Evaluation of Longer Life for MCFC Using Single-cells

Background

Molten carbonate fuel cell (MCFC) is expected to be used in power generation systems, having high efficiency and lower emissions of NOx and SOx. Thus MCFC is a power generation technology that can apply widely to power generating systems. MCFC, however, needs to have 40,000 hours longevity for commercial power plants, but internal nickel short-circuiting (Ni-shorting) is a barrier to achieving this longevity target. Various strategies are proposed as preventive measures of Ni-shorting, and finally, it is necessary to apply these strategies to small bench-scale single cell examination, and to confirm the availability of preventive measures under actual operating conditions. Another obstacle to long service life is performance decay with operating time. In order to clarify factors related to performance decay, it is necessary to conduct longer time operation tests and performance analysis.

Objective

The objective is to evaluate longer life for MCFC using small single cells by verifying the availability of preventive measures for Ni-shorting, and accumulating prolonged operating data.

Principal Results

1. Acceleration test of Ni shorting

(1) It was verified that the starting time of Ni-shorting became longer by applying the advanced components (1: $MgFe_2O_4$ (Fe/Mg) coated cathode, 2: additives ($BaCO_3$ and $CaCO_3$, Ba/Ca) into electrolyte, 3: electrolyte of 70% Li_2CO_3 and 30% Na_2CO_3 (Li/Na = 70/30%), and 4: α-type $LiAlO_2$ for electrolyte matrix (Table 1).

(2) Based on the assumption of independence of the above effects (1 to 3), the starting time of Ni-shorting with three advanced components simultaneously was estimated at about 36,500 hours and agreed with that time [*1] estimated by the experimental result in FY2002.

(3) It was clear that the acceptable upper Ni deposition limit in a pore of the α-$LiAlO_2$ matrix at the starting time of the Ni shorting increased compared with that of γ-$LiAlO_2$ (Fig.1).

(4) It was clarified that the effects of thickness of electrolyte matrix, cathode partial pressure, and temperature for the starting time of Ni-shorting were estimated in the cells with the α-$LiAlO_2$ matrix (Fig.2).

2. Long-term operation tests for life time

It was clarified that voltage decay depends almost completely on increasing internal resistance, and the resistance increase with time is mainly caused by electrolyte loss in the cell (Fig.3). And the cell voltage estimated by the cell lifetime estimation method developed by CRIEPI agreed with the measured cell voltages [*2]. It was capable of accurately predicting the long-term performance of MCFC (Fig.3).

As a result, we estimated durability for Ni-shoritng over life of 40,000 hours. Consequently, we obtained data from continuous operation of over 37,000 hours, and we verified that MCFC can maintain performance and durability over the long term.

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Reference: "Evaluation on Reliability of MCFC Short-stack - Study on Longevity of MCFC Cells and Short-stacks" NEDO Final Report (FY2003 - FY2004).

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*1 : "Evaluation on Reliability of MCFC Short-stack - Study on Longevity of MCFC Cells and Short-stacks" NEDO Annual Report (FY2002)
*2 : Y. Mugikura, et.al., CRIEPI Technical Report W03029 (2003).

Table 1 Summary of acceleration test results

Forcus	Advanced Components				Estimated starting time of Ni-shorting Pco_2 in ca.0.08MPa Electrolyte thickness:1.3mm
	Electrolyte Li/Na	Ba/Ca Additives (mol%)	Cathode	Electrolyte Matrix	
Base data	60/40	–	Normal	γ-type $LiAlO_2$	14,500hours
Advanced Cathode			Mg/Fecoated		20,300 hours (1.4 times)
Electrolyte composition	70/30	–	Normal		21,500 hours (1.5 times)
Additives into electrolyte		3/3			25,600 hours (1.2 times) Compared above
Matrix material	60/40	–		α-type $LiAlO_2$	16,600 hours (1.2 times)

It was verified that the starting time of Ni-shorting became longer by applying the advanced components (1: Fe/Mg coated cathode, 2: additives ($Ba/CaCO_3$) into electrolyte, 3: electrolyte of Li/Na_2CO_3 = 70/30%, and 4: α-type $LiAlO_2$ for electrolyte matrix.

