Enhanced Grain Boundary Diffusion of Oxygen through Alumina-Nickel Inclusion Composites via Humidified Oxidation

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Introduction

The magnitude of enhanced grain boundary and surface diffusion in the presence of water vapor for oxide materials has yet to be thoroughly explained. It is believed that the incorporation of protons from water vapor at high temperatures enhances oxygen diffusion at the grain boundary. Presented here is a study of Ni particles imbedded in an Al_2O_3 matrix and oxidized to form Ni-spinel.

Experimental Procedures

1. Initial Powder Preparation

Al_2O_3 and NiO powders are grounded, milled, and mixed to ensure homogeneity.

2. Ni Reduction

Powders are heat treated at 700°C for 5 hours in 4% H_2-Ar environment to reduce the NiO to Ni.

3. Sintering

Reduced powders are pressed into pellets and sintered in 4% H_2-Ar environment at 1500°C for 3 hours to increase their density to ~98%

4. Ni Oxidation

Samples are sectioned and polished to a 100nm finish, then oxidized at 1300°C in a dry or humid (0.2atm) environment for 5, 10, 15 or 20 hours.

X-Ray Diffraction Characterization

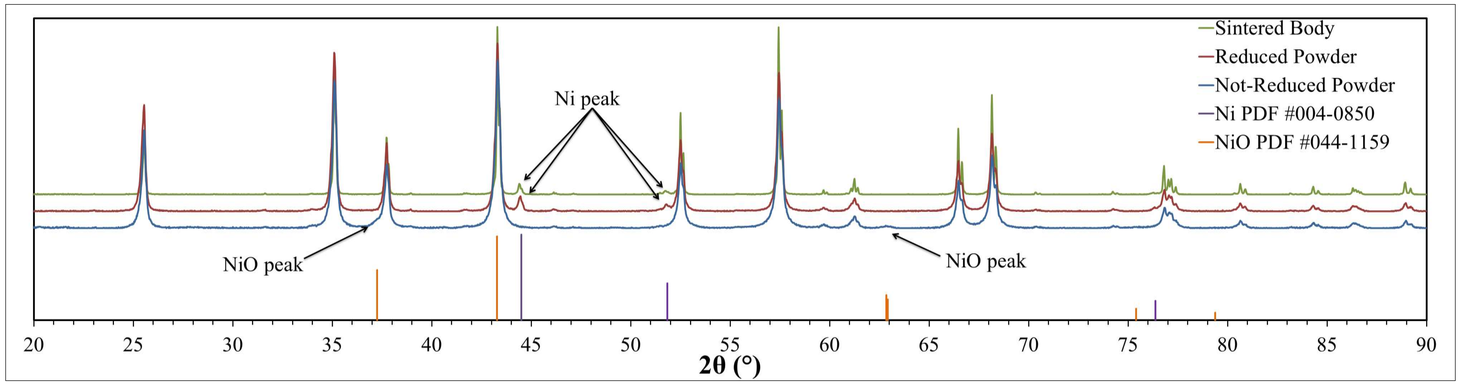


Figure 1: X-Ray diffraction patterns for sample at various steps of the processing.

Before reduction, NiO peaks can be seen. In the reduced powder, NiO peaks no longer exists but Ni peaks have now formed. Showing NiO was successfully reduced to Ni.

Dry Oxidation vs. Humid Oxidation

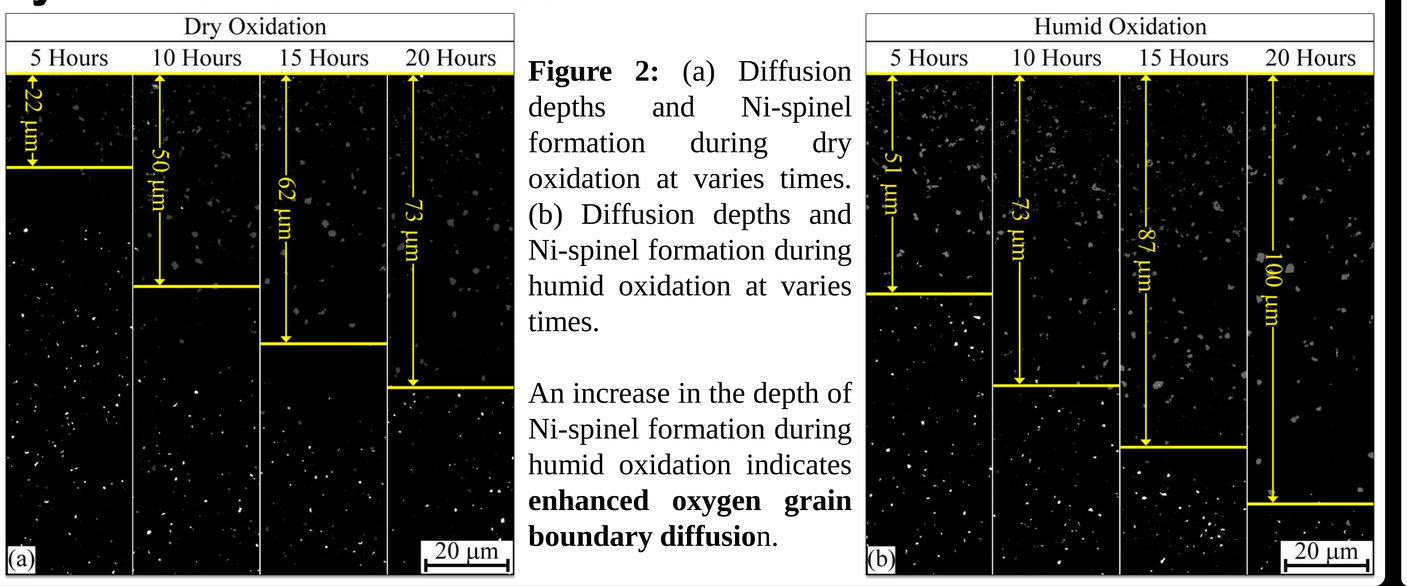


Figure 2: (a) Diffusion depths and Ni-spinel formation during dry oxidation at varies times. (b) Diffusion depths and Ni-spinel formation during humid oxidation at varies times.

An increase in the depth of Ni-spinel formation during humid oxidation indicates **enhanced oxygen grain boundary diffusio**n.

Reaction Kinetics

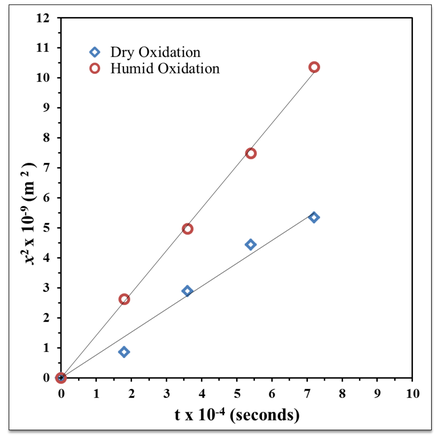


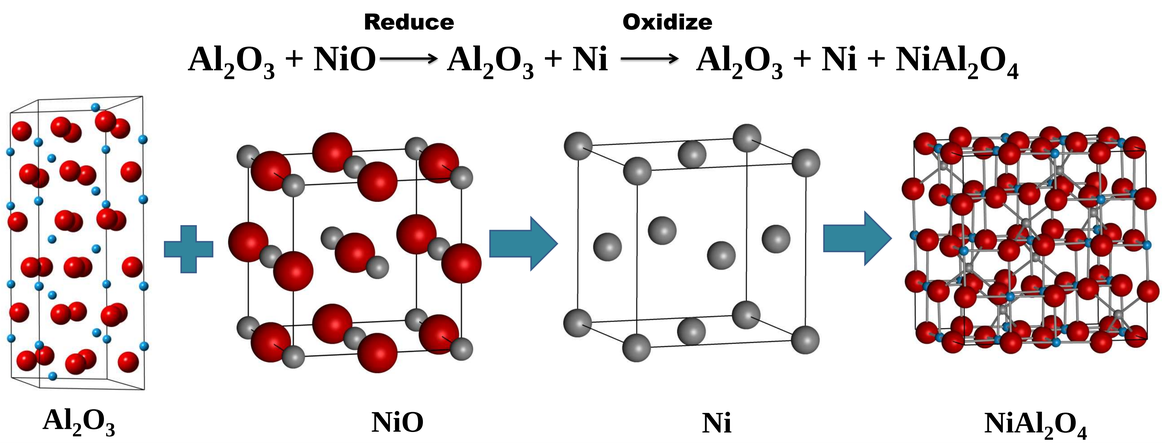
Figure 3: Comparison of the reaction kinetics between dry oxidation and humid oxidation process.

Overall Reaction

After Al_2O_3 and NiO are mixed, NiO is reduced to Ni using hydrogen gas.

During oxidation, the presence of oxygen causes the top layer of Ni to react and form Ni-spinel.

Longer oxidation times yields a deeper Ni-spinel layer.



Conclusions and Future Work

- It is observed that the presence of water vapor enhances oxygen diffusion. In comparison to the dry oxidation process, the diffusion lengths in the humid oxidation process are greater.
- Determine the reaction energy at 1350°C, 1400°C, 1500°C.
- Vary the water vapor content to determine the optimal level needed for enhanced diffusion to occur.

Acknowledgments

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