Influence of the Thin Anode Geometry on the Performance of Molten Carbonate Fuel Cells

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ABSTRACT

The Ni-Al anodes of the molten carbonate fuel cell (MCFC) with three different structures were successfully fabricated in order to reduce the thickness of the anode down to 0.3 mm; one was the non-supported anode made by a conventional tape casting method, and others were the supported anodes made by lamination or direct casting on the nickel screen. It was seen from the physical analyses and cell operation that the supported thin anodes made by direct casting showed good mechanical strength and cell performance because of a good contact between the anode materials and the support. The single cell using the above anode showed the cell voltage of 0.858 V at the current density of 150mA/cm² with the nitrogen cross-over of only 0.6% at the operation time of 1,000 h, which was similar to the performance of the conventional thick (0.7 mm) anode. The ability to utilize a thin configuration of anode should cut down the amount of nickel alloy and consequently reduce its manufacturing cost.

KEY WORDS: Molten carbonate fuel cell(용융탄산염 연료전지), Ni-Al anode(니켈-알루미늄 연료극), Supported thin anode(지지체가 있는 얇은 연료극), Direct casting(직접 캐스팅), Cell performance(셀 성능)

1. Introduction

The fuel cell system is a device that directly converts chemical energy of a fuel into electrical energy by an electrochemical reaction. Fuel cell technology has advantages of high energy efficiency, low emissions, and multi-fuel feasibilities. In regard to the commercialization of MCFC, it is required a lifetime of 40,000h and a voltage decay rate of less than 10% during this period1,2. Furthermore stack cost down is one of the primary challenges in stack research for many developer besides
scale-up and demonstration. There are many approaches to achieve the cost reduction by using alternative low-cost materials, reducing the quantity of material used, and improving manufacturing methods\(^3,4\). The conventional MCFC anode is a porous nickel alloyed with aluminum or chromium with thickness of around 0.7 mm. The Ni–Cr or Ni–Al alloy anodes show good performance and acceptable strength against sintering and creepage, but the cost is relatively high and developers are investigating alternative materials\(^5\).

As one of the alternative anode material, copper based alloys such as Cu–Al, Cu–Ni–Al, and Cu–Ni–Cr have been evaluated as cheaper anode materials and their electrochemical activities have been found similar to the nickel based anode\(^6\). Copper has high electrical conductivity and chemical stability in eutectic carbonate, but its sintering and creep resistance have not been satisfactory for MCFC anode. Considerable effort has been devoted to develop sulfur-tolerance anode materials because coal-gasifier derived fuels are heavily laden with sulfur compounds including H\(_2\)S, COS, CS\(_2\), etc. If the anode itself had a high tolerance toward sulfur impurities, the sulfur removal process could be scaled down and consequently to reduce the capital costs of the MCFC plant. LiFeO\(_2\) was suggested as sulfur tolerant materials of MCFC anode\(^7\). Yoon and coworkers reported that ceria-coated anode had the ability to suppress the degree of sulfur poisoning due to the ceria reacted with H\(_2\)S to form Ce\(_2\)O\(_2\)S as a sulfur sorbent\(^8\).

Some approaches for reduction of manufacturing cost were concentrated on fabrication of thin anodes\(^9\). The anode hydrogen oxidation exhibits relatively fast reaction kinetics at the MCFC temperature of 650°C compared with the cathode oxygen reduction. Partial flooding of anode with molten carbonate is also acceptable, and this is used to act as a reservoir for carbonate. The major problem of thin anode is mechanical deformation under compressive load in the MCFC operation. Doyon et al. suggested that the lamination technique could fabricate the thin anode with thickness in the range of 0.13 to 0.64 mm, and the laminated thin anode was found to exhibit the good mechanical strength\(^10\). Porous nickel support can provide the thin anode with mechanical strength and gas diffusion path. However the lamination method is a complex technique requiring many steps including tape casting and pressing under pressure of 10 to 20 MPa with porous support materials.

In this study, three types of anode were prepared by different manufacturing methods to reduce the total thickness from conventional 0.7 mm down to around 0.3 mm. The different types of the thin anode architecture were illustrated in Fig. 1. As can be seen in Fig. 1, the anode geometry could be classified according to fabrication process. The non-supported anode is

![Image](a) Non-supported anode by tape casting
(b) Supported anode by lamination
(c) Supported anode by direct casting

Fig. 1 Illustration of the different types of thin anode architecture