Development of Lifetime Estimation Method for MCFC

Background

Cell voltage of molten carbonate fuel cell (MCFC) decreases with operating time since the electrolyte in the cell is consumed by mainly corrosion of cell components. In Japanese project of MCFC development, the target lifetime of MCFC is 40,000 hours. Cell voltage has to be higher than 90% of initial cell voltage after 40,000 hours operation. Five years is required to approve this target. However, if a lifetime estimation method that can predict cell voltage change with time based on initial cell voltage is developed, improvement of material or design for MCFC will be achieved efficiently. The estimation of initial cell voltage can use the reaction resistance model developed by CRIEPI. Reaction resistance model is related to reaction area and physical properties. If dependence of reaction area on operating time is confirmed, cell voltage change with time can be estimated. And Cell voltage after 40,000 hours operation can be estimated by this method

Objective

To estimate cell voltage after 40,000 hours operation, a new equation, which is able to estimate electrolyte content in the cell at a certain operating time, is proposed. The relationship between electrolyte content and reaction area is clarified. Using these results, the lifetime estimation method is developed.

Principal Results

(1) Reaction area seemed to depend on electrolyte content. At first, a method for quantitative estimation of electrolyte content from observed internal resistance (IR) was developed. An equation for calculating electrolyte content with time was derived based on electrolyte loss by the corrosion. Parameters of the equation in Table 1-① were determined using observed IR. Electrolyte content based on IR agrees with the equation as shown in Fig. 1.

(2) A method for determining reaction area from reaction resistance model and observed data which were measured at various conditions such as electrolyte composition and temperature, was developed. Subsequently, the relationship between reaction area and estimated electrolyte content was investigated. Relative reaction area (for example S_{H2}), which is divided by initial reaction area, was proportional to electrolyte content as shown in Fig. 2. As a result, estimation of cell voltage at a certain operating time was achieved.

(3) Cell voltage was estimated based on electrolyte content change with time according to the procedure described in Table 1. Estimated cell voltage agreed with observed voltage within ±5 mV. Cell voltage estimation after 40,000 hours operation was achieved. (Fig. 3a,b).

Future Developments

This method is a strong tool for estimating 40000 hours lifetime of MCFC and will be applied to contract research with NEDO. This method will be improved for application to actual stack in which electrolyte loss behavior is different from that of single cell.

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Reference

Y. Mugikura and H. Morita, 2003, “MCFC Cathode Performance Estimation Method Using Electrolyte Properties Based on Reaction Resistance Model”, The 11th FCDIC Fuel Cell Symposium Proceedings, pp. 133-136, (in Japanese)

Table 1 Lifetime estimation method based on reaction resistance model

①Electrolyte content at certain time (e) (for Li/K cell)	$e = 3.1 - (0.01124t^{0.5} + 0.08233)\exp(\frac{-10170}{1/T - 1/923})$
②Reaction area (S_{H_2}, S_{H_2g})	$S_{H_2} = 0.318e,\ S_{H_2g} = 1.75S_{H_2}$
③Parameters (A_1, A_2)	$A_1 = RT\delta_{H_2}/F^2n^2K_{H_2}D_{H_2}S_{H_2},\ A_2 = R^2T^2/F^2n^2K_{H_2R}S_{H_2g}$
④Reaction resistance (R_a)	$R_a = (A_1 + A_2P^{0.5})P_{H_2}^{-0.5}$
⑤Cell voltage (V)	$V = E - \eta_{NE} - j(R_a - R_c - R_{ir})$

t : Time, T : Temperature, R : Gas constant, K : Henry constant, F : Faraday constant, n : Electron number, P : Pressure, D : Diffusion constant, δ : Diffusion distance, S : Reaction area, E : Open circuit voltage, j : Current density, η_{NE} : Nernst loss, Rc : Cathode reaction resistance, R_{ir} : Internal resistance, g : Gas phase

①Calculation of e, ②Calculation of S from e, ③Calculation of A with S and physical properties, ④Calculation of R from A and P, ⑤Calculation of V from E, η, j and R

