Tailoring Low-Cr Fe-Ni Alloys for Intermediate Temperature SOFC Interconnect Application+

+AGREEMENT NO. DE-FC26-04NT42223, OCT. 1, 2004-JULY 2006

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SECA Core Technology Program Meeting, Sept. 12-14, 2006

Philadelphia, PA

Why low-Cr alloys as SOFC interconnect material?

- **Currently, the metallic interconnects for intermediate-temperature SOFC are the Cr_2O_3-forming alloys such as Ebrite, Crofer, and Haynes 230 due to the electrically conductive nature of Cr_2O_3 compared to Al_2O_3 and SiO_2.**
- **However, an inherent weakness of Cr_2O_3-forming alloys is the formation of volatile Cr species due to chromium evaporation, which will migrate to and thus poison the cathode, resulting in SOFC performance degradation.**
- **Two approaches can be taken to address this issue:**
  - ✓ ***Surface coating approach***
  - ✓ ***Alloy design approach***

Low-Cr Fe-Ni alloys specifically tailored for SOFC interconnect application might resolve the Cr poisoning issue in SOFC stacks.

Alloy Design Strategies

- **CTE Match with Other Cell Components**

  Fe, Co, Ni, Mo, Nb, and Ti contents are being controlled to maintain the CTE values of the new Fe-Ni alloys at the desired level.

- **Cr Volatility and Electrical Resistance of the Oxide Scales**

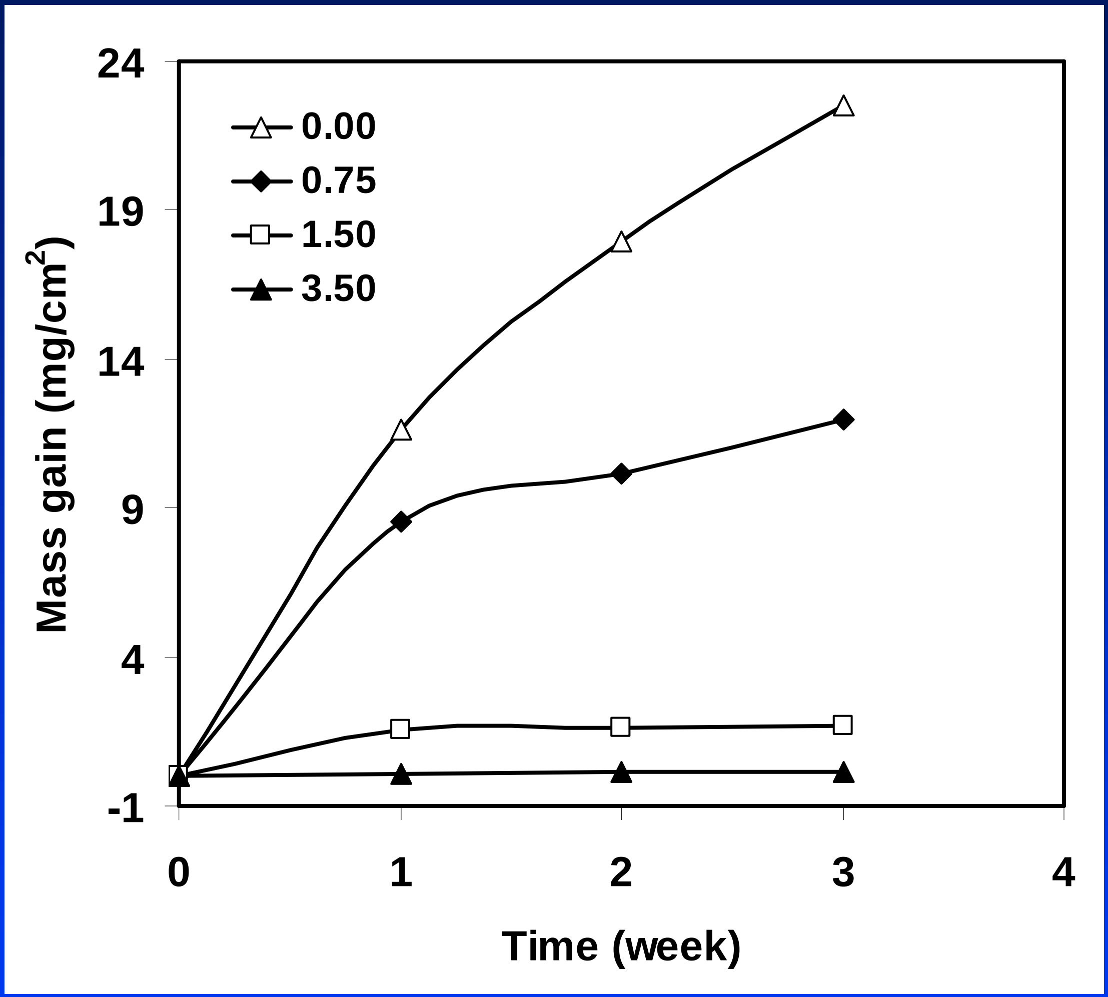
  In addition to controlling the Fe-Ni ratio, other transition metals will be added to facilitate the formation of highly-electrically conductive, Cr-free outer-spinel layer.

