

## EFFECT OF FEED GAS PROFILE ON THE PERFORMANCE CHARACTERISTICS OF MOLTEN CARBONATE FUEL CELLS

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The effect of feed gas profile on the performance of molten carbonate fuel cell, by altering the wetting characteristics of Ni-10 wt % Cr anode structure was experimentally analyzed and described. The feed gas profile was altered in such a way that the oxidant environment was maintained at the anode compartment till the cell temperature is raised to 773 K (little above the melting point of the carbonate mixture) and changed to simulated MCFC feed gases after 873 K. This developed profile can be conveniently applied for operating MCFC with 100 % reproducibility of the cell performance.

**Key words:** MCFC, Fuel cell, Gas profile, Feed gas, wetting.

### INTRODUCTION

Anode material used in molten carbonate fuel cells is porous Ni- 10 wt % Cr having porosity of ~ 60 % and ~ 4 micron median pore size [1]. Chromium [2] and aluminum oxide [3] are used as additives in these electrodes to stabilize the structure against sintering, at the operating cell temperature of 923 K. Though this anode structure is insensitive to the flooding by the carbonate electrolyte, poor wetting is experienced due to its metallic nature than that of its counter part lithium doped nickel oxide electrode (cathode). Performance and life of the molten carbonate fuel cells mainly depends on the effective distribution of the carbonate mixture in the pore structure of the cell components.

So in this study the applicability of the new profile for the gas feed at various operating temperatures was explored to improve the electrolyte wetting which in turn affect the distribution of the electrolyte in the anode pore structure under the operating cell conditions.

### EXPERIMENTAL

Test cells of area 45 cm<sup>2</sup> were used in this study. The cells employed 1.0 mm thick tape cast Ni- 10 wt % Cr as an

anode and a lithium doped nickel oxide cathode (reinforced with 0.25 mm expanded 316L stainless steel mesh).

Respective gas chambers were made of stainless steel. The schematic of the cell assembly is shown in Fig.1. Perforated nickel and stainless steel sheets (1.0 mm thickness) were used as current collectors for the anode and cathode respectively. All the cell tests were conducted by in-situ firing of the tape cast cell components.

Electrolyte retention matrix was made from lithium aluminum oxide (LiAlO<sub>2</sub>) powder of surface area 12 m<sup>2</sup>/g, prepared by combustion synthesis [4] and cast as a tape of 1.0 mm thick (green tape thickness). The amount of

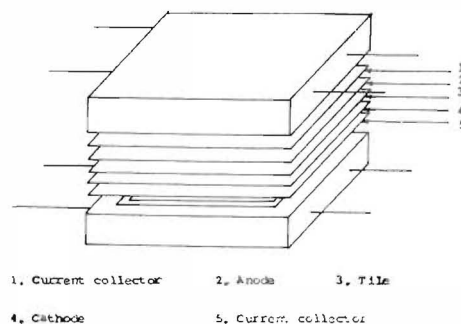


Fig.1: Cell assembly

Table - I: Physical parameters

Cell components	Porosity (%)		Median pore dia ( $\mu\text{m}$ )		Thickness (mm)	
	Ini-tial	after 100 hrs of test	Ini-tial	after 100 hrs of test	Ini-tial	after 100 hrs of test
Anode	65	60	4	4.6	1.0	0.75
Cathode	75	67			1.0	0.8
Tile	42	39			1.0	0.70

carbonate electrolyte needed by the cell components for an effective operation of the cell was calculated from the porosity and volume percentage values of the respective components. This amount with some excess to compensate for other losses, was loaded in the form of cast tapes. The porosity and pore size of the cell components were measured by using mercury porosimeter (Micromeritics USA). Particle size and surface area values were measured from a BET surface area analyzer (Carlo Erba 1800). The effect of feed gas profile over the distribution of the electrolyte in the anode pore structure was studied by changing the feed gas profile at various levels of temperature during cell operation. The carbonate content in the cell components was estimated by leaching out the carbonate electrolyte using a mixture of 70 % acetic acid and 30 % acetic anhydride solution. The difference in weights of the carbonate was correlated with the change in feed gas profile.

## RESULTS AND DISCUSSIONS

Table. I shows the porosity, pore diameter and thickness values before and after the in-situ firing of the tape cast

Table - II: Gas feed profile

Temperature K	Rate of heating K/minute	Anode gas	Cathode gas
Room Temperature-373	4	Oxidant	Oxidant
373-723	1	Oxidant	Oxidant
723-723	Hold (24 hrs)	Oxidant	Oxidant
723-773	4	Oxidant	Oxidant
773-773	Hold (48 hrs)	Oxidant	Oxidant
773-873	1	Inert	Oxidant
873-923	4	Fuel	Oxidant

Composition (%)

Oxidant:  $\text{CO}_2$ -30,  $\text{O}_2$ -15 and  $\text{N}_2$ -55. Fuel:  $\text{H}_2$ - 60 and  $\text{CO}_2$ - 40. Humidified at 333 K.

Table-III: Electrolyte content

Component	Initial loading (g)	After 100 hrs of test (g)
Anode	2.80	3.14
Cathode	1.62	2.10
Tile	9.35	9.64
Excess	1.23	-
Total	15	14.88

anode, cathode and the matrix tile. From the available results after 100 hours of operation, it was observed that a little increase in median pore size in the range 4.0  $\mu\text{m}$  to 4.6  $\mu\text{m}$ , with a large broadening of the pore size distribution. This may be due to the effect of carbonate melt on the anode structure. In spite of in-situ sintering of the anode material in the reduced atmosphere, no appreciable change in porosity was found after 100 hrs of continuous operation. The observed results confirm the role of lithiated chromium oxide film formed by the reaction of chromium and lithium carbonate (from the electrolyte) with enough small pores, on the anode structure [2].

Identical electrode components and same temperature profile were used for the entire cell test. Different researchers [5-7] have recommended different feed gas profiles. The developed profile under the present investigation is shown in Table-II.

In order to obviate the difference in initial wetting ability of the anode and cathode, the oxidant gas feed was maintained at the anode side till the temperature is raised to 773 K (little above the melting point of the carbonate mixture). The feed gases were switched to simulated MCFC gas feed at 873 K. Results of the post test analysis of the cells after holding the cell temperature at 773 K for about 48 hrs and after 100 hours of continuous test at 923 K is tabulated in Table- III. It would appear from the table that maintaining the oxidant feed gas on both the anode and cathode sides, till the temperature reaches 773 K resulted in effective initial wetting of both the electrodes. The estimated carbonate content in the anode and cathode structure after 100 hrs of continuous test showed little difference in higher percentage of electrolyte uptake than the calculated one. The percentage difference was found to be in the ratio 1:2 respectively. This difference for the cell with other gas feed profile was high and the ratio was found to be 1: 8. From the above results it is clear that the excess electrolyte found in the cathode of the cells tested with conventional gas feed profile was due to the anode structure, which could not wick more

electrolyte, resulted in poor cathode performance. Thus the performance of the MCFC depends on the amount of electrolyte predetermined and loaded for the cell components and wetting characteristics of the anode structure. By following the developed gas feed profile, effective wetting of the anode structure can be achieved.

The open circuit voltage of all test cells with the developed gas feed profile, rose to a normal value of 1.1 V at 923 K without any difficulty. 100% reproducibility of the cell performance was obtained instead of 70% for cells while employing the other feed gas profiles.

### CONCLUSIONS

MCFC containing tape cast components, when operated with the developed feed gas profile exhibited 100% performance reproducibility. The experimental observations shows that the developed profile is efficient than the other profiles and

would be conveniently followed for operating the molten carbonate fuel cells at 923 K.

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