An Innovative Carbonate Fuel Cell Matrix

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Introduction

The electrolyte matrix is a microporous ceramic structure sandwiched between the electrodes to isolate the fuel from the oxidant, store electrolyte and facilitate ionic transport. The electrolyte distribution and fill levels in carbonate fuel cell are controlled by the balance in capillary forces of the porous cell components. The matrix needs to remain completely filled; therefore, pores are required to be fine and significantly smaller than the electrodes to exert sufficient capillary force to prevent electrolyte from moving to the electrodes at all times during endurance operation. A balanced pore structure between matrix and electrodes is necessary to avoid electrodes flooding and gas cross-over and to maintain stable cell resistance (1). FCE has advanced direct fuel cell (DFC) electrolyte matrix over the years and demonstrated that the matrix meets the requirements for greater than 5 year life based on accelerated tests and field stack operations. However, development of advanced designs and materials that can further increase the performance and extend cell life will enable accelerated MCFC deployment.

This paper will report the progress on the development of an unique and innovative matrix design that offers numerous benefits to the carbonate fuel cell performance and durability. In addition, this paper will also review parameters that affect matrix material stability and approaches to extend cell life.

Experimental

Experiments were performed with button and single cells (3 cm^2 and 250 cm^2, respectively). Each cell consisted of a porous Ni-alloyed anode, a porous in-situ lithiated NiO cathode and a porous matrix ($LiAlO_2$) filled with the carbonate electrolyte. Tests were performed at different temperatures under standard fuel (72.8%H_2-18.2%CO_2-9%H_2O) and oxidant (18%CO_2-12%CO_2-67%N_2-3%H_2O) conditions. Other specially designed out of cell tests (OCT) were also performed at different temperatures and gas atmospheres to investigate parameters and processes affecting matrix material stability. Different techniques such as XRD, SEM, Mercury porosimetry, AC-impedance and steady-state polarization were carried out to evaluate and characterize matrix stability under fuel cell operating conditions.

Results and Discussion

The carbonate fuel cell matrix stability holds an important key to maintain higher electrolyte capacity and longer service life. The matrix particles ($LiAlO_2$) stability is mainly controlled by the material purity, particles uniformity, temperature and electrolyte composition. Literature studies and accelerated tests showed localized matrix particles coarsening during long-term use. Such coarsening may lower capillary force, leading to an increase in cell ohmic resistance and gas crossover. FCE has made a substantial improvement in the matrix structure and the mechanical strength to enhance electrolyte storage capacity and extend cell life. Figure 1 shows a comparison of the snap strength of the advanced and the conventional matrix designs. Results showed that the advanced matrix offers >40% improvement in mechanical strength and more than 20% reduction of large pores at (0.2µm). These improvements are projected to enable low electrolyte loss from the fuel cell matrix and extend cell life.

This paper reports the requirements, approaches and progress in achieving a higher performance and longer life carbonate fuel cell matrix.

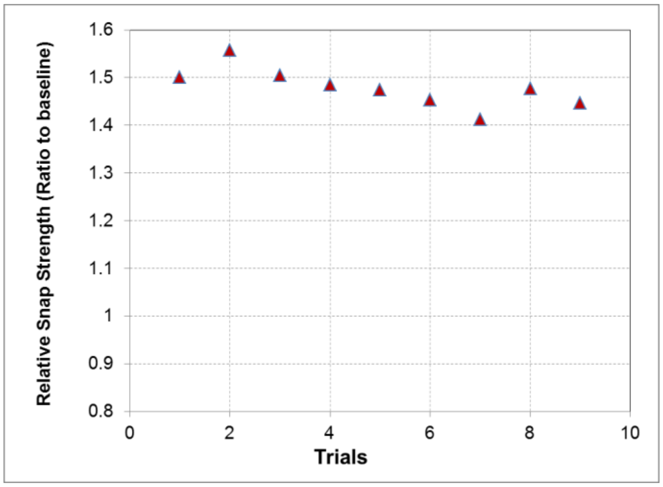

Figure 1: Comparison of the snap strength of advanced vs. baseline matrix design.

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1. C. Yuh, A. Franco, L. Chen, A. Hilmi, R. Venkataraman and M. Farooque., “Liquid-Electrolyte Fuel Cells Electrolyte Management Progress,” Abstract 192, Fuel Cell Seminar and Energy Exposition, November 10-13, 2014, Los Angeles, CA.