- **Oxidation Resistance of Fe-Ni Alloys**

  By controlling the oxygen-active elements in the alloys, an inner layer of dense, protective, and electrically conductive oxide (e.g. Cr_2O_3) will be formed underneath the spinel layer.

Schematic of the Desirable Double-Layer Oxide Structure

Effect of Element X (in wt.%) on the Oxidation Behavior of Low-Cr Fe-Ni Alloys in Air at 800°C

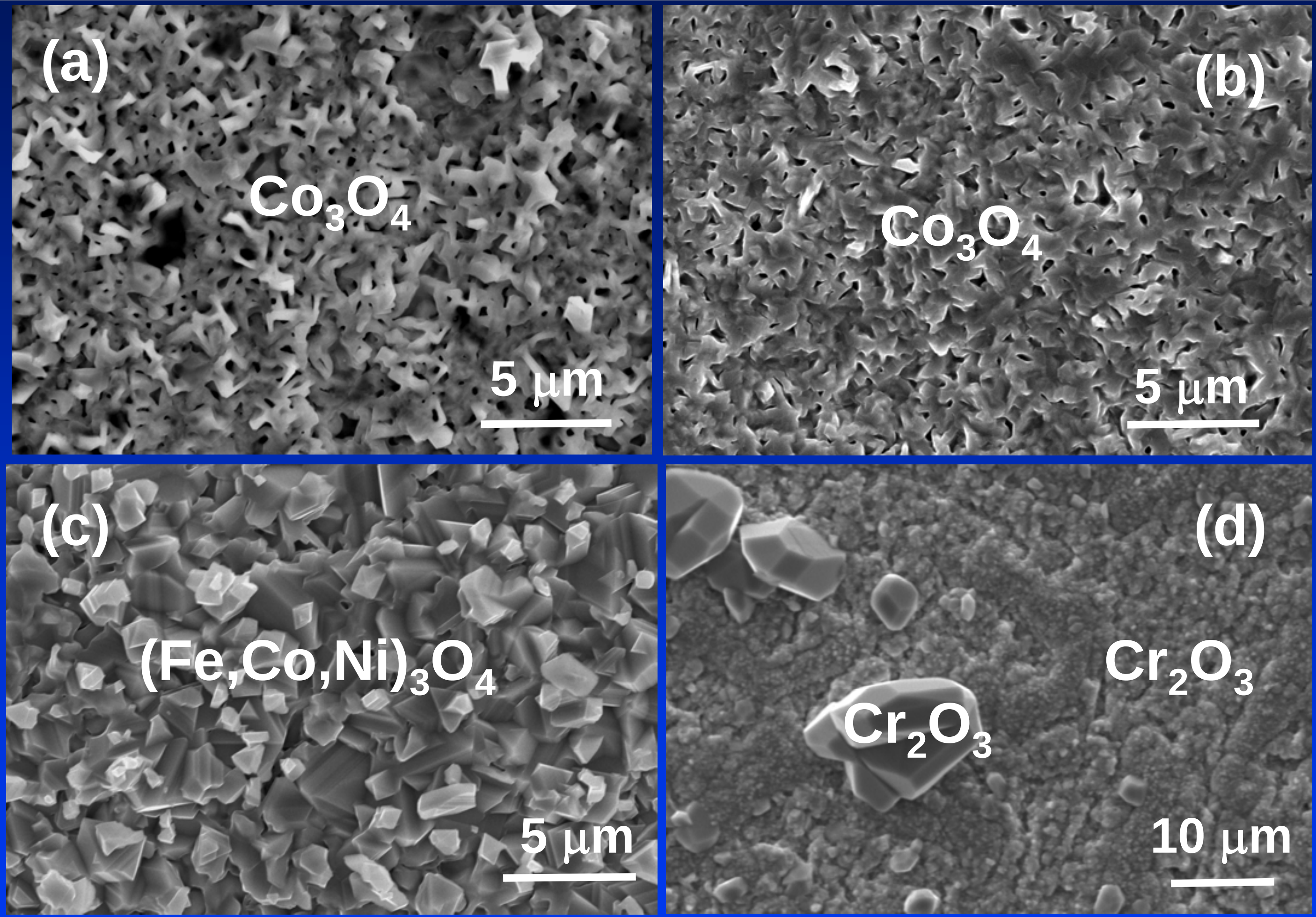


