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Corrosion Behavior of Stainless Steel Type 630 in an Alkaline Solution at Different Temperature

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1. Introduction

Stainless steel type 630 (SS630), also known as a 17-4PH, is a precipitation hardening martensitic stainless steel used in many applications such as turbine foams in the aerospace industry, hydrometallurgy, gas (oil) extraction and refinement. In particular, this material is widely used as parts of turbine, pumps, and valves in pressurized water reactors (PWRs) [1-4].

Small modular reactor (SMR) with an electrical output less than 300 MW has been receiving much attention as a clean energy source reducing carbon emissions due to its many advantages such as factory production, easy mobility, extended output, and low initial investment cost. SMR includes many types of reactor such as integrated PWR (i-PWR), molten salt cooled reactor (MSR), high-temperature gas-cooled reactor (HTGR), and micro reactor. However, the majority of reactor types are the i-PWR is used the light water as a coolant. SMRs such as SMART, ARA, Bandi-60S, and i-SMR, which are recently being developed in Korea, are also classified as the i-PWR. It is expected that SS630 will be used as a material of main components in primary coolant system of SMRs.

To mitigate the corrosion of the structure materials, the conventional PWRs cooling system contains certain chemicals such as ammonia (NH_3) and ethanolamine (ETA) to create a slightly alkaline environment as pH control agent. In a water chemical environment, evaluating corrosion properties is indeed crucial to determine the stability of materials under various temperature conditions [5].

Therefore, the corrosion behavior of structural materials used in operational PWRs should be investigated to understand the durability and safety of next-generation modular nuclear reactor materials. This study aims to investigate the corrosion behavior of SS630 under various temperatures in alkaline solutions.

2. Experimental Methods

SS630 composite samples were machined with dimensions of 38 mm length × 15 mm width × 2 mm thickness for corrosion tests, and a 3 mm hole was machined at the top of each sample for placement in the sample holder.

The surface samples was continuously grounded by using SiC papers with #600 and #1000 grit. Corrosion tests were conducted at four temperatures (120, 180, 240, and 300 °C) for 200 and 1000 h. The test solution was prepared by adding ammonia to deionized water, resulting in a pH of 10.5 at 25 °C. The corrosion rate (CR) of specimens was evaluated using the gravimetric method by measuring the weight changes before and after tests.

The surface morphology of corroded samples was also observed using scanning electron microscope (SEM). The phases of corroded samples were identified using X-ray diffraction (XRD) analysis before and after corrosion tests.

3. Results and Discussion

Fig. 1 shows the CR of SS630 specimens at various temperature for 200 and 1000 h. The CR of SS630 specimen increased with increasing from 120 ºC to 300 ºC. Under all temperatures, the CR of SS630 for 200 h was faster than that for 1000 h due to the difference in the passive film formation of SS630. The relation equation between CR and solution temperature for specimens tested for 200 h was calculated by CR = 0.00281T - 0.29777, while that between the CR and solution temperature for specimens tested for 1000h was calculated by CR = 0.00103T - 0.14115. In the range from 120 to 300 ºC, the slope of CR equation of SS630 specimen for 200 h is about 2.7 times higher than that of specimen for 1000 h.

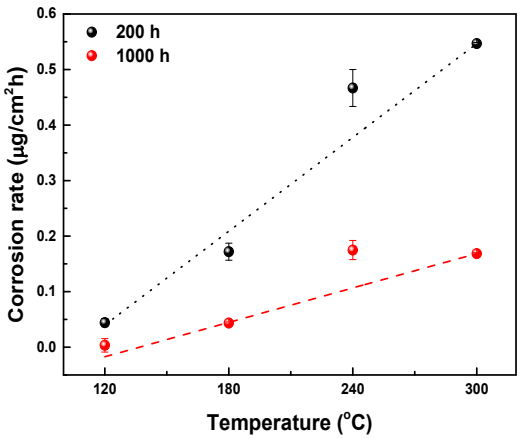
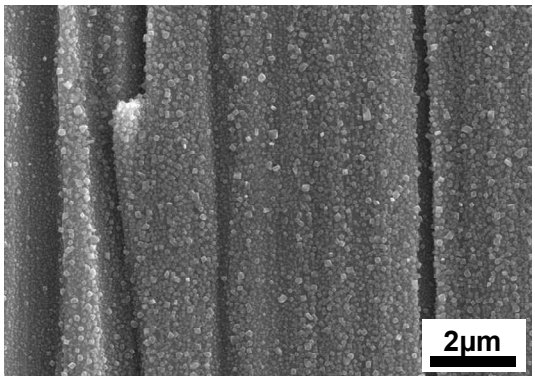


