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Power generation characteristics of pulse jet rechargeable direct carbon fuel cells at different isooctane fuel supply frequency

Akinori Yabuki, Fuhito Ohba, Hiroyuki Shimada, Shuhei Sakamoto, Hiroki Tanaka and Manabu Ihara
Department of Chemistry,
Graduate School of Science and Engineering,
Tokyo Institute of Technology
2-12-1 Ookayama, Meguro-ku, Tokyo 152-8552, Japan

INTRODUCTION

Our research group previously proposed a new type of a direct carbon fuel cell (DCFC) called a *rechargeable direct carbon fuel cell* (RDCFC), which uses as fuel the solid-state carbon deposited on the electrode [1~6]. In a typical RDCFC, lower hydrocarbons such as propane are the supplied fuel, and deposition of the solid-state carbon (charging) into the anode is done by pyrolysis. In an RDCFC, this charging method causes several problems, such as low carbon extraction efficiency and batch-type rather than continuous operation. Our research group thus developed a *pulse jet* RDCFC because a constant power density can be maintained by supplying small amounts of high energy density liquid fuel by a pulse jet while generating electricity and continuous power generation by repeating the charging and power generation at short intervals. In addition, in a pulse jet RDCFC, deterioration of anodes due to carbon is minimized by frequent carbon removal and high energy conversion efficiency by utilizing hydrogen, methane, and other hydrocarbons as well as the solid-state carbon generated by the pyrolysis of liquid fuel.

In a pulse jet RDCFC, the frequency at which isooctane fuel is supplied influences the power generation characteristics. When this supply frequency is increased, the power generation characteristics of a pulse jet RDCFC are thought to change to those of a flow-type SOFC. In this study, the effect of a supply frequency of isooctane on power generation characteristics of a pulse jet RDCFC was investigated.

EXPERIMENTAL

The electrolyte of the pulse jet RDCFC studied here was a ScSZ disk (10 mol% Sc_2O_3 -1 mol% CeO_2 -89 mol% ZrO_2, 0.3mm thickness and 20mm diameter), the anode was a Ni / $Gd_{0.33}Ce0_{.67}O_{2-\delta}$ (Ni / GDC) anode, and the cathode was a LSM ($La_{0.8}Sr_{0.2}MnO_3$) / ScSZ composite cathode. First, power generation experiments of the pulse jet RDCFC's cell were conducted to measure the terminal voltage change with current density while supplying hydrogen to the anode at STP 200 ccm and oxygen to the cathode at STP 60ccm at 900 ºC. (Note that RDCFCs have exactly the same design configuration as conventional coin cell-type SOFCs, and thus the RDCFCs can be used as SOFCs.) After removing residual fuel by flowing Ar, the anode side was closed to change the flow-type SOFC to the batch-type SOFC and power generation of the pulse jet RDCFC was evaluated for a supply frequency of one pulse per second at the constant current density of 250 mA/cm^2 at 900 ºC. The pulse jet supply was started with the power generation and stopped after 30 minutes.

RESULTS AND DISCUSSION

Figure 1 shows current density-power density curve of a pulse jet RDCFC cell when the hydrogen flow rate was kept constant. The maximum power density was 150.1 mw/cm^2 at 300 mA/cm^2. Figure 2 shows the terminal voltage as a function of time at a constant current density of 250mA/cm^2 and at isooctane supply frequency of one pulse per second. The power density was ranged from 117.0 to 150.2 mW/cm^2 during supply of isooctane. Figure 2 shows that the terminal voltage was relatively constantly. The power generation characteristics of a pulse jet RDCFC with high isooctane supply frequency was similar to those of a flow-type SOFC. In the case of high isooctane supply frequency, fuel such as hydrogen gas will be consumed preferentially by electrochemical reactions, because the gas fuel seem to have higher reactivity compared to carbon and is plentiful. By reducing the isooctane fuel supply frequency, the deposited carbon could react electrochemically. Therefore, the pulse jet RDCFC can control the electrochemical reactions used for the power generation by adjusting the frequency.

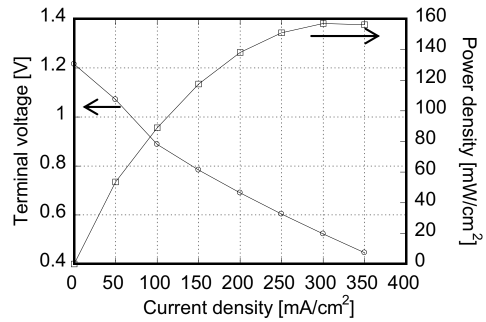

Figure 1 Power generation characteristics of a pulse jet RDCFC with Ni/GDC anode at constant hydrogen fuel supply rate (cathode: pure oxygen at STP 60 ccm, anode: pure hydrogen at STP 200 ccm, power generation temperature: 900 ºC.)

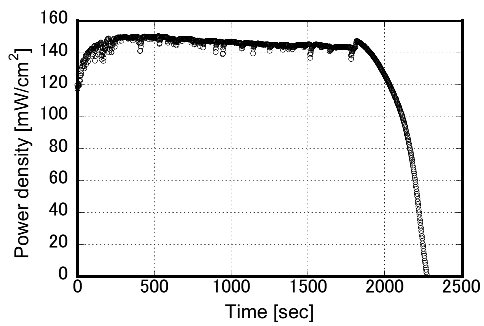

Figure 2 Power generation characteristics of pulse jet RDCFC with Ni/GDC anode with fuel supplied at one pulse per second (cathode: pure oxygen at STP 60 ccm, anode: pure hydrogen at STP 200 ccm, power generation temperature: 900 ºC).

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