Metallurgical Study on Corrosion of 304 Stainless Steel Accelerated by Electromigration in Liquid Metal Pool

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Electrical current flow in liquid metal pool can accelerate the corrosion of structural materials according to an electromigration phenomenon. The purpose of this study is to clarify the effect of electrical current flow on the chemical compatibility of structural material in a liquid Pb pool. The electromigration test was performed with 304 austenitic steel specimens in liquid Pb pool under electrical current of 10 A. The 304 specimens were analyzed using STEM with EBSD after the corrosion test. The dissolution corrosion was shown to be promoted on the electron-receiving side. The corrosion damage was observed mainly on the bulk area of the grain because of higher electron flow due to its lower electrical resistivity compared to the grain boundaries.

Keywords: Liquid metal, Electromigration, Corrosion, Grain Boundary Dissolution, Precipitation

1. Introduction The flow of electrons and ions in the liquid metal components of fusion reactors may result in electrical current flow. The flow of electrical current in liquid metal pool can cause a mass transport phenomenon called electromigration. The theoretical model on the electromigration had been studied on our previous research [1]. The purpose of the current study is to clarify the effect of electromigration on the material corrosion by metallurgical analysis.

2. Experimental condition The corrosion test of 304 austenitic steel (Fe-18Cr-12Ni) was performed in liquid Pb pool at 773 K for 250 hours. Figure 1 shows the apparatus used to conduct the corrosion test. Two 304 specimens were installed to act as the electron-receiving side and the electron influx side in the crucible. Liquid Pb was filled between the two specimens. Electric current of 10 A was flowed through the specimens. According to the theoretical model, the migration of Pb atoms will be induced along with the electron flow by electromigration.

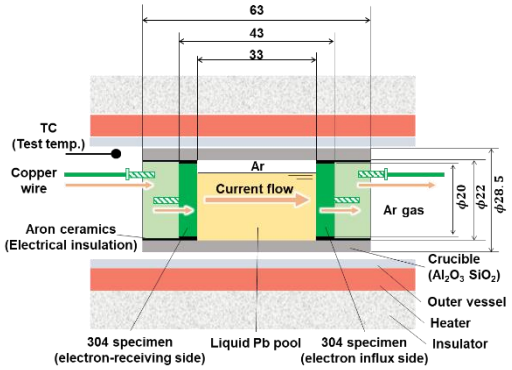

Fig. 1 Apparatus for corrosion test under electric current flow.

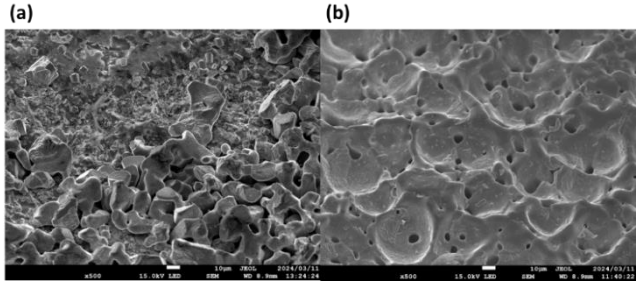

Fig. 2 SEM surface images of 304 specimens, (a) electron influx side and (b) electron-receiving side.

3. Metallurgical analysis and discussion The specimens were analyzed using SEM/EDX analysis after the corrosion test. Dimple-like patterns and cavities were observed on the surface of the electron-receiving side, indicating dissolution corrosion. EBSD analysis was performed on the electron-receiving side and reveals that the dimple-like patterns are centered on the bulk area of the grain. Grain boundaries have higher electrical resistivity due to higher electron scattering cross-section, resulting in less electron flow along the grain boundaries. The dimple-like patterns are the result of the different electron collisions frequency between the grain bulk area and the grain boundaries. The formation of the cavity was possibly caused by the dissolution of carbides within the material.

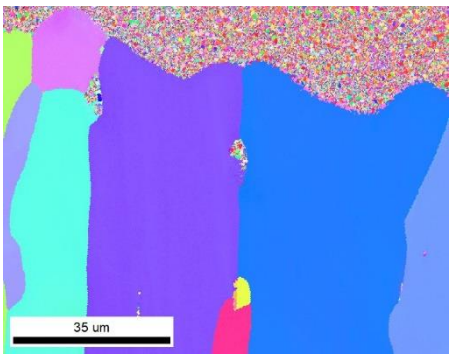

Fig. 3 EBSD map of the electron-receiving side.

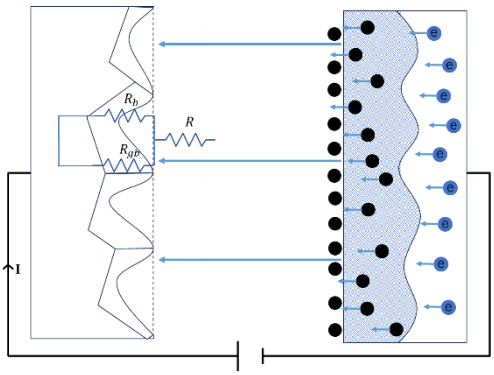

Fig. 4 Illustration of grain boundary electrical circuit during electromigration.

References [1] Humam, Hatakeyama, S., Kondo, M. (2024). Study on Electromigration Behavior in High Temperature Liquid Metal Pool. *AESJ 2024 Spring.* 3G01-05.