Low Cost MCFC Anodes

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CONTRACT INFORMATION

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INTRODUCTION

M-C Power Corporation (MCP) was founded in 1987 to commercialize molten carbonate fuel cell (MCFC) stacks based on an internally manifolded stack concept. Since then, MCP has successfully scaled up the manufacturing and design of the MCFC technology to commercial area (1-m^2) . A total of five commercial-area subscale (20 kW) stacks and one commercial (250 kW) stack have been built and operated. A second commercial (250 kW) stack has been assembled and conditioned and is scheduled to go on-line in late 1996. In addition to the commercial-area production and testing of fuel cell stacks, M-C Power has a program which focuses on developing lower cost stack components with improved endurance and performance. This paper outlines a project, funded under a DOE Small Business Innovative Research (SBIR) grant, which tested a potentially lower cost method of manufacturing MCFC stack anodes and evaluated the feasibility of utilizing the technology in the existing MCP manufacturing facility. [1]

OBJECTIVES

The state-of-the-art high performance MCFC anode requires either the use of expensive pre-alloyed powders or costly physical mixtures of fine metallic particles requiring expensive heat treatment procedures for alloying the metal powders. The objective of this work was to complete subscale manufacturing trials of an anode manufacturing process to define the processing parameters and demonstrate the technical feasibility of mass producing Ni-Al and Ni-Cr anodes with alloy contents less than 3% by weight. In addition, a cost and feasibility study was completed for comparing the total manufacturing cost of the new anode alloying process with that currently utilized by M-C Power for commercial production of the MCFC anodes.

APPROACH

The overall approach involved modifying an innovative anode tape casting and heat treating process, such that the anode microstructures and alloy compositions that are required for M-C Power's endurance cell package are obtained. The procedure involves adding activator salts to the anode tape casting slurry with the nickel and chromium or aluminum powders.[2] During heat treating in a reducing environment, two different processes occur: sintering of the base nickel structure, and alloying or cementation of the chromium or aluminum metal powders. Cementation occurs when the metal powders react with the activator salt (e.g. NH_4Cl) forming vapor phase aluminum or chromium chlorides which deposit on the nickel powder surfaces and diffuse into the base metal. With the combination of solid state diffusion and vapor phase transport of the diffusing species, the alloying dispersion is greatly improved for physical mixtures of nickel with either Al or Cr metal.

Three activator salts were selected for laboratory scale manufacturing trials based on their physical properties and compatibility with the existing tape casting formulations: ammonium chloride (NH_4Cl), common salt (NaCl), and aluminum chloride ($AlCl_3 \bullet 6 H_2O$). Laboratory scale (16-cm wide) tape casting trials were completed for each alloy/activator salt combination, resulting in a homogeneous physical mixture of the metal powders and the activator salt. Cast green tapes were heat treated in two different atmospheres using a heat profile similar to that utilized for commercial production of the state-of-the-art anodes.

The effect of the manufacturing parameters on the anode porosity and degree of alloying was evaluated for the cementation anodes and control samples (physical mixtures of metal powders without activator salts) using chemical analysis and scanning electron microscopy (SEM) coupled with energy dispersive x-rays (EDX) to quantify the degree of alloying across the base nickel powders and to detect residual metal powders in the heat treated samples. Porosimetry analysis was utilized to measure the pore size distribution of the alloyed anode samples after heat treating.

To determine whether it was cost-effective to implement the cementation alloying manufacturing process, the M-C Power manufacturing cost model was utilized to determine the impact of the different material costs and processing parameters on the total anode cost. In addition, the cost analysis included equipment expenditures and facility modifications required by the cementation alloying process.

RESULTS

Aluminum and chromium alloying levels of 1-2.8% were obtained with a uniform concentration of the alloying element through the base nickel powder particles. Residual Cr and

Al metal particles were evident in most of the samples; these could be eliminated through further analysis and development of the manufacturing procedures.

The cost analysis indicated that, due to the presence of the halide vapors, significant equipment expenditures and facilities modifications were required which negated the cost savings resulting from increased manufacturing rates and lower material costs.

CONCLUSION

Although this project successfully demonstrated the technical feasibility of manufacturing low alloy content nickel-based MCFC anodes by cementation techniques, the economic viability of these techniques was not demonstrated, mainly because of facility and equipment expenditures required to implement the process in the existing M-C Power manufacturing facility.

ACKNOWLEDGMENTS

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1. "Final Report: Low Cost Molten Carbonate Fuel Cell Anodes," M-C Power Corporation, June 23, 1996, SBIR Grant No. DE-FG02-95ER82015.

2. "Methods of Manufacturing Porous Metal Alloy Fuel Cell Components," Diane S. Erickson and E. T. Ong, U. S. Patent Number 5,312,580 (1994) May 17.