Corrosion Behaviors of SS316 and Ni-base Alloys in Molten LiCl-KCl Salt at High Temperature

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Introduction

▪ Properties of Molten Salt

- Liquid phase due to high temperature and low vapor pressure
- High solubility of actinides and lanthanides

Case 1: Pyroprocessing

Utilizing molten salts as the electrolyte to separate U and TRU

Case 2: Molten Salt Reactor

Utilizing molten salts as the coolant (involving molten nuclear fuel)

▪ Molten Salt Reactor (MSR)

- Fluoride (LiF-NaF-KF, LiF-BeF_2, etc.) medium for thermal reactors
- Chloride (NaCl-$MgCl_2$, NaCl-$MgCl_2$-KCl, etc.) medium for fast reactors
- Operation at high temperature for a long period of time with impurities (nuclear fuels, fission products, corrosion products, oxides, etc.)

→ Structural Material Corrosion Issue

but, a lack of knowledge under various conditions of chloride salts

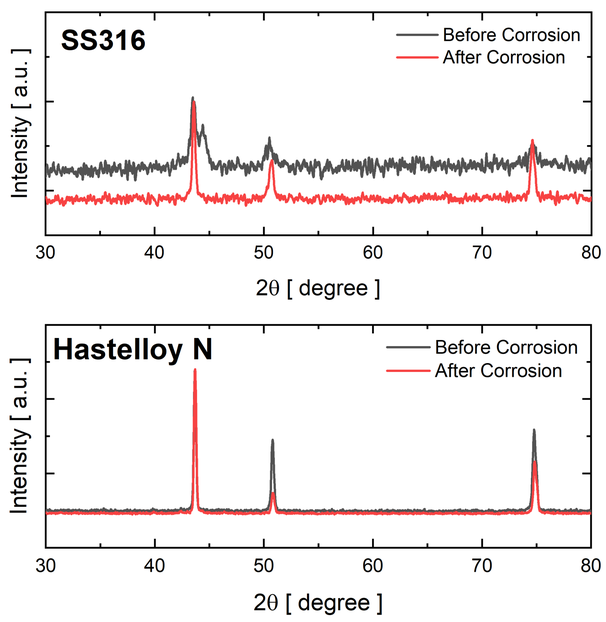
Experimental

- Experiments in Ar-filled glovebox at 500°C for 100hrs/200hrs
- Use of LiCl-KCl eutectic salt (99.99% purity, Anhydrous beads)
- Preparation of specimens (1.5mm×5mm×10mm) ground up to #2000 SiC paper and polished with 0.05μm alumina suspension

Elemental compositions of MSR structural materials

Element [wt%]	SS316	Alloy 617	Hastelloy N
Ni	10.7	bal.	bal.
Cr	17.3	22.9	7.3
Mo	2.0	9.5	16.6
Fe	bal.	1.1	4.3
Co	-	13.1	-
Si	0.7	0.2	0.3
Mn	1.0	1.0	0.5
C	0.07	-	0.06

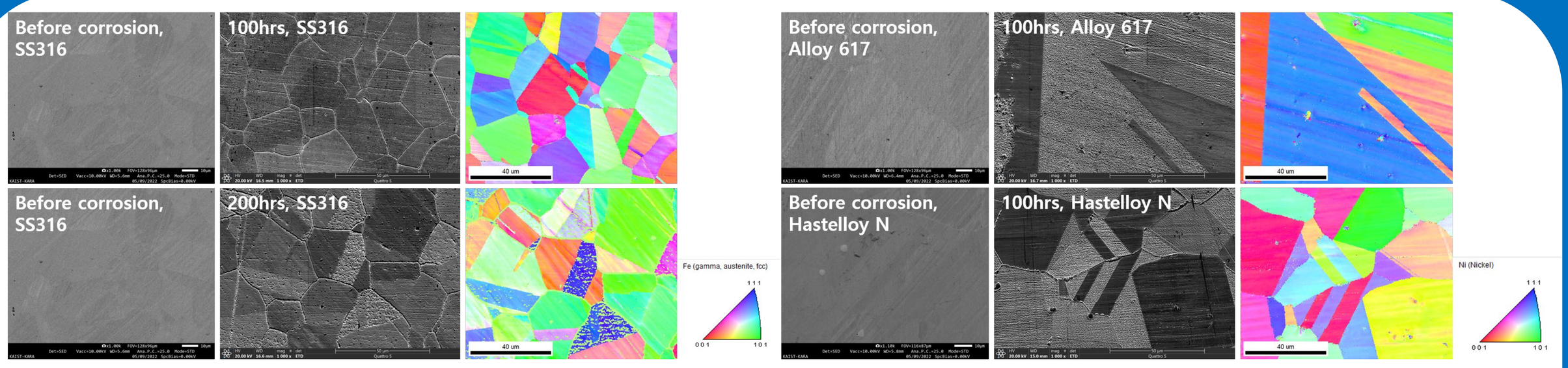
XRD Analysis



- γ-phase peaks of FCC, but in the same peak positions before/after corrosion

→ No phase change in these experimental conditions (500°C, 100hrs)

SEM and EBSD Analysis



▪ Dissolution Behaviors Depending on Grain Orientation

- Higher dissolution for grains close to {111} planes, lower dissolution for grains close to {001} planes, as reported in aqueous corrosion systems [1,2]

▪ Grain Surface Energy and Adsorption of Corrosion Inhibitor

- Approximate grain surface energy = $2\frac{2|h|+|k|}{\sqrt{h^2+k^2+l^2}} \times \frac{E_b}{d^2}$ → lowest SE at {111} planes [1,2]
- Lower adsorption of chemical species at lower surface energy grains ({111}) [3,4]

→ Weak adsorption of corrosion inhibitor at lower surface energy grains ({111})

Conclusions and Outlook

▪ Corrosion Behaviors of SS316 and Ni-base Alloys at 500°C in LiCl-KCl

- There is no change in the phase
- Usually, a grain-orientation dependent dissolution takes place

→ Further Experiments under Various Conditions

- Different salts, temperature, and structural materials
- Identify the chemical species that can act as corrosion inhibitors in molten salts

Reference
[1] S. Wang et al. (2014), Corros. Sci., 85, 183-192.
[2] S. Dong et al. (2020), Mater. Des., 191, 108583.
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[4] A.N. Pour et al. (2015), Int. J. Hydrogen Energy, 40, 7064-7071.

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