Improvement of Corrosion Resistance of Titanium used in NPP Condenser tubes by Plasma Electrolytic Oxidation

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1. Introduction

Titanium has today replaced copper alloy as the most favored tube material for water cooled condenser of reactor such as molten salt reactor and fast breeder reactor. Titanium has immunity to seawater, good strength to weight ratio, resulting in long term life. Oxides such as TiO_2 form a thin layer to increase corrosion resistance. However, the film can be destroyed by an error-corrosion damage such as high cycle fatigue, galvanic corrosion, water-drop decay, and flow-assisted corrosion. [1], [2]

Usually, corrosion resistance can be improved by creating nano structures using PVD, CVD, and anodization methods. However, at a certain point exceeding the threshold, corrosion failure occured over the oxide layer. M.Aliofkhazraei et al. and Maryam Molaei et al. improve corrosion resistance by using PEO(Plasma electrolytic oxidation) method coated with different materials. The PEO method can create a stable crystalline oxide layer without ordered nanopores through high temperature heat and high pressure. The oxide layer manufactured by the PEO method has compact and remarkable hardness, which has a good effect on corrosion resistance. It is also an economically eco-friendly method that is applicable to various metals. [2] [3]

This paper will conduct a research to improve corrosion resistance by coating Al_2O_3 on the surface of titanium and then forming a stable compact oxide layer with the PEO method.

2. Methods and Results

2.1 Sample Preparation

The sample was processed to 1 cm × 2 cm and 2 mm thick using Type CP-Ti Grade2. Sonication was performed on acetone and distilled water for 10 minutes each as a preprocessing process. As a post-treatment process, the sample was rinsed with ethanol and then dried in an oven.

2.2 Plasma Electrolytic Oxidation Experimental

PEO experimental was conducted as shown in **Fig. 1**. Electrolyte is composed of sodium aluminate (15 g/L) and sodium phosphate (2 g/L) solutions. Working electrode is connected to CP-Ti Grade 2 and counter electrode is connected to platinum sheet. Through the power supply, the PEO was performed by setting the applied voltage to 500 V and 0 V, the duty cycle to 30 %, and the frequency to 100 Hz. Duty cycle represents the percentage of time the voltage is applied in one cycle of this experiment, meaning that the duty cycle of 30% is on for 30% of the time in one cycle. PEO Time was 5 min, 10 min, and 15 min.

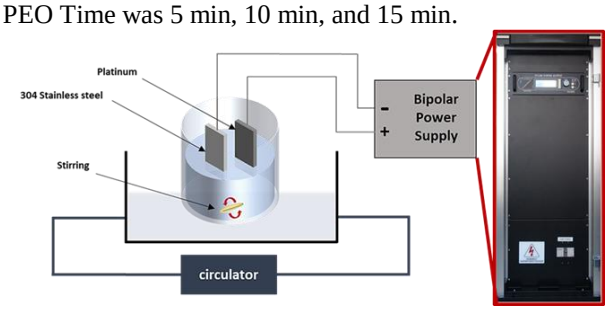
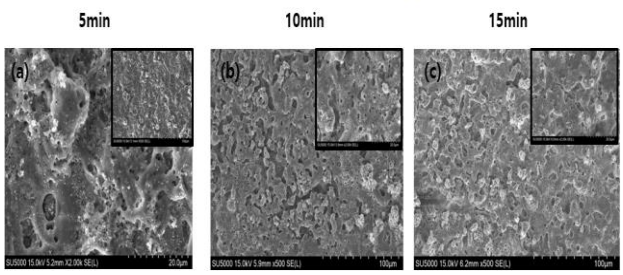


Fig.1 Anodization Experimental Schematic

2.3 Results

The sample in which the compact layer was formed could be obtained through the PEO process. The SEM picture in **Fig. 2 (a), (b), (c)** shows that the surface becomes smooth and dense over time, and the diameter of the pore decreases. EDS mapping in **Fig. 2 (d)** shows that Al and O are 66% and 27%, respectively, on the surface, indicating that Al_2O_3 is coated on TI.



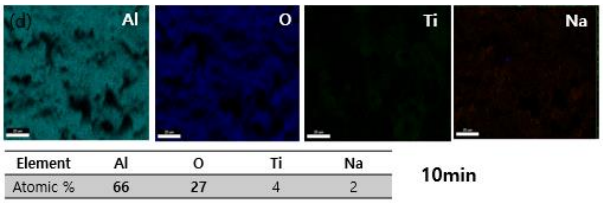


Fig.2 FE-SEM images and EDS mappings of the top-view morphology

In Figure 3, the cross-sectional photograph of the sample showed an oxide layer (0 to 50 um) with little Porous. Each time the time of PEO increased by 5 minutes, the oxide layer increased by about 20 μm. But **Fig. 3 (c)** indicated debonding between oxide layer and substrate. In the case of debonding, it is assumed that it fell off due to impact in the polishing process, and further development is required. In the EDS line scanning results of **Fig. 3**, it was also found that the oxide layer increased, and Mapping data shows that the Al_2O_3 oxide layer is well formed. In **Fig. 3(f)**, it can be seen that two oxide layers exist. These layers could be identified through EDS. A buffer layer exists on the way from the substrate to the oxide layer, which is presumed to be a compact layer.

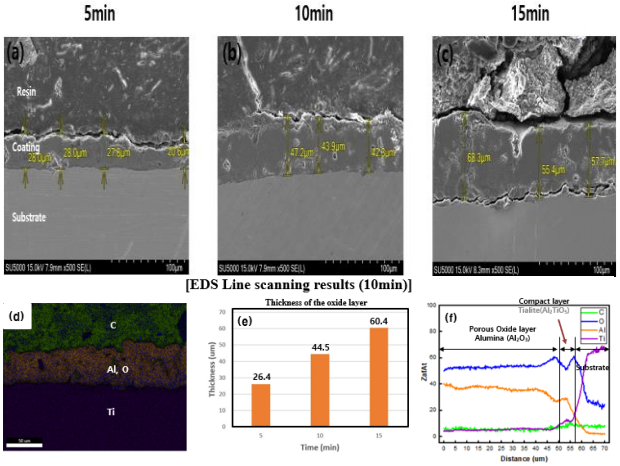


Fig.3 Thickness of oxide layer, FE-SEM images, EDS mappings, EDS Line scanning of the cross section-view

3. Conclusions

To improve the corrosion resistance of the main material used for the NPP condenser tubes, we can obtain an Al2O3 oxide layer with little porosity using by simple and fast PEO(plasma electrolytic oxidation) method. Titanium with Al2O3 oxide layer is expected to improve corrosion resistance, and it is expected to have a good effect as a tube material for water cooled conductor of reactor such as molten salt reactor and fast breeder reactor.

further work, The facts will be confirmed through the evaluation of corrosion resistance and evaluation of stress corrosion cracks (SCC) by environment through time, ductility and visual observation of specification through measurement of pitting potential and forest pitting temperature.

REFERENCES

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