

OXYGEN PRODUCTION FROM CARBON DIOXIDE BY ZIRCONIA ELECTROLYSIS; K. Araghi¹

Introduction: Research has been conducted on issues related to the production of oxygen from carbon dioxide and air, using zirconia cell and ceria tube. Both in-house fabricated disk cells and vendor-supplied tube cell are being tested and characterized. These processes are under consideration for a Mars sample return mission which would manufacture their own oxygen from CO₂ in the martian atmosphere. Most of the present effort has been concentrated on the development of a reliable test bed that can provide repeatable and accurate measurements of cell and tube performance. Initial experiments, including endurance tests as long as thousands of hours, were conducted with two identical cells and one tube.

System Construction: The zirconia electrochemical cell consists of a solid yttria-stabilized zirconia (ZrO₂-Y₂O₃ 8 mole%) disk with platinum electrodes, sandwiched between two zirconia crucibles. Alumina tubes inserted into the crucibles feed and exhaust the gases. Figure 1 is a cutaway of the cell. The electrodes are platinum and can be applied in several different ways. One is to use a commercially available platinum paste, which is thinned with ethanol and applied to the disk with a swab in a thin layer. Another method that has been tried is vapor deposition. This technique allows precise control over the thickness of the electrode layer and also allows the layer to be very thin.

The tubular ceria electrochemical cell consists of calcia-stabilized ceria with one close end tube with silver electrodes. Alumina tube inserted into the ceria tube feed the gases. Figure 2 is a cutaway of the ceria tube. The tubular unit can also be used as an oxygen compressor.

System Test Bed: A schematic drawing of the zirconia cell system test bed as it currently exist is shown in Figure 3. The CO₂ is supplied by a high-pressure cylinder and is fed into the system through a metering valve, which controls the flow. The CO + CO₂ exhaust is connected to a valve that can send it either to a 25 cc soap-film flowmeter or to the gas chromatograph (GC) for analysis. The O₂ produced is also connected to a valve that can send it either to a 1 cc soap-film flowmeter or to the GC. The cell is surrounded by a clamshell heater and then by blanket insulation. The heater is controlled by a thermo-controller. Power is supplied to the cell by a Hewlett Packard power supply, with cell voltage and current monitored by digital panel meters.

A schematic drawing of the ceria tube system test bed as it currently exist is shown in Figure 4. The CO₂ is supplied by a high-pressure cylinder and is fed into the system through a metering valve, which controls the flow. The CO + CO₂ exhaust is connected to a valve that can send it either to a 25 cc soap-film flowmeter or to the gas chromatograph (GC) for analysis. The O₂ produced is also connected to a valve that can send it either to a 1 cc soap-film flowmeter or to the GC. The flange is surrounded by a clamshell heater and then by blanket insulation. The heater is controlled by a PC equipped with a data-acquisition card. Power is supplied to the cell by a Hewlett Packard power supply, with cell voltage and current monitored by digital panel meters.

Results and Discussion: Zirconia Cell #1 completed a test with 1 cm² electroded area in which it ran continuously for almost 253 hours with CO₂ as the inlet gas. All experiments with cell were run with a CO₂ flow of 10 cc/min. Oxygen, produced by the dissociation of CO₂ to CO, was passed through the disk as O²⁻ ions and measured in the exhaust gas. Figure 5 is a graph showing the performance of cell #1 plotting current against voltage for a range of temperature. This cell performance was outstanding, no leak ever appeared in the cell. In an electrochemical cell oxygen flow rate is proportional to current as:

$$\text{O}_2 \text{ Flow Rate [cc/min]} = \text{Current [A]} * (1/5.33399) * (\text{room-Temp [K]} / \text{room-Press [psi]})$$

The maximum oxygen flow rate measured in these testes was 1.5 cc/min. This is equivalent to a 30% conversion of CO₂ to CO plus O₂. The maximum voltage of 2.2 V and minimum voltage of 1 V was applied to this cell.

Zirconia Cell #2 completed a test with 2 cm² electroded area in which it ran continuously for almost 200 hours with CO₂ as the inlet gas. Measurements of the cell indicated a small air leak on the oxygen side of the cell, this assumption was made by sending the product gas true to the GC for analysis. No leak was found in the inlet side of the cell and around the joint point of the disk with the two crucibles. Figure 6 is a graph showing the performance of cell #2 plotting current against voltage. The test temperature for this cell was 950 C° with maximum voltage of 2 V and minimum voltage of 0.2 V.

Ceria Tube #1 completed a test in which it ran continuously for over 1000 hours with Air as the inlet gas. All experiment was run with a Air flow of 30 cc/min. Measurement on the tube was done by measuring the current since oxygen flow rate is proportional to current. The maximum oxygen flow rate measured in this test was about 9.0 cc/min. The test temperature for

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this tube was 700 C° with maximum voltage of 1 V and minimum voltage of 0.1 V.

