Oxide Film Characterization of Fe-based Alloys for Potential Accident Tolerant Fuel Application in Simulated PWR Environment

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NU_Html Nuclear & High Temperature Materials Laboratory

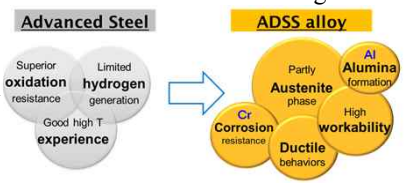
I. Introduction

❖ ATF (Accident Tolerant Fuel)

- Since the Fukusima accident in March 2011, many studies focused on reducing the hydrogen generation rate of zirconium alloy.
- General Requirement for ATF cladding material is resistance to degradation and corrosion for maintaining integrity when accident happen and normal operation as well.

❖ ADSS (Alumina-forming Duplex Stainless Steel)

- Author's group have developed model alumina-forming duplex stainless steel (ADSS) which is candidate for ATF cladding material.
- Evaluation of corrosive behavior in simulated PWR environment will be discussed in this poster.



II. Experiment

❖ Test environment

Environment		Simulated PWR steam
Temperature		400 ℃
Pressure		20 MPa
Water Chemistry	Dissolved hydrogen	25 cc/kg
	Dissolved oxygen	< 5 ppb
	Conductivity	22-26 μS/cm
	H_3BO_3	1200 ppm
	LiOH	2.2 ppm

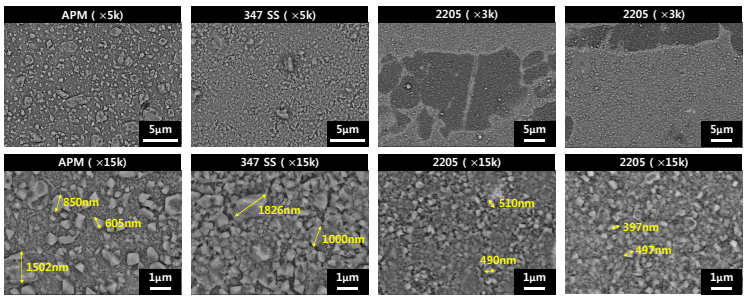
- Steam corrosion test in simulated PWR for 1755 hr

❖ Material composition for corrosion test

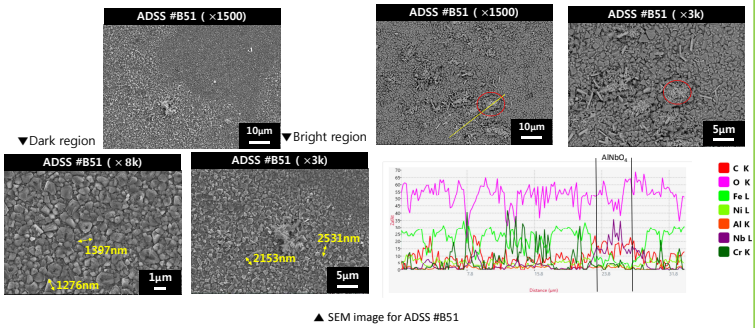
[wt.%]	Fe	Cr	Ni	C	Mn	Si	Nb	Al
ADSS #B51	Bal.	16.33	18.77	0.11	1.04	0.31	0.53	6.14
347 SS	Bal.	17.25	10.22	0.03	1.68	0.4	0.28	
APM	Bal.	21.99	0.15	0.03	0.16	0.28		5.81
2205	Bal.	22.5	4.8	0.01	0.87	0.45		

III. Result

❖ SEM Analysis After 1755hr PWR Steam Oxidation



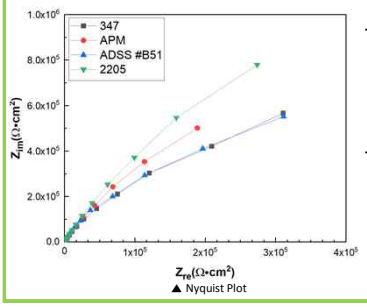
▲ SEM image for APM ▲ SEM image for 347 SS ▲ SEM image for 2205 Ferrite ▲ SEM image for 2205 Austenite



▲ SEM image for ADSS #B51

- **Surface Analysis**
  - All 4 materials shows good coverage on the surface with oxide.
  - #B51, larger particles on bright part than on dark part that can be explained by high content of Cr in Ferrite region (dark region).
  - In #B51, there are $AlNbO_4$ known as cause of degradation on corrosion resistance.

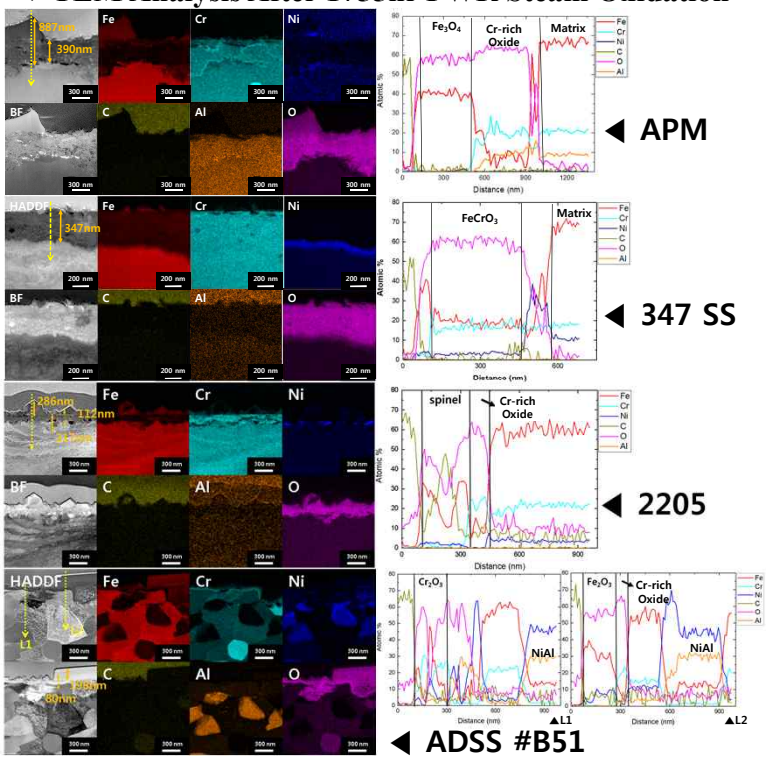
❖ Electrochemical measurement



▲ Nyquist Plot

- Radius of capacitance loop (reaction resistance of oxide)
  2205 > APM > ADSS = 347 SS
- The EIS result completely match with Cr content order.

❖ TEM Analysis After 1755hr PWR Steam Oxidation



- **Oxide layer thickness observation**
  - Single phase steels (APM, 347 SS) have more thicker oxide than duplex steels (2205, ADSS #B51).
  - 2205 have uniform thickness of oxide, ADSS #B51 shows different oxide thickness depending on phase.
  - For ADSS #B51, chromium oxide is formed on ferrite (higher Cr%) and thin inner oxide and large particles are formed on austenite.

IV. Conclusion

❖ADSS #B51

Author's group previous research have shown that ADSS #B51 gain weight but APM loose weight in PWR environment. ADSS #B51 shows reasonable corrosion resistance similar with 347 SS (better than APM) even if their target is high temperature corrosion resistance.