§33. In-situ Impedance Measurement of Corrosion Interface in Liquid Metal Pb-17Li

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

Liquid metal lead lithium alloy (Pb-17Li) is candidate to be liquid breeder in fusion blanket system. The compatibility of Pb-17Li with structural materials is critical issue. Corrosion characteristics of reduced activation ferritic martensitic (RAFM) steels in Pb-17Li have been investigated by a series of corrosion tests. The corrosion behaviors were classified into two types, i.e. liquid metal corrosion and oxidation corrosion. The occurrence of either corrosion may be determined due to an oxygen potential of liquid Pb-17Li. These corrosions cannot be caused in the same time, and can be sequentially caused when the oxygen potential changed during the exposure. Liquid metal corrosion or oxidation corrosion caused just before the end of corrosion tests might affect the result of the corrosion test. For example, a trace of oxidation corrosion cannot be easily detected on the specimen tested if a liquid metal corrosion occurred after the oxidation corrosion during the exposure. The interface between a specimen and a liquid metal has impedance when the specimen surface is oxidized in the liquid metal. Then, the interface condition can be known by the on-line measurement of the impedance. In the present study, experimental study on an in-situ impedance measurement of a corrosion interface in liquid metal Pb-17Li was performed. The purpose is to investigate the basic corrosion kinetics in the liquid metals.

Figure 1 shows the experimental apparatus. Rectangular specimen (10 mm x 15 mm x 1 mm) of an unalloyed iron (Fe) were immersed in the liquid metals Pb-17Li (30 cc) at 773 K. The reason for the use of Fe specimen is that Fe is the base metal of RAFM steel. An electro impedance of the specimen surface contact with Pb-17Li was measured by an impedance measurement system (Princeton applied research, VERSASTAT 3). Some oxide was initially formed on a free surface of Pb-17Li by heating procedure in cover gas with air. Therefore, the oxygen concentration in Pb-17Li must be fixed at the oxygen saturated condition. The surface cross section of the specimen tested was analyzed by an electron-probe micro analyzer (EPMA) after the corrosion test. An electro resistance R [Ω] of an oxide layer formed on a specimen surface in Pb-17Li is expressed with an electrical resistivity ρ [Ω·m], an area of wetted part A [m^2] and a thickness of the oxide layer t [m],

$$R=\rho\frac{t}{A} \qquad (1).$$

Here, the electro resistance of Pb-17Li and a leading wire is negligibly small. An electro resistivity of Fe oxide (Fe_3O_4) and lead oxide (PbO) is known as approximately 1 Ω·m and 3×10^3 Ω·m, respectively. The wetted area A is 2.3×10^{-4} m^2 in the present work. When the thickness of the oxide layer increased according to the growth, the electrical resistance also increased based on Eq. (1).

The measured results were obtained as Nyquist plot. Then, the electro resistance was evaluated and summarized in Fig. 2. Initially, the electrical resistance was not obtained possibly because an oxide layer was not formed at low oxygen potential in liquid Pb-17Li. After 150-hour exposure, the electro resistance increased up to approximately 260 Ω, and kept constant. The result indicated the formation of the oxide layer, which had small impedance. Fig.3 shows the results of EPMA analysis on the surface cross section of the specimen, which was exposed to Pb-17Li for 311 hours. There was double layer consisted of lead lithium oxide and iron oxide. The thickness of the iron oxide is approximately 20 μm. Then, the electro resistance by Fe_3O_4 is expected to be 0.2 Ω. The electro resistance of the PbO layer is approximately 260Ω when the layer thickness is 20μm, and agrees with that obtained in the experiment. The Pb-Li-O layer formed due to oxidation of Pb-17Li, and had an electro resistivity.

These results indicated that the in-situ impedance measurement method can be applied to the corrosion monitoring in Pb-17Li when the lead oxide does not form or the impedance of the corrosion product is much larger than that of the lead oxide.

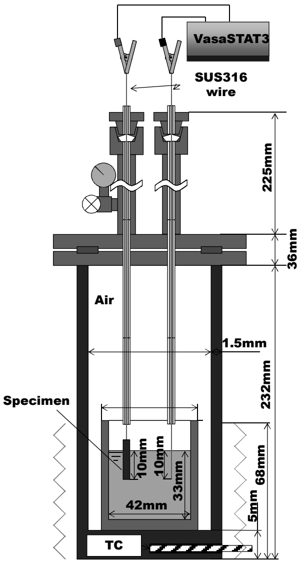

Fig. 1 Experimental apparatus

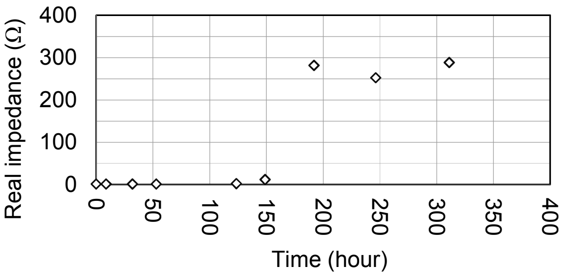

Fig. 2 Electro resistance of the corrosion products

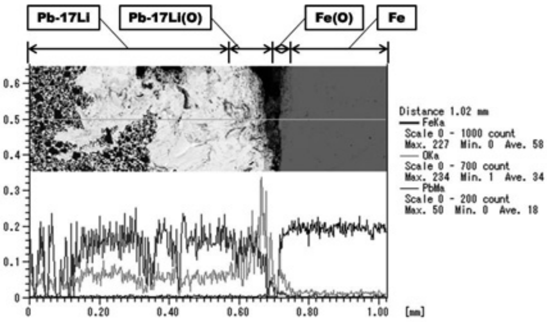

Fig. 3 Result of cross-sectional EPMA analysis on specimen surface