Effect of Alloy Composition on the Oxidation Behaviour and Cr Vaporisation of High-Cr Steels for SOFC Cathode Air Pre-heater

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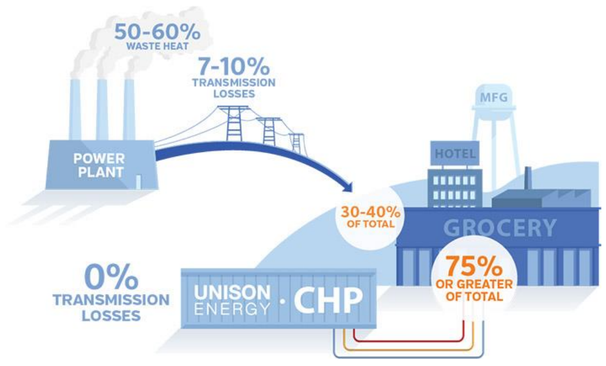
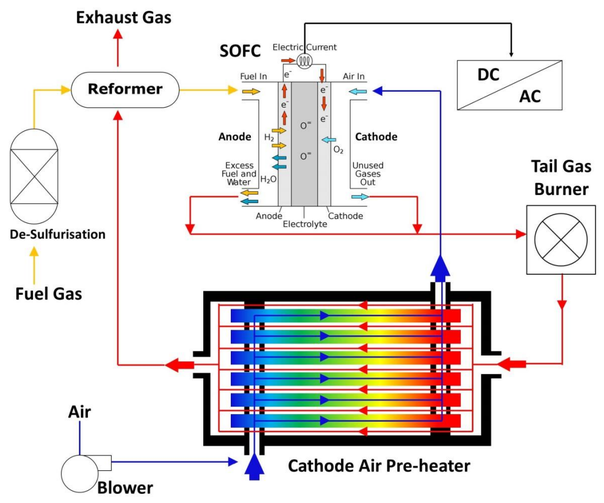
1. Introduction



Combined Heat and Power (CHP)

1. Simultaneous production of electrical and thermal energy from fuel cell; **2.** High efficiency level of 75% compared to 35% for traditional power plant; **3.** More cost effective; **4.** Reduced greenhouse gas emission; **5.** More efficient use of natural resources



Cathode Air Pre-heater (CAPH)

1. Type: gas to gas heat exchanger; **2.** Function: to recover heat from an exhaust gas to heat air to the target temperature before it enter the fuel cell; **3.** Cost: One of the most expensive components within the whole CHP system; **4.** Material: ceramic or metallic heat exchanger.

Stainless Steel CAPH

Pro's: 1. Reduced material use and costs; **2.** Improved oxidation resistance; **3.** Good high temperature strength. **Con's: 1.** High chromium leakage; **2.** Gas leak associated with welding process

Research Goals

1. Evaluate the long-term corrosion behaviour of different steels for CAPH application;
2. Quantitatively measure the Cr evaporation for different steels under SOFC environment.

2. Materials and Methods

Table: The chemical compositions of the researched materaials supplied by manufacturer.

(wt.%)	Fe	Cr	Mn	Al	Ni	Si	Nb	W	Co	others
Inconel 625	5.0	20-23	0.5	0.4	Bal.	0.5	4.15	-	1.0	Ti 0.4; Mo 8-10; P 0.015; S 0.015
AluChrom 318	Bal.	18.8	0.21	**3.58**	0.24	0.32	0.73	2.02	--	Hf 0.06; Y 0.07; Zr 0.03; Cu 0.03 C 0.01; N 0.01
SS309	Bal.	22-24	2.0	--	12-15	0.75	--	--	--	C 0.2; P 0.045; S 0.03
Aluminised SS309	1 µm aluminium coated was deposited on SS309 surface by PVD technique.									

❖ **Experiments:**
- High Temperature Oxidation Test: **Normal Tubular Glassware**
- Quantification of Cr Evaporation: **Denuder Technique**

❖ **Test Condition:**
- 850 ˚C; 6.0 L/min Air Flow; 3 vol% H_2O

❖ **Evaluation:**
- Mass Measurement;
- Surface SEM/EDX;
- Cross-section SEM/EDX;
- XRD;