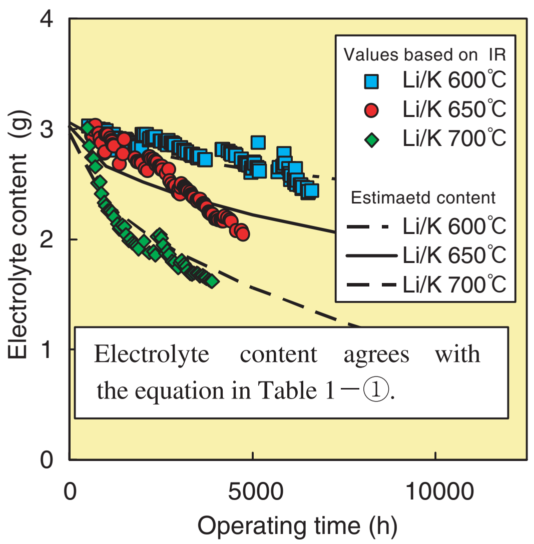

Fig.1 Comparison between measured and estimated electrolyte content.

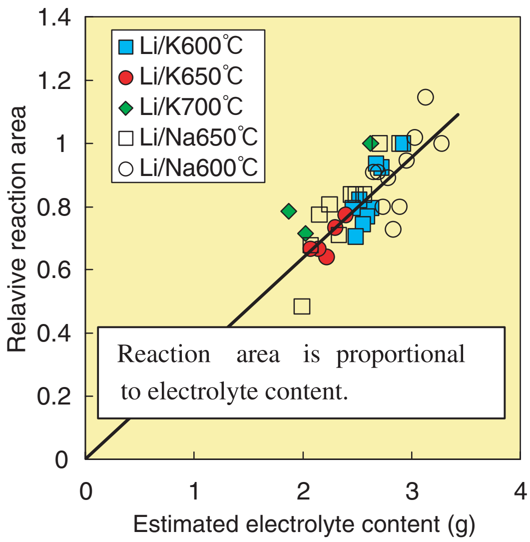

Fig.2 Relationship between electrolyte content and reaction area.

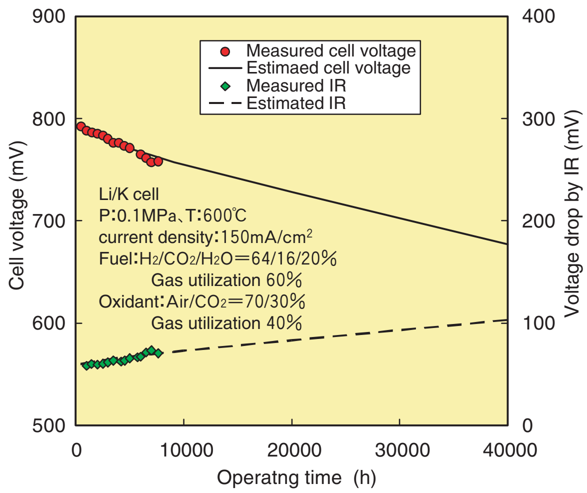

Fig.3-a Result of lifetime estimation for Li/K cell

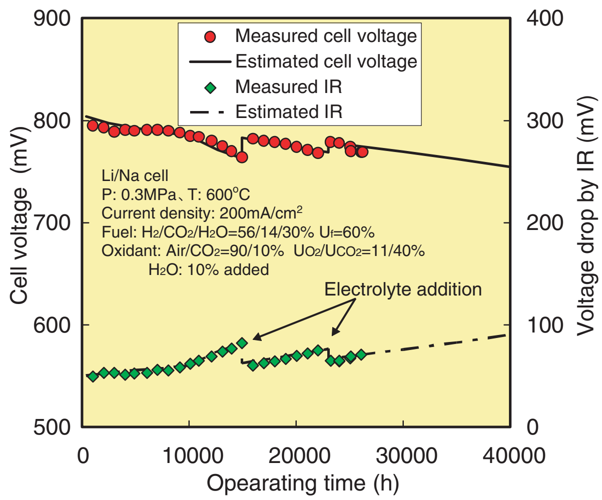

Fig.3-b Result of life time estimation for Li/Na cell

Cell voltage and IR based on Table 1 agree with measured values even if electrolyte composition and temperature are different.