

Investigation on Gaseous $ZrCl_4$ Reactions with Structural Materials for Off-gas System of Molten Chloride Salt Reactor Condition

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1. Introduction

Molten salt reactor (MSR) is one of the advanced reactor types which has advantages in small design and wide applicational properties. Some of MSR designs utilize fuel salt system, which has original safety of reactivity control and emergency feedback system. From the original property of fuel salt system, various species of fission products can be released as gas, liquid and solid type in primary circuit of the system. From literature study, some species in molten salt was investigated as impurity, how they affect on material degradation. However, gaseous phase fission products were not yet clearly defined its effect on structural material degradation. In this study, representative volatile fission product $ZrCl_4$ was investigated for defining its reaction as fission product gas with structural material alloys.

2. Experimentals

2.1 Gas reaction test with capsule cell

Gaseous $ZrCl_4$ was investigated with capsuled system with quartz crucible and Resbond™ quartz sealant. Four types of alloys-SS304, Inconel 600, Inconel 625, Hastelloy N-was selected as target alloy and fabricated to 1 mm thick coupon shape. Before the test, surface of specimens were polished with 320, 600, 800 grit emery paper and down to 1 μ m diamond suspension. Specimens were cleaned with acetone, ethanol and DI water for removing surface contaminants.

Quartz capsule was assembled in glovebox system with Ar (99.99%) condition with its oxygen and moisture concentration below 0.1 ppm. Quartz chips were inserted in capsule to avoid any contact of each specimens. After putting specimens, 100 mg of anhydrous $ZrCl_4$ (Sigma-Aldrich, 99.99%) was inserted inside the capsule. Then capsule was sealed by quartz sealant with another quartz capsule lid. Quartz sealant was dried for 24 hr and solidified for 2 hr in 120 °C of glovebox furnace.

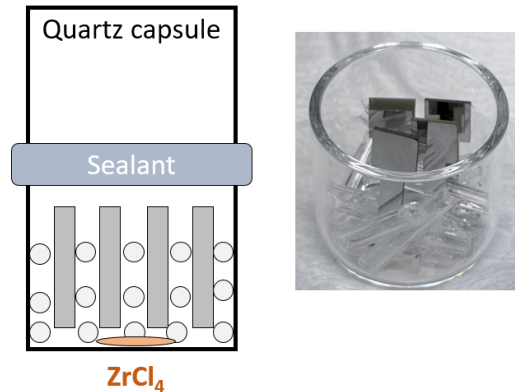


Fig 1. Quartz capsule cell design for gas reaction test

Assembled quartz capsule were exposed to 700 °C of furnace installed in glovebox for 7 days. After the test, capsule was taken apart and specimens were analyzed with SEM-EDS(Quanta 200 FE SEM, FEI).

2.2 Gas reaction test with gas flow cell

For investigating reactions of gaseous $ZrCl_4$ in simulative condition of MSR off-gas system, flowing cell tests are planned. Previously invented N-type molten salt cell was certified to maintain $ZrCl_4$ concentration in molten salt, which can indicate that stable flow rate is kept on the escaping tube of the cell. These cell system with hanged specimens can show the less reactive condition test of $ZrCl_4$ effect as fission product gas.

3. Results and Discussions

From the SEM analysis on surface of each specimens showed intergranular degradation which is shown to be similar with corrosion damage in molten salt condition. Corrosion damage in SS304 was more aggressive than other nickel based alloys by electrochemical priority of Fe and Ni. Also, overall alloys showed slight damages on grain boundary, which can be the most vulnerable site. On the surface of all specimens, some chrome oxide-identified as Cr_2O_3 was observed, which can be formed from $CrCl_2$ corrosion product on the surface.

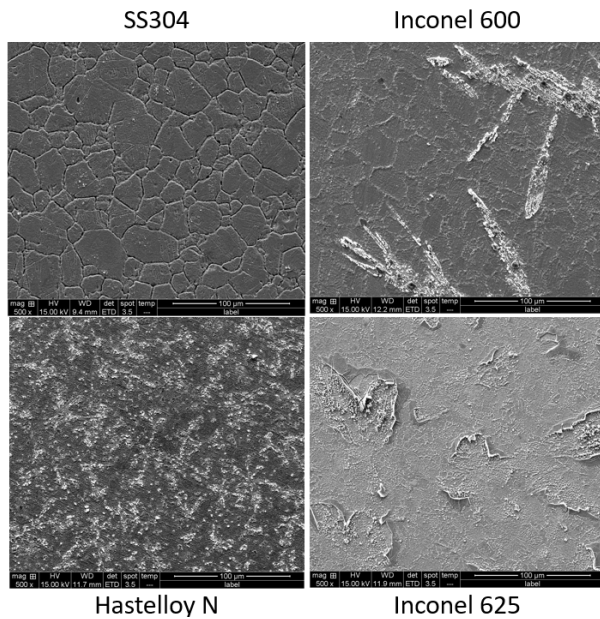


Fig 2. SEM images of corroded surface of each specimens in 700 °C of gaseous $ZrCl_4$ for 7 days

Even the corrosion damage from $ZrCl_4$ vapor was reported in literature study [1], however, only limited data was obtained like corrosion rate to discuss the mechanism of corrosion procedure. Further analysis should be recommended to indicate the chlorination or chloride exchange reaction of $ZrCl_4$ and other elements in the alloy. If the decomposition of $ZrCl_4$ is certified in 700 °C, redox exchange of Cr_2O_3 with Cl_2 can be candidate reaction [2]. Also, quartz capsule cell should be checked for identifying whether moisture or oxygen contamination was occurred to affect the reaction procedure of forming HCl or other species with $ZrCl_4$.

4. Conclusions

Effect of $ZrCl_4$ gas was investigated via capsuled cell exposure test with various types of alloys. Each specimens suffered from corrosion damage, which was the worst on SS304 specimen, showing aggressive intergranular corrosion. Some part of the specimens were observed to form chromium oxide, which may formed from oxidation of $CrCl_2$ with atmospheric moisture when it was taken out of glovebox. Gas analysis and test on gas flow rate control would be suggested as further studies.

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