	x
Y	Pb-17Li			359	316		675	x
Er		Ar（0.2ppm O)	314	52	2	38	406	x
Al			163	778			941	x
Er	Li			46	248		294	O