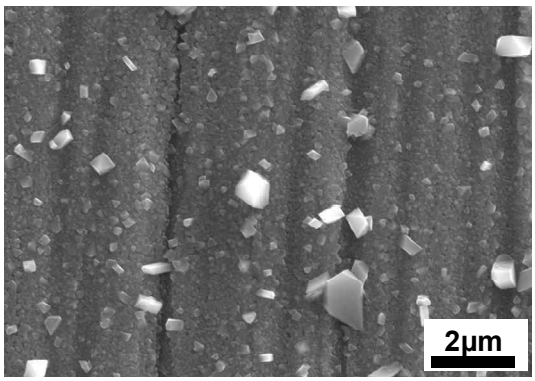
Fig. 1. Corrosion rates of SS630 at various temperatures for 200 and 1000 h.

Fig. 2 shows the SEM micrographs of surface of SS630 specimens tested at 120 ºC and 180 ºC for 200 h. The polyhedral particles with size of 100~200 nm were observed on the surface of corroded specimen at 120 ºC. However, compared to specimen corroded at 120 ºC,

the larger particles were observed on specimen at 180 ºC. This result indicates that temperature is one of the growth kinetic factors for external oxide formation of SS630 in alkaline solution.



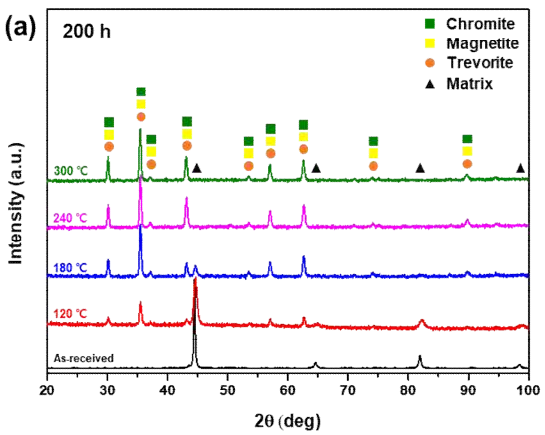
(a)



(b)

Fig. 2. SEM micrographs of surface of SS630 specimens corroded for 200 h at (a) 120 ºC and (b) 180 ºC.

Fig. 3 shows the XRD patterns of SS630 at various temperatures for 200 and 1000 h. As-received SS630 specimen had only a martensitic crystal structure which correspond to chromium iron nickel ($Cr_{0.2}Fe_{0.1}Ni_{0.7}$, JCPDS 00-033-0945). After the corrosion tests, the XRD pattern of iron containing oxides were observed under all conditions. The XRD patterns of oxides were identified as chromite (Cr_2FeO_4, JCPDS 01-075-3312), magnetite (Fe_3O_4, JCPDS 01-085-1436), and trevorite ($Ni_{1.3}Fe_{1.7}O_4$, JCPDS 01-080-0072).



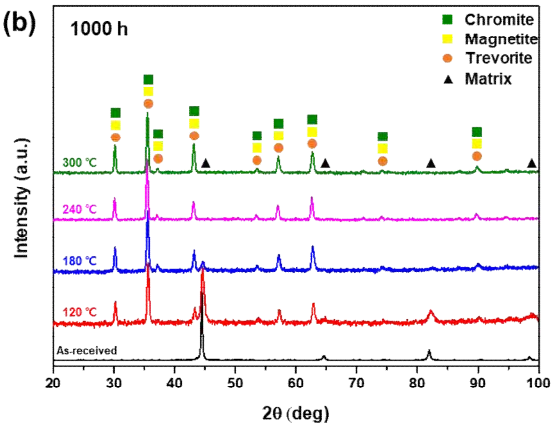


Fig. 3. XRD patterns of SS630 after each temperature condition for (a) 200 h and (b) 1000 h.

4. Conclusions

The corrosion behavior of SS630 material was investigated under various temperatures in alkaline solution. The following conclusions were obtained from this work.

(1) In the range from 120 to 300 ºC, the slope of CR equation of SS630 specimen for 200 h is about 2.7 times higher than that of specimen for 1000 h. Under all temperatures, the CR of SS630 for 200 h was faster than that for 1000 h due to the difference in the passive film formation of SS630.

(2) Based on the SEM analysis, temperature has an influence on the growth rate of oxide particles formed on SS630 in alkaline solution.

(3) The oxides formed on SS630 specimen were three types of iron containing oxides such as chromite, magnetite, and trevorite.

ACKNOWLEDGEMENTS

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