3. Denuder Technique

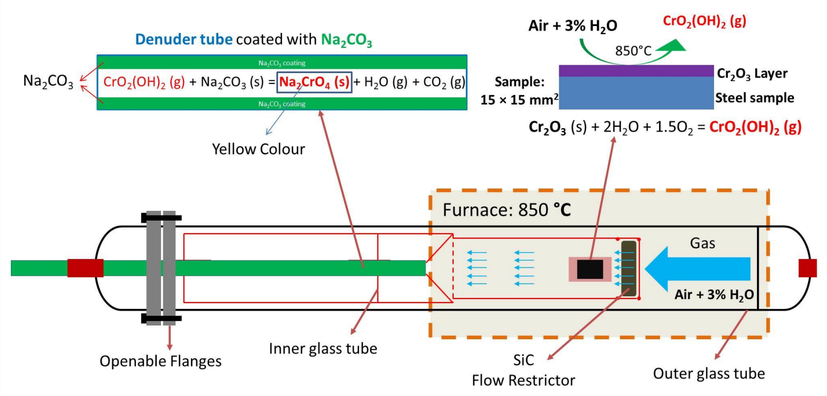


Figure: The schematic diagram of denuder technique.

4. Exposure Tests

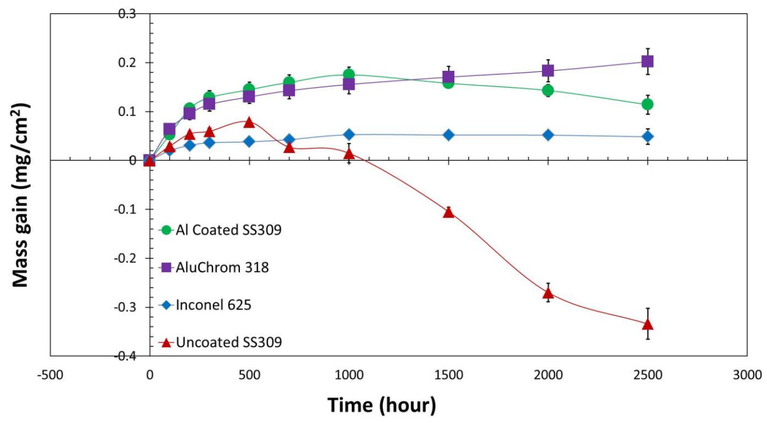


Figure: Discontinuous mass gain measurement over 2500 hours.

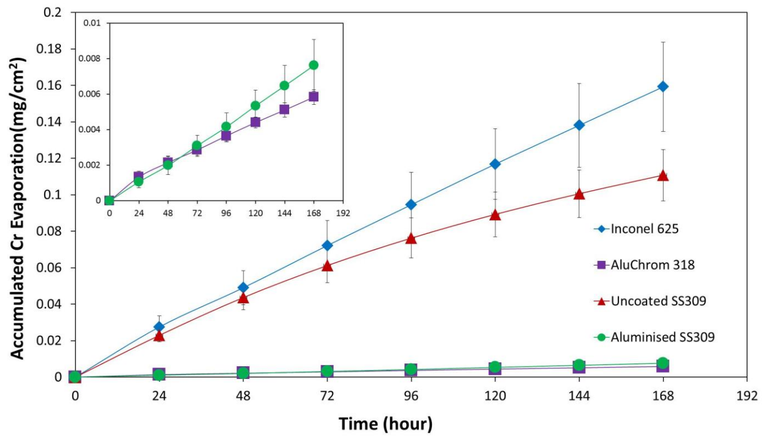


Figure: Accumulated Cr evaporation over 168 hours .