Oxidation kinetics of low-Cr Fe-Ni alloys with different X levels at 800°C in air

- **An element X[+] has been identified which effectively controlled the oxidation kinetics of the low-Cr Fe-Ni alloys.**
- **The mass gain of the alloys decreased with the increase in X content in the alloys**
- **The oxidation resistance of the alloys was notably improved by the addition of X.**

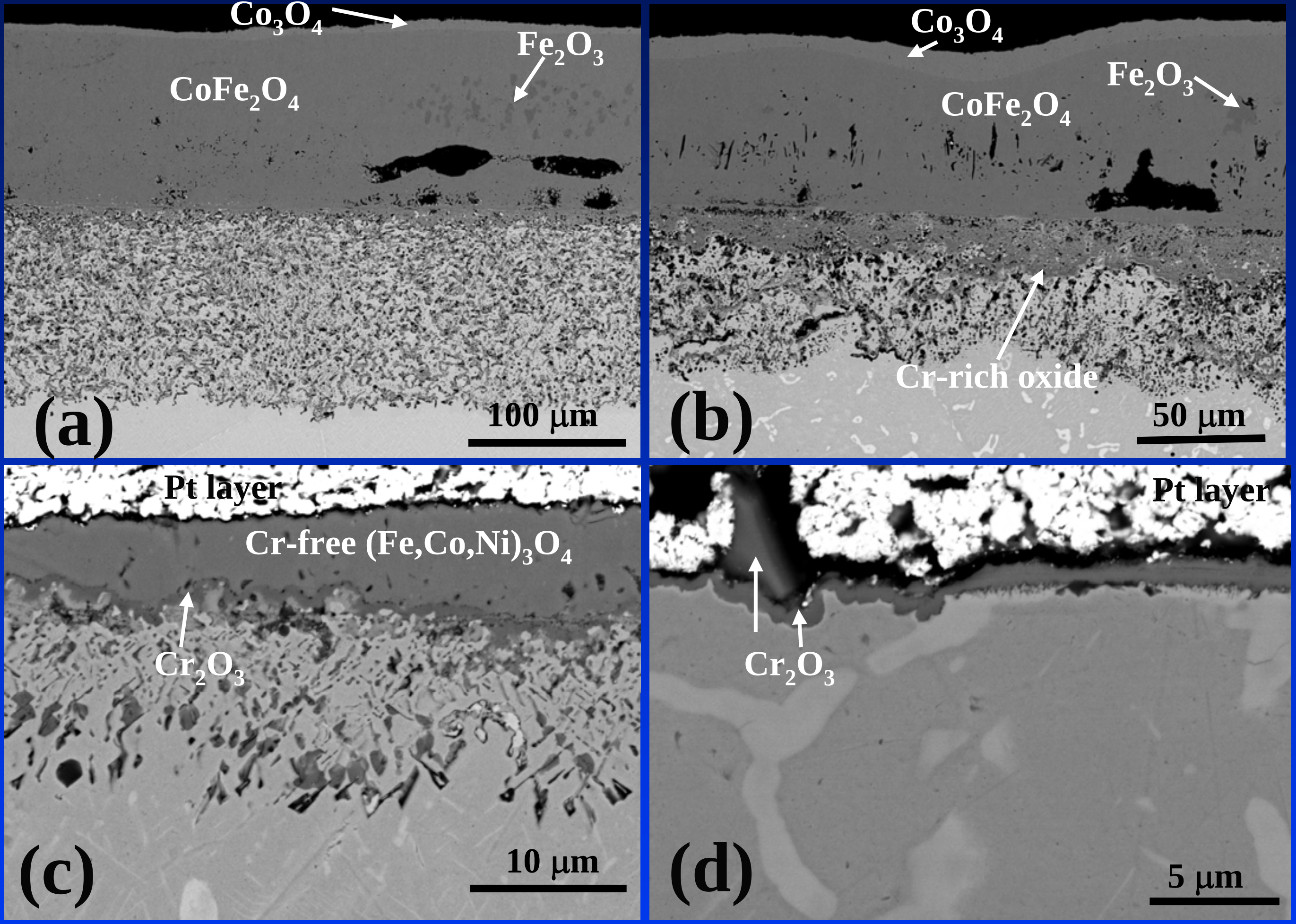
[+] The exact alloy composition – proprietary information