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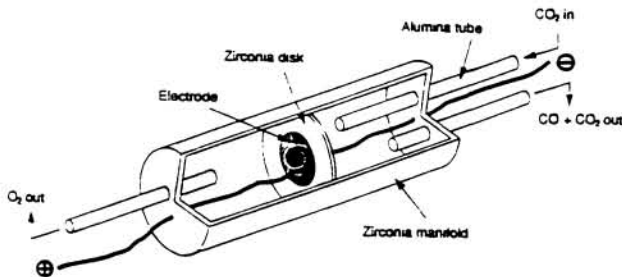


Figure 1. Cutaway of the electrochemical cell

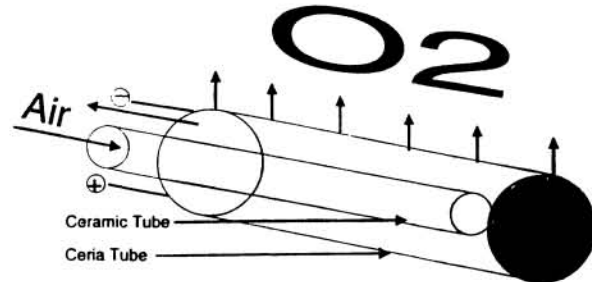


Figure 2. Cutaway of the Ceria Tube

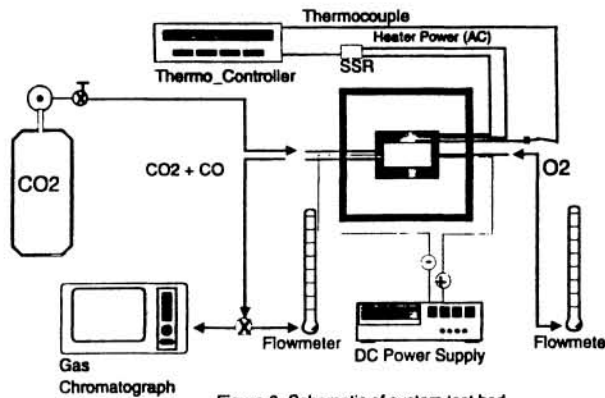


Figure 3. Schematic of system test bed

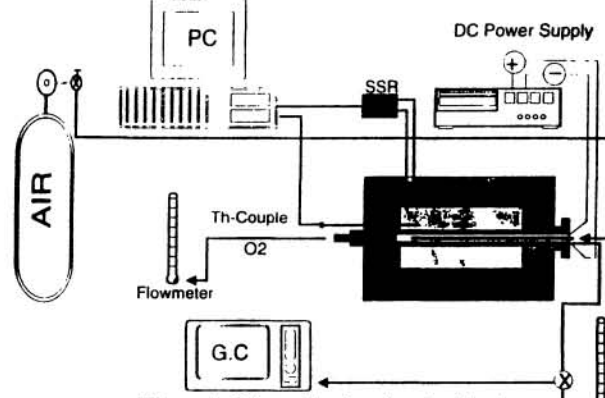


Figure 4. Schematic of system test bed

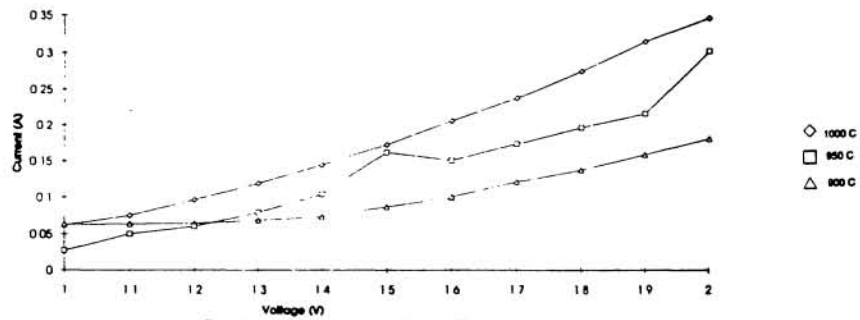


Figure 5. Variation of current with voltage of different temperatures

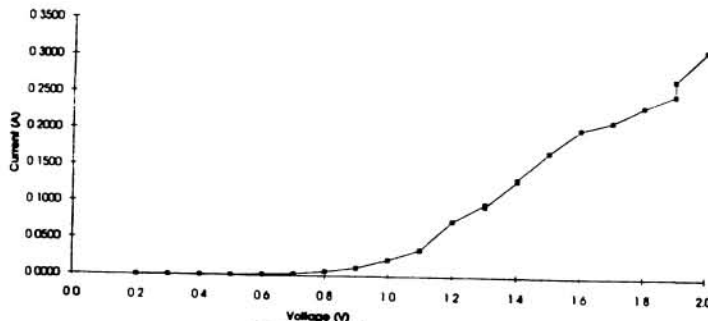


Figure 6. Variation of current with voltage of 900 C