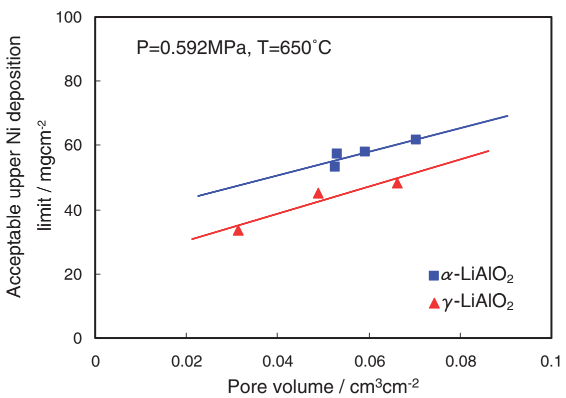

Fig.1 Acceptable upper Ni deposition limit in matrixon pore volume

The acceptable upper Ni deposition limit in a pore of the α-$LiAlO_2$ matrix at the starting time of Ni-shorting increased compared with that of γ-$LiAlO_2$.

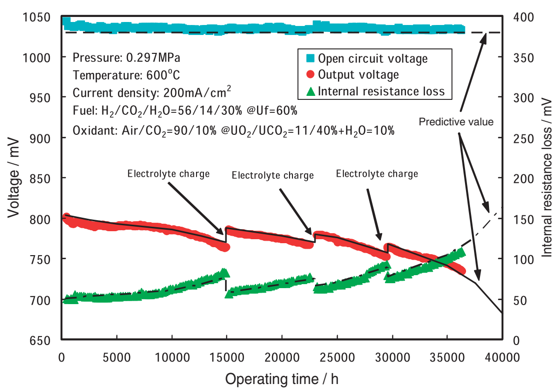

Fig.3 Longest durability test result of a bench-scale cell and predictive value

(1) The voltage decay depends almost completely on increasing internal resistance caused by electrolyte loss in the cell.
(2) It was capable of accurately predicting the long-term performance of MCFC.

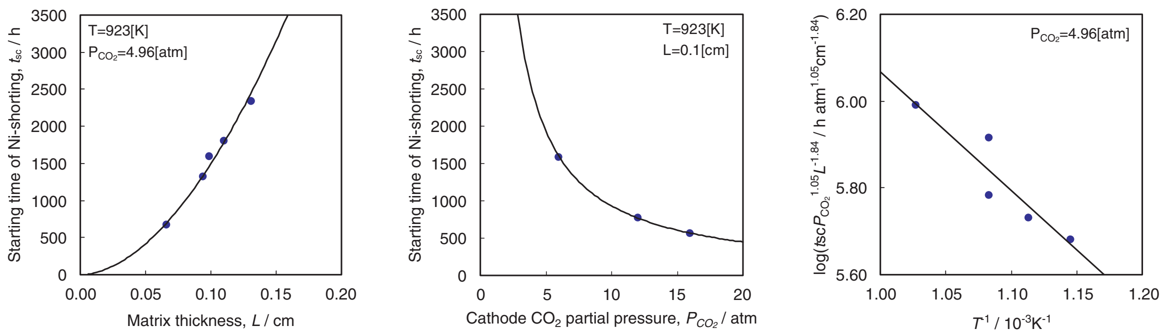

Fig.2 The effect of the matrix thickness, cathode CO_2 partial pressure, and the temperature on Ni shorting time for α-type $LiAlO_2$.

We estimated the effect of the matrix thickness, cathode CO_2 partial pressure, and temperature on the starting time of the Ni shorting for α-type $LiAlO_2$.