# Quarterly Management Report

| WBS Element | Project Title | Contract Number | Contract Start | Contract End |
|---|---|---|---|---|
| 01 | Development of Seals for Membranes | 12461 | 10/01/03 | 09/30/04 |

| Performer Name and Address | Principal Investigator(s) |
|---|---|
| Pacific Northwest National Laboratory<br>902 Battelle Blvd<br>P.O. Box 999<br>Richland WA 99352 | K Scott Weil |

## BUDGET AND COST REPORT

| | |
|---|---|
| **Prior Year Funds [$K]** | 135 |
| **Total Current Year Commitment $K]** | 485 |
| **Projected Current Year Costs [$K]** | 400 |

| | O | N | D | J | F | M | A | M | J | J | A | S |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Planned Costs** | 45 | 100 | 130 | 160 | 190 | 220 | 250 | 280 | 310 | 340 | 370 | 400 |
| **Actual Costs** | 45 | 91 | 124 | 132 | 135 | 143 | | | | | | |
| **Variance** | 0 | 9 | 6 | 28 | 55 | 77 | 250 | 280 | 310 | 340 | 370 | 400 |

## MILESTONE REPORT

| Milestone Designation | Milestone Description | Due Date | Revised Due Date | Completion Date |
|---|---|---|---|---|
| 3-1 | Initiate an investigation of the mechanisms of Ag-CuO wetting on dense and porous alumina bodies. | 11/30/03 | | 11/30/03 |
| 3-2 | Complete our investigation of the mechanisms of Ag-CuO wetting on dense and porous alumina bodies. | 02/28/04 | 03/30/04 | 03/30/04 |
| 3-3 | Assess the viability of aluminum-based alloys in air brazing. | 05/31/04 | 06/30/04 | |
| 3-4 | Demonstrate the viability of a compliant braze to be used in sealing ceramic membranes and aluminide gas manifolds for long-term, high-temperature | 09/30/04 | 10/30/04 | |
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## TECHNICAL HIGHLIGHTS

Investigation of the mechanisms of Ag-CuO wetting on dense and porous alumina bodies
(Partial Completion of Milestone 3-2 for FY2004)
In collaboration with Professor Alan Meier at Alfred University and Professor Amit Bandyopadhyay and Jens Darsell at Washington State University, we have conducted a series of investigations into the mechanisms of wetting and adhesion between Ag-CuO and porous and dense alumina substrates. Essentially our research indicates that initial wetting takes place via a surface reaction between the CuO in the braze and the alumina, forming predominantly copper aluminate, which is further wetted by the remaining filler material. The kinetics of this reaction are under further investigation as is the effect of pores size on reaction in the case of the porous substrates. The braze does infiltrate the porous substrate and initial indications suggest that the degree of infiltration can be controlled either by slight modifications in the braze chemistry or by adjusting the microstructure of the porous substrate.

Use of Aluminum in Air Brazing
(Partial Completion of Milestone 3-3 for FY2004)
To date, our research has focused on the Ag-CuO system as the basis for the reactive air braze. We are now examining the effects of alloying additions on the base properties of the braze, including its liquidus temperature and wettability on various substrates, as well as on the subsequent properties of the resulting joints, including maximum use temperature, strength, and high-temperature oxidation resistance. One of the alloying elements of interest is aluminum, since aluminum in Ag-CuO is expected to yield an interconnected composite structure similar to products of the DIMOX process, which is known to provide excellent strength and corrosion and wear resistance. Initial alloying experiments were conducted with aluminum in an effort to determine whether the melt and re-melt temperatures of the braze could be substantially separated to effect a lower temperature joining process. Surprisingly, we found that alumina could be brazed in open air using pure aluminum foil. Furthermore it was found that the resulting joint is quite ductile and will plastically deform under high stress, although it is not as strong as the base ceramic substrate. What is particularly surprising though, is that the aluminum air brazed joints retain their ductility and increase measurably in strength after extended exposure to high temperature oxidation conditions. Based on these results, we feel that aluminum can form the basis of a new family of air brazes for ceramic joining and that the final properties of the resulting joints should be tailorable via appropriate alloying modifications to the aluminum. In particular, greater joint strengths should be obtainable by mitigating interfacial porosity in the joint.

Papers Accepted for Publication During the 2nd Quarter of FY2004
1. K. S. Weil, C. A. Coyle, J. S. Hardy, J. Y. Kim, and G-G. Xia, "Alternative Planar SOFC Sealing Concepts," Fuel Cells Bulletin.
2. J. Y. Kim, J. S. Hardy*, and K. S. Weil, "Effects of CuO Content on the Wetting Behavior and Mechanical Properties of a Ag-CuO Braze for Ceramic Joining," Journal of the American Ceramic Society.

Papers Submitted for Publication During the 2nd Quarter of FY2004
1. K. S. Weil, J. Y. Kim, and J. S. Hardy, "Interfacial Analysis of (La0.6Sr0.4)(Co0.2Fe0.8)O3 Substrates Wetted by Ag-CuO and Ag-CuO-TiO2," invited paper, Interface Science.
2. J.S. Hardy, J.Y. Kim, J.T. Darsell, and K. Scott Weil, "Pd-Modified Reactive Air Braze for Increased Melting Temperature," Proceedings of the Surfaces, Interfaces, and the Science of Ceramic Joining Symposium, American Ceramic Society (2004).
3. J. S. Hardy, J.Y. Kim, J.T. Darsell, E.C. Thomsen, and K.S. Weil, "Ti-Modified Ag-CuO Reactive Air Brazes for Improved Wettability on Mixed Ionic/ Electronic Conductors," Proceedings of the Surfaces, Interfaces, and the Science of Ceramic Joining Symposium, American Ceramic Society (2004).
4. J.T. Darsell, J.S. Hardy, J.Y. Kim, and K.S. Weil, "An Investigation of Wettability and Microstructure in Alumina Brazed With Ag-CuO-TiO2," Proceedings of the Surfaces, Interfaces, and the Science of Ceramic Joining Symposium, American Ceramic Society (2004).
5. J.T. Darsell, J. S. Hardy, J.Y. Kim,and K.S. Weil, Microstructure, "Melting and Wetting Properties of Pd-Ag-CuO Air Braze on Alumina," Proceedings of the Surfaces, Interfaces, and the Science of Ceramic Joining Symposium, American Ceramic Society (2004).
6. J. Y. Kim, K. S. Weil, and J.S. Hardy, "Wetting and Mechanical Characteristics of the Reactive Air Braze for Yttria-Stabilized Zirconia (YSZ) Joining, Proceedings of the Surfaces, Interfaces, and the Science of Ceramic Joining Symposium, American Ceramic Society (2004).
7. K. S. Weil, C. A. Coyle, J. S. Hardy, J. Y. Kim, and G-G. Xia, "Alternative Methods of Sealing Planar Solid Oxide Fuel Cells," Proceedings of the Surfaces, Interfaces, and the Science of Ceramic Joining Symposium, American Ceramic Society (2004).
8. K. S. Weil and J. P. Rice, "Evaluation of Gold ABA Braze for Joining High Temperature Electrochemical Device Components," Proceedings of the Surfaces, Interfaces, and the Science of Ceramic Joining Symposium, American Ceramic Society (2004).

## ISSUES

| Report Prepared By | Date |
|---|---|
| K Scott Weil | 05/22/04 |