Effect of Element X on the Oxide Structure of Low-Cr Fe-Ni Alloys in Air at 800°C



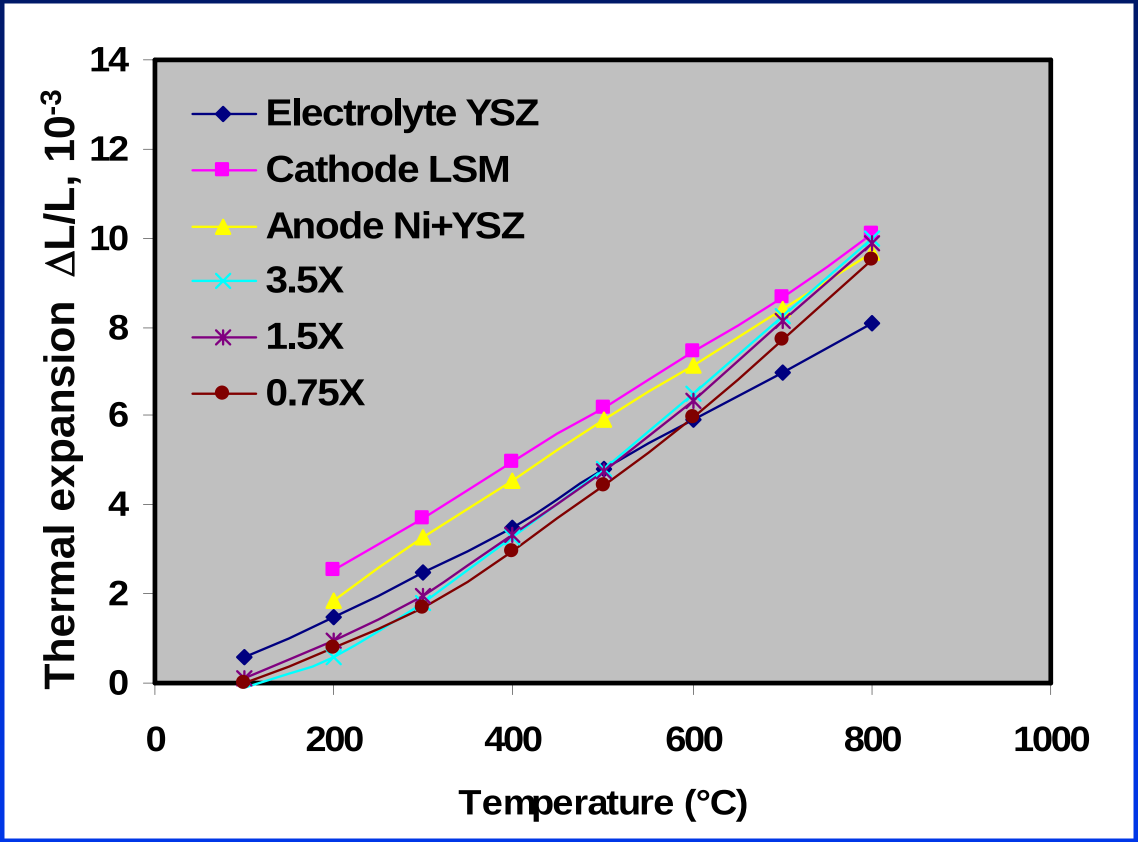
Surface morphologies of the alloys with different X contents after oxidation for 3 weeks (a) 0; (b) 0.75; (c) 1.5; (d) 3.5

