Fabrication of Direct-Utilization SOFC from a Single Laminated Structure

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This paper describes the fabrication of mechanically strong, high-performance solid oxide fuel cell (SOFC), able to operate using hydrocarbon fuels. The method uses a single, high-temperature calcination step and involves the synthesis of electrodes by impregnation of the electroactive components into the porous YSZ matrix.

The best SOFC electrodes are composites of an electronically conductive component and an ionic conductor, with the ionic conductor usually being the same material as the electrolyte itself. However, because solid-state reactions can occur between the components of the composite during the sintering process, the choice of materials used in the electrