

FABRICATION AND PERFORMANCE OF ZIRCONIA ELECTROLYSIS CELLS FOR CARBON DIOXIDE REDUCTION FOR MARS *IN SITU* RESOURCE UTILIZATION APPLICATIONS. N. Q. Minh, B. W. Chung, R. Doshi, G. R. Lear, K. Montgomery, and E. T. Ong, AlliedSignal Aerospace Equipment Systems, 2525 West 190th Street, Torrance CA 90504-6099, USA (nguyen.minh@alliedsignal.com).

Introduction: Use of the Martian atmosphere (95% CO₂) to produce oxygen (for propellant and life support) can significantly lower the required launch mass and dramatically reduce the total cost for Mars missions. Zirconia electrolysis cells are one of the technologies being considered for oxygen generation from carbon dioxide in Mars In Situ Resource Utilization (ISRU) production plants. The attractive features of the zirconia cell for this application include simple operation and lightweight, low volume system.

A zirconia electrolysis cell is an all-solid state device, based on oxygen-ion conducting zirconia electrolytes, that electrochemically reduces carbon dioxide to oxygen and carbon monoxide. The cell consists of two porous electrodes (the anode and cathode) separated by a dense zirconia electrolyte. Typical zirconia cells contain an electrolyte layer which is 200 to 400 micrometer thick. The electrical conductivity requirement for the electrolyte necessitates an operating temperature of 900° to 1000°C. Recently, the fabrication of zirconia cells by the tape calendaring has been evaluated. This fabrication process provides a simple means of making cells having very thin electrolytes (5 to 30 micrometers). Thin zirconia electrolytes reduce cell ohmic losses, permitting efficient operation at lower temperatures (800°C or below). Thus, tape-calendered cells provides not only the potential of low temperature operation but also the flexibility in operating temperatures. This paper describes the fabrication of zirconia cells by the tape calendaring method and discusses the performance results obtained to date.

Fabrication Process: The tape calendaring process for making zirconia electrolysis cells is shown in Figure 1. This process involves first mixing electrolyte (zirconia) and cathode (mixture of platinum and zirconia) powders with organic binders in a high-intensity mixer to form plastic masses. Electrolyte and cathode plastic masses are rolled into tapes using a two-roll mill. Electrolyte and cathode tapes of certain thickness ratio are laminated and rolled into a thin bilayer tape. This bilayer tape is then laminated with a cathode tape and rolled again into a thin tape. This process can be repeated until an electrolyte of the desired thickness is obtained. In general, it takes only three rollings to produce mi-

cometer-thick electrolyte layers. The final bilayer tape is cut to size and fired at elevated temperatures to remove the organics. The anode layer (mixture of platinum or strontium-doped lanthanum manganite and zirconia) is then applied on the electrolyte surface to produce a complete cell.

Zirconia cells having thin electrolytes have been successfully fabricated by the tape calendaring process described above. Figure 2 shows, as an example, a micrograph of a fracture surface of a zirconia cell produced by tape calendaring.

Performance of Zirconia Cells: Zirconia cells made by the tape calendaring process have been tested for their electrochemical performance. Performance tests mainly involve the determination of cell current/voltage characteristics at different temperatures (700° to 900°C). Figure 3 shows an example of performance curves obtained at 800°C for a 5 cm x 5 cm zirconia cell. High CO₂ utilization (up to 78%) has also been demonstrated. Thermal cycle and thermal shock properties of tape calendered cells have been evaluated. Thermal cycle tests involve repeated heating and cooling of cells between room temperature and 900°C at a ramp rate of 10°C/minute. Thermal shock tests involve exposing room-temperature samples to a 900°C environment and then removing the red hot samples to quench in room temperature. Zirconia cell samples tested to date show no structural damage or degradation after the thermal cycle and thermal shock tests. Multicell (two- and three-cell) stacks were successfully fabricated and operated. Figures 4 and 5 show a photograph of a three-cell stack and its current/voltage curves, respectively. As seen in Figure 5, performance of individual cells in the stack is well matched. The stack is able to sustain multiple (5) thermal cycles from room temperature to 800°C without significant performance degradation (Figure 6).

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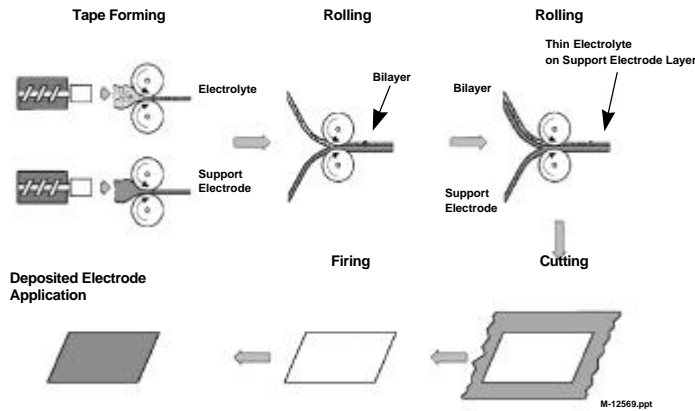


Figure 1. Tape calendaring fabrication process.

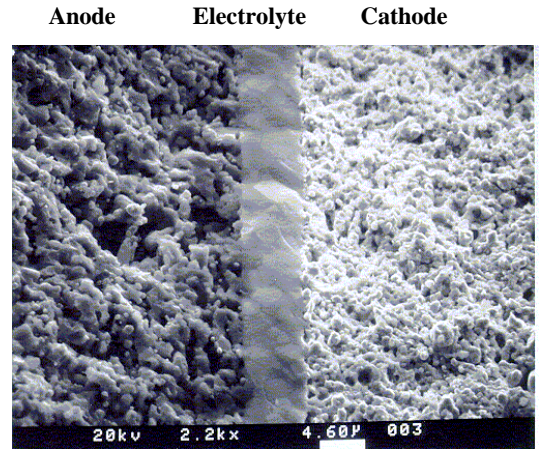


Figure 2. Micrograph of fracture surface of zirconia cell. Anode is a mixture of strontium-doped lanthanum manganite and zirconia. Cathode is a mixture of platinum and zirconia.

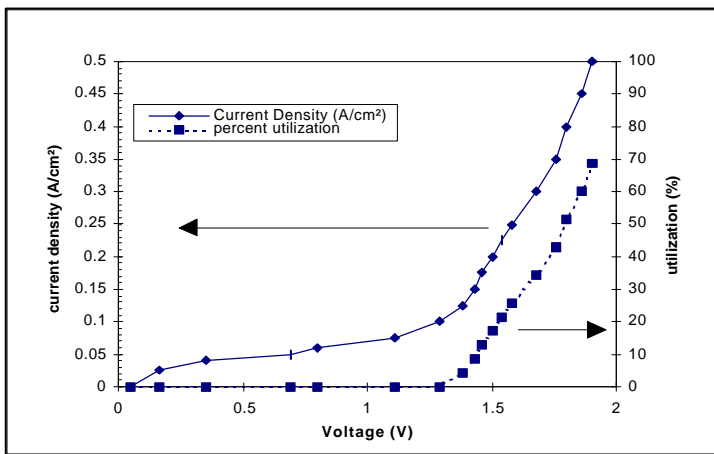


Figure 3. Performance curves of a 5 cm x 5 cm cell at 800°C.

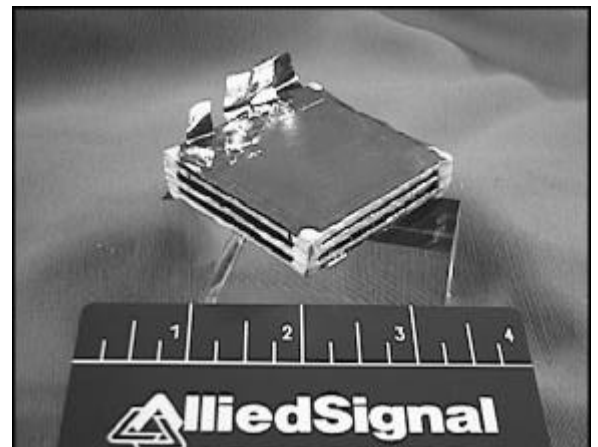


Figure 4. Photograph of a three cell stack.

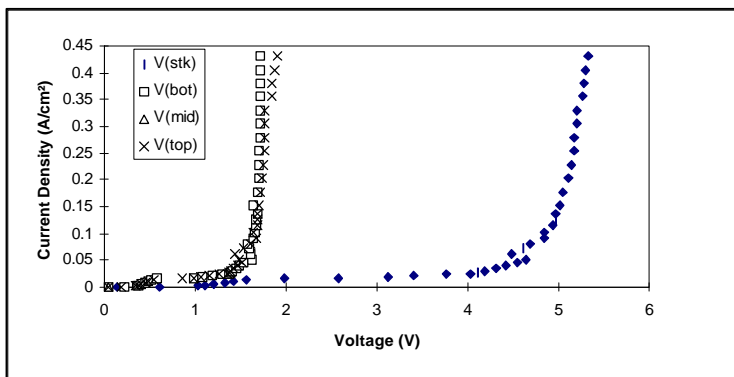


Figure 5. Voltage/current curves at 800°C of three-cell stack

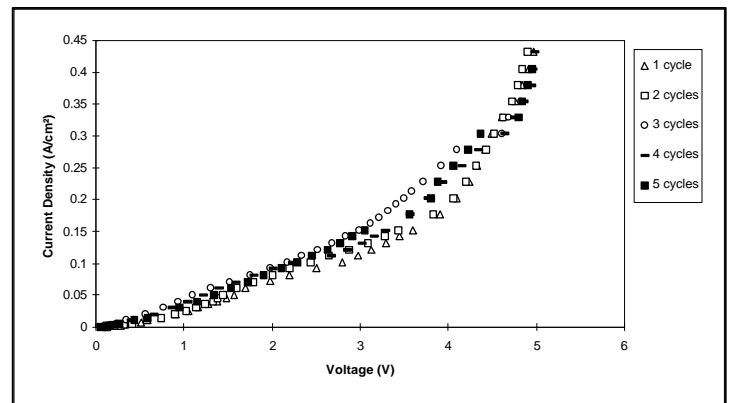


Figure 6. Voltage/current curves at 800°C of three-cell stack after thermal cycling.