5. Surface: SEM/EDX

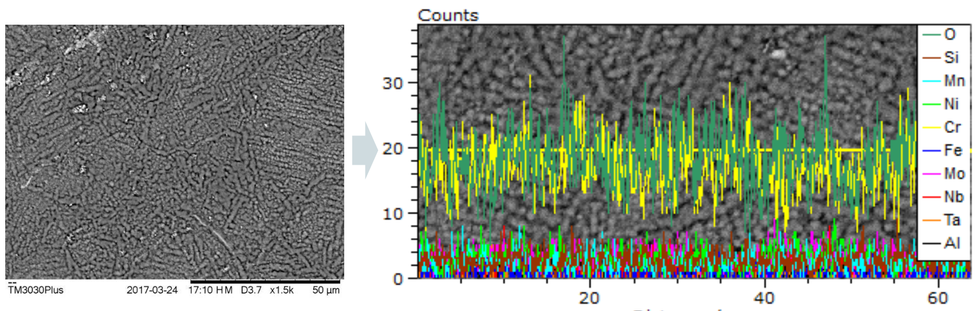


Figure: Inconel 625

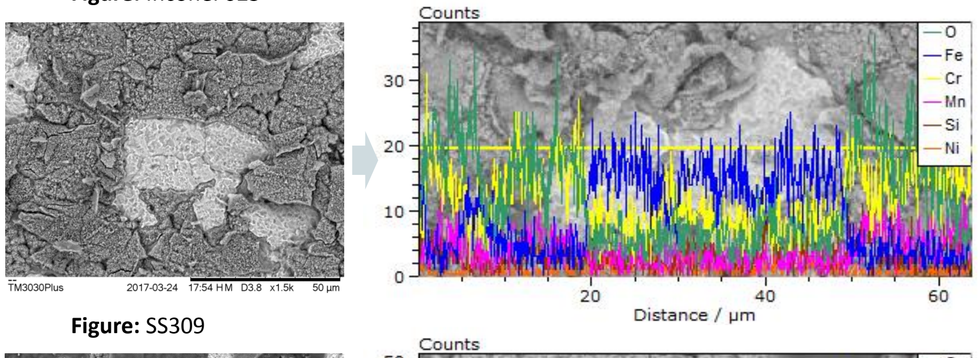


Figure: SS309

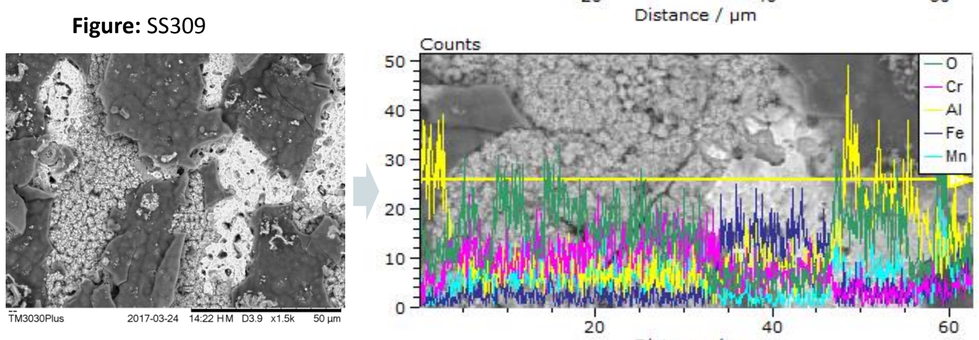


Figure: Aluminised SS309

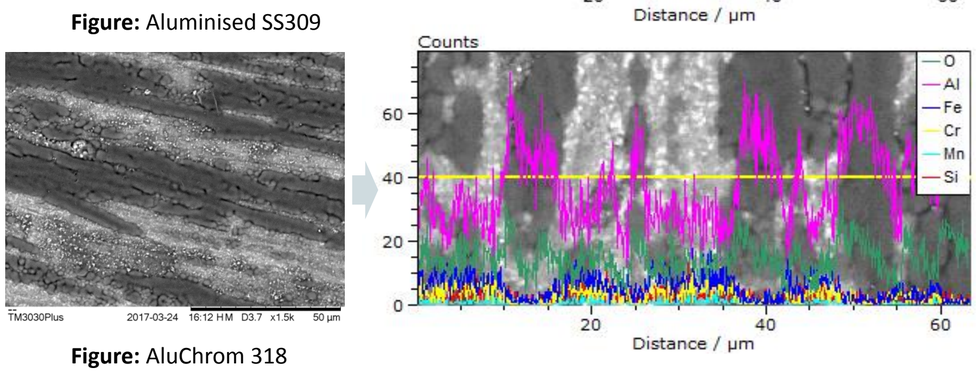


Figure: AluChrom 318

All the samples above was exposed in the furnace for 1000 hours.

6. XRD Analysis

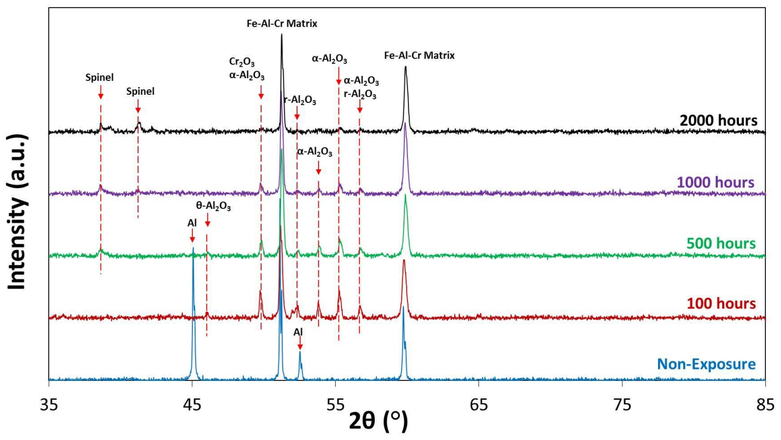


Figure: XRD patterns of aluminised SS309.

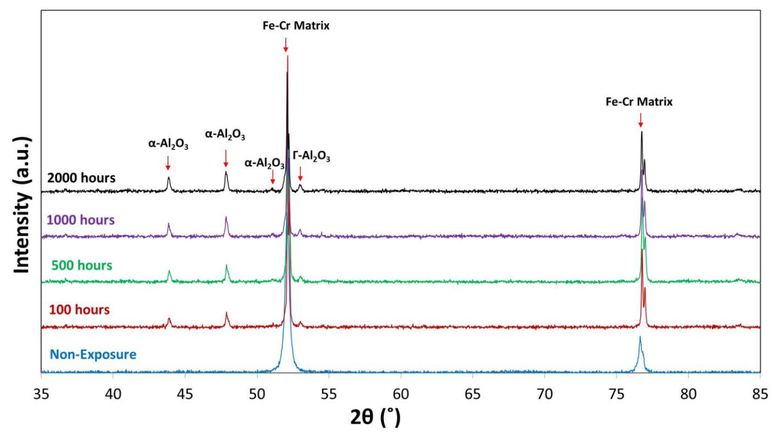
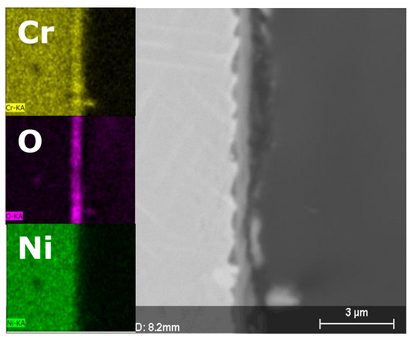


Figure: XRD patterns of AluChrom 318.

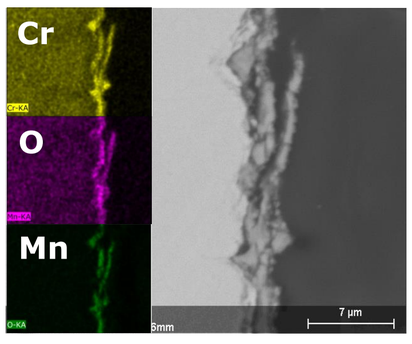
7. Cross section: SEM/EDX

Figure: Inconel 625



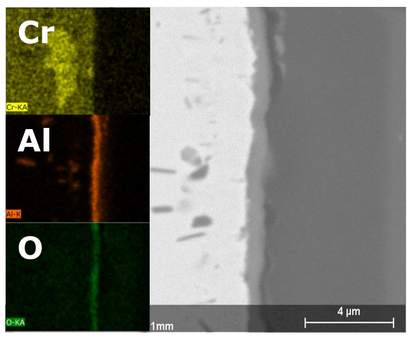
Oxide scale: Cr_2O_3
Thickness: 473 nm
Exposure: 1000 hours
Status: Voids formed beneath oxides and high level of Cr evaporation

Figure: SS309



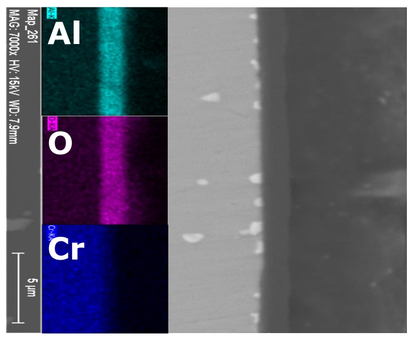
Oxide scale: $(Cr,Mn)_3O_4$ spinel
Thickness: None
Exposure: 1000 hours
Status: Porous Spinel layer and Serious scale spallation

Figure: Aluminised SS309



Oxide scale: Al_2O_3
Thickness: 704 nm
Exposure: 1000 hours
Status: Bad adhesion, Al and Cr agglomeration under oxide scale

Figure: AluChrom 318



Oxide scale: Al_2O_3
Thickness: 931 nm
Exposure: 1000 hours
Status: Dense oxide scale and very good scale adhesion

8. Conclusions

The measurement of Cr evaporation from different alloys by the denuder technique exhibited that the amount of Cr evaporated from alumina-forming steel or aluminised steel are approximate by one order of magnitude lower than those from pure chromia-forming steels. Although the Cr vaporisation level of aluminised SS309 was comparable to that of AluChrom 318 for 168 hours, the Cr retention of AluChrom 318 was confirmed to be better than that of aluminised SS309 in the long term due to the spallation of the Al_2O_3 scale on the aluminised SS309 surface.

9. Acknowledgements

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