Effect of Element X on the Oxide Structure of Low-Cr Fe-Ni Alloys in Air at 800°C



Cross-sections of the alloys with different X levels after oxidation for 3 weeks: (a) 0; (b) 0.75; (c) 1.5; (d) 3.5

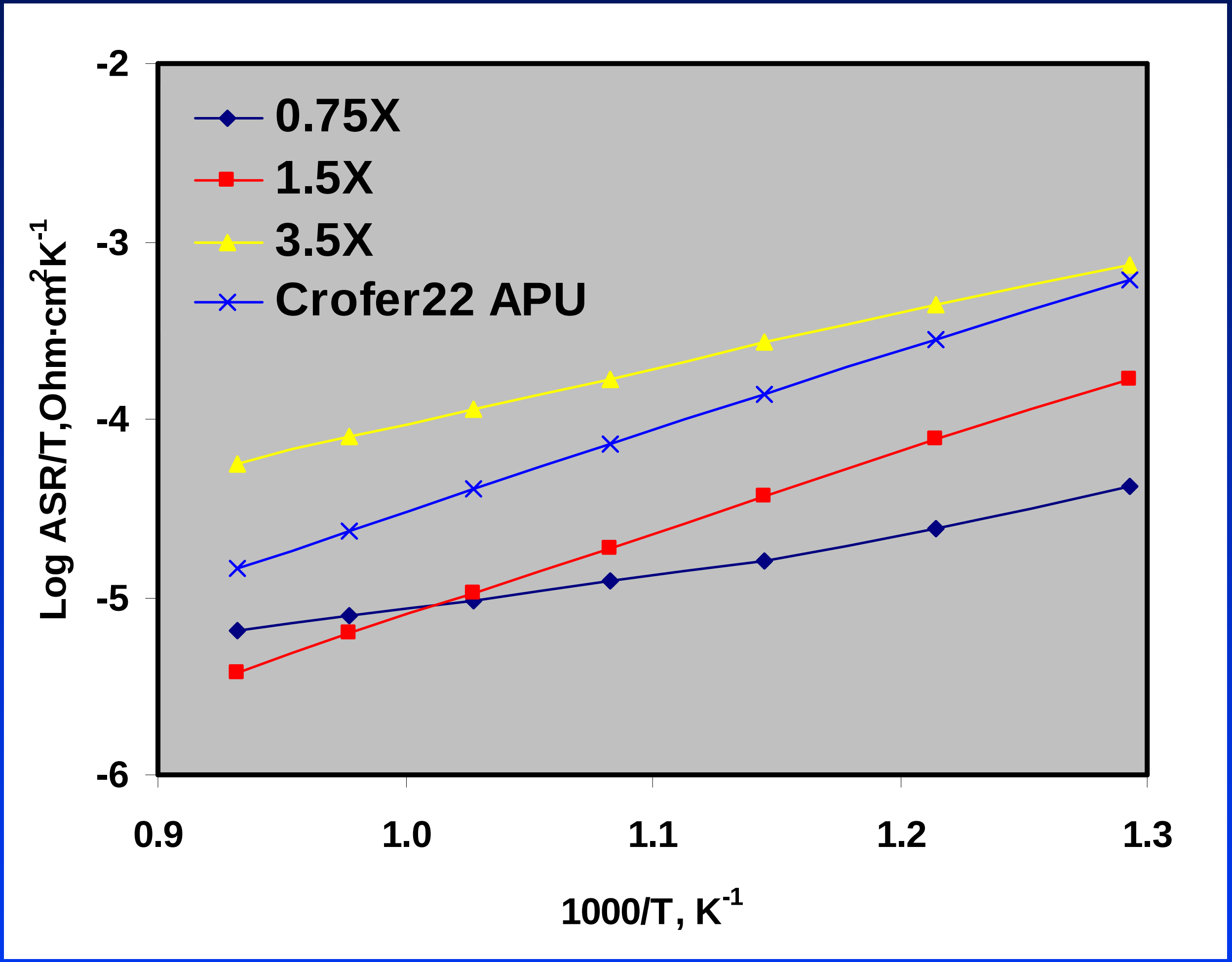
Effect of Element X on Thermal Expansion Behavior of the Low-Cr Fe-Ni Alloys



Thermal Expansion vs. Temperature for the Low-Cr Fe-Ni Alloys (wt.%), as Compared to Other Cell Components

- **Element X was found to have negligible effect on the thermal expansion behavior of the low-Cr Fe-Ni alloys**
- **The CTE of the low-Cr Fe-Ni alloys with different levels of X was close to that of other cell components**

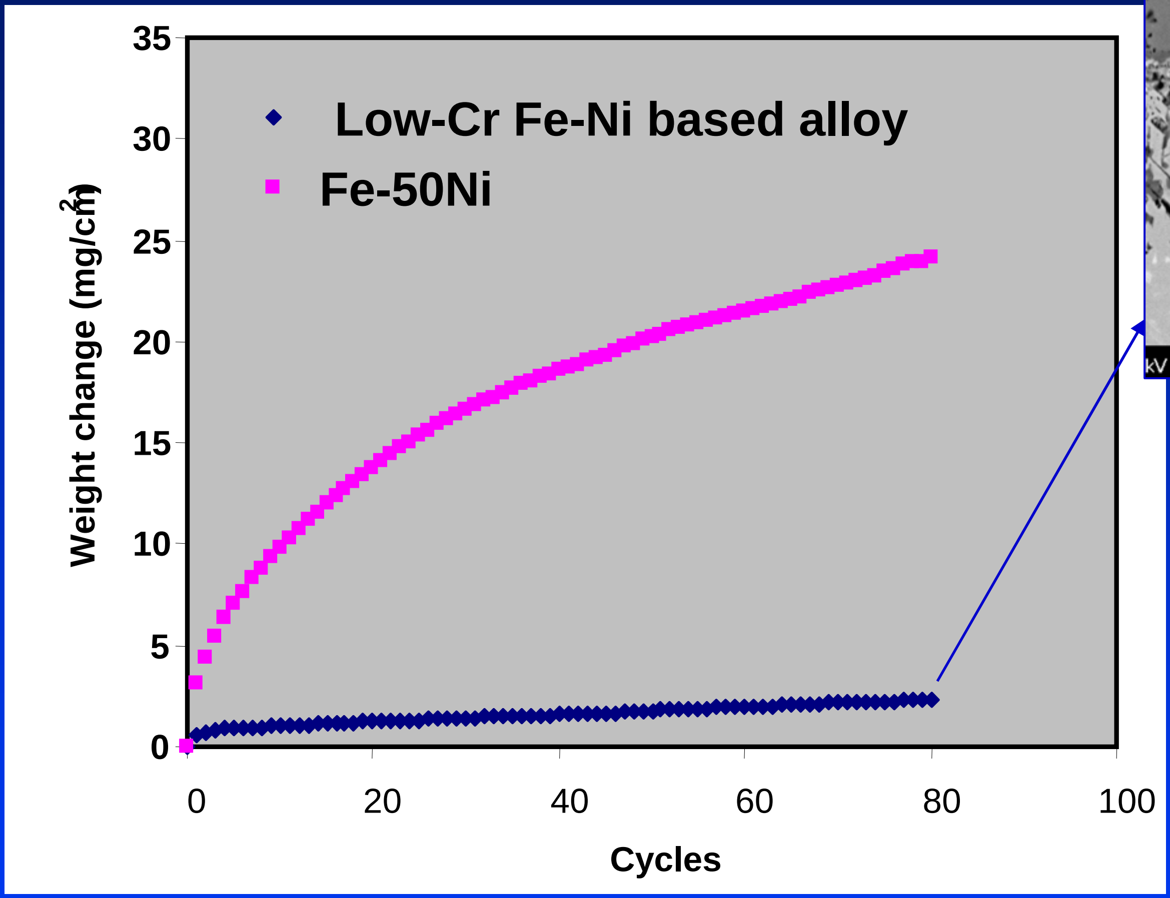
Effect of X on the Scale ASR of Low-Cr Fe-Ni Alloys

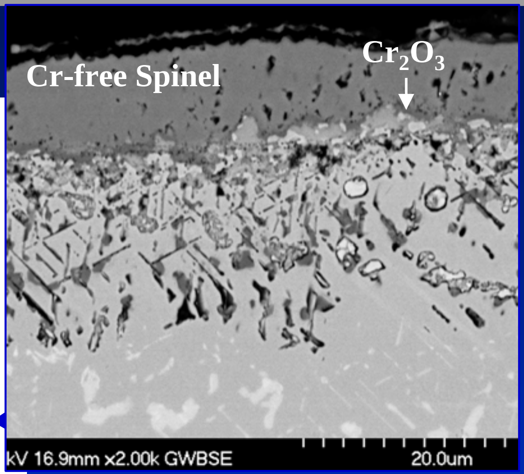


- The ASR of the oxide scale developed on the low-Cr Fe-Ni alloys increased with the X content
- The alloy with 1.5%X exhibited lower scale ASR than Crofer 22 APU

Scale ASR of the low-Cr alloys with different X levels after oxidation for 3 weeks in air at 800°C

Cyclic Oxidation of the Low-Cr Fe-Ni Alloy





Oxidation kinetics of two Fe-Ni alloys after 80 cycles (25-h cycle, 800°C, air cooling)

- The mass gain of the low-Cr Fe-Ni based alloy was significantly lower than that of the Fe-50Ni alloy.
- No scale spallation was observed for both alloys, indicating good scale spallation resistance for the Fe-Ni system.

Cr volatility of the new Fe-Ni alloy was much lower than that of Crofer 22 APU

- The Cr transport experiment was conducted at PNNL;
- Experimental details: 800°Cx500 h, moist air with a velocity of 1.1 cm/s

Summary

- **CTE (√)**
  The CTE of the low Cr Fe-Ni alloys is close to that of other cell components.
- **Oxidation Resistance (√)**
  Effective alloying elements have been identified that significantly improve oxidation resistance of low-Cr Fe-Ni alloys.
- **ASR (√)**
  The ASR of the oxide scales formed on the new alloys is comparable to that of current interconnect alloys.
- **Cr Volatility (√)**
  The Cr transport rate for the new alloys is much lower than that of Crofer 22 APU.

Current/Future Work

- **Current Work: On-going Phase II Study**
  - Further Optimization of Alloy Compositions
  - Oxidation Tests in Anode- & Dual-environment Atmospheres
  - Evaluation of Scale Spallation Resistance of the New Alloys
  - Detailed Study of Alloy/Cathode Interaction/Compatibility
  - Cell Testing with the New Interconnect Alloys

- **Future Work:**
  - Scale-up of Alloy Production (in Collaboration with Commercial Alloy Producers)
  - Stack Testing with the New Interconnect Alloy (In-house, National Laboratories, SECA Industrial Teams)
  - Evaluation of Other Properties (Forming, Tensile, Creep, etc.)

Acknowledgements

- This research was sponsored by the DOE SECA Core Technology Program (DOE Award #DE-FC26-04NT42223). The authors wish to thank Drs. Lane Wilson and Ayyakkannu Manivannan at NETL for helpful discussions regarding this work.
- Additional support was provided by the Center for Manufacturing Research, Tennessee Technological University.