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Optimization of Laboratory Experimental Conditions for Molten Chloride Salt Corrosion Experiment

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1. Introduction

The molten salt reactor is one of the GEN IV reactors chosen for its characteristics of sustainability, safety and reliability, economic competitiveness, proliferation resistance and physical protection [1]. Recently, the use of molten chloride salts in molten salt reactors has gained significant attention. Molten chloride salts can harden the neutron spectrum, making it possible to design fast-type reactors capable of burning spent nuclear fuel [2].

One of the key challenges in developing molten salt reactors is managing the corrosion of structural materials. To select suitable materials, it is essential to evaluate the corrosion behaviors of potential candidates. However, it is known that corrosion rates are highly dependent on experimental conditions such as the types of crucibles used for corrosion experiments in the laboratory [3].

In this work, SS316, a candidate structural material, was corroded under various experimental conditions which can affect corrosion behaviors. Two different crucibles made of glassy carbon and alumina were used. In addition, the corrosion experiments were started at various insertion points of the specimens into the salt at high temperature or room-temperature. By altering several conditions, the optimal parameters for corrosion tests were determined.

2. Methods and Results

2.1. Experimental Setup

All corrosion experiments were conducted in the Ar-filled glovebox. O_2 and H_2O concentrations inside the glovebox were controlled below 2ppm.

NaCl (99.99%, Alfa-aesar, 50.6mol%) and KCl (99.998%, Alfa-aesar, 49.3mol%) were mixed as base salts. SS316 with a size of 5mm×10mm×1.5mm were hanged with 0.5mm SS316 wire. SS316 were corroded in molten NaCl-KCl salts at 750°C for 100 hours.

Four different experiment conditions were applied for comparison. First, the SS316 specimen (Sample 1) was inserted into the salt in alumina crucibles at room temperature, and then the temperature was increased to 750°C. Second, the SS316 specimen (Sample 2) was inserted into the salt in alumina crucibles at 750°C. Third, the SS316 specimen (Sample 3) was inserted into the salt in glassy carbon crucibles at room temperature, and then the temperature was increased to 750°C. Finally, the SS316 specimen (Sample 4) was inserted into the salt in glassy carbon crucibles at 750°C.

2.2. Results and Discussion

The weight change results for samples 1 to 4 are listed in Table I. Given the high temperatures of the corrosion experiments, the weight loss observed for sample 1 and sample 4 were unexpectedly low. Additionally, the weight gain for sample 2 was unusual, as most oxides are known to be unstable under molten salt conditions. Only the case of sample 3 showed a significant weight loss.

Table I: Weight change of SS316 under different experiment conditions

Experimental Conditions	Weight Change [mg/cm^2]
Sample 1 (Crucible: Alumina, insertion at room T)	-0.03±0.01
Sample 2 (Crucible: Alumina, insertion at 750°C)	0.07±0.01
Sample 3 (Crucible: Glassy carbon, insertion at room T)	-0.50
Sample 4 (Crucible: Glassy carbon, insertion at 750°C)	-0.04±0.03

The SEM images of corroded SS316 are shown in Figures 1 and 2. Samples 1 and 2, corroded in alumina crucibles, exhibited similar surface characteristics, with small particles below 100nm dispersed on the surface. In contrast, larger particles, approximately 1μm in size, were observed on the sample 3, corroded in the glassy carbon crucible. For sample 4, particles of irregular sizes covered the entire surface.

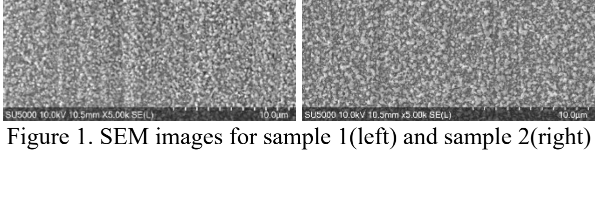

Figure 1. SEM images for sample 1(left) and sample 2(right)

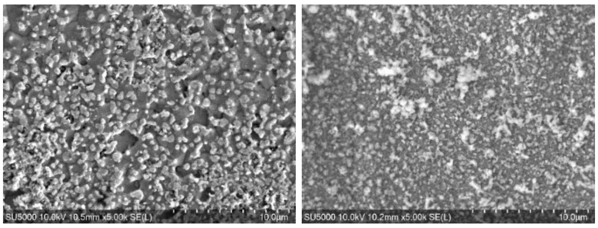

Figure 2. SEM images for sample 3(left) and sample 4(right)

The cross-sectional STEM-EDS results of corroded SS316 are shown in Figure 3. With the exception of sample 3, all samples were covered with Cr-rich oxide layers. Sample 3 exhibits Cr-depletion corrosion behavior, which is commonly known for molten salt corrosion.

The Cr-rich oxides formed on sample 1 and sample 2 adhered well to the SS316 surface, whereas those on sample 4 were detached. These observations suggest that the type of crucible affects the corrosion behavior. The alumina crucible is expected to dissolve in molten salts at high temperature and release oxygen, but further evidence is needed.

In sample 1, Cr-rich oxides were evenly distributed over the surface, compared to sample 2. This difference in element distribution also implies that the insertion temperature of SS316 affects the corrosion behavior. Given that sample 3 exhibits a typical corrosion behavior, it is recommended to immerse the specimen in salt in a glass carbon crucible at room temperature to gain more accurate results in corrosion experiments.

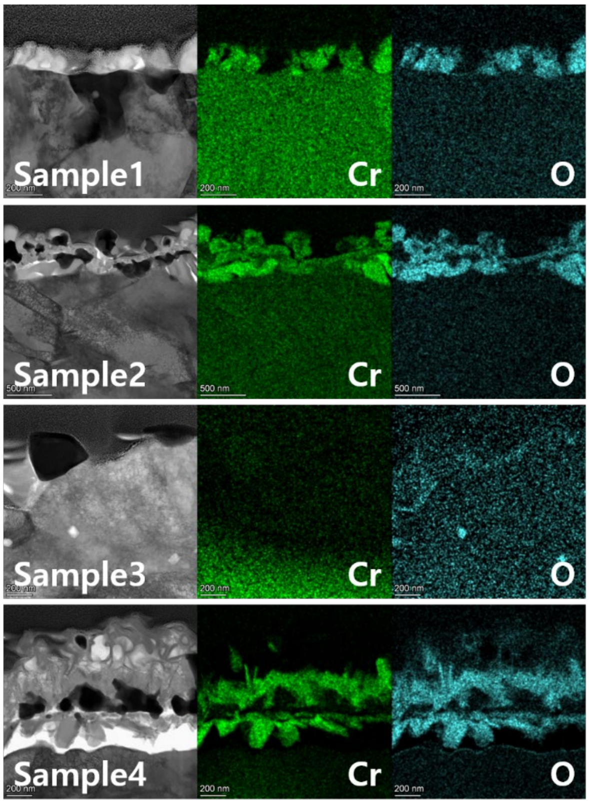

Figure 3. STEM-EDS results for samples 1 to 4

3. Conclusion

The corrosion experiments on SS316 were performed in molten NaCl-KCl salts, with variations in crucible types and specimen insertion temperatures. Using alumina crucibles and inserting specimens at high temperatures was found to cause unusual corrosion behavior. To gain a deeper understanding of these corrosion results, further experiments will explore different ratios of specimen surface area to salt volume and varying specimen extraction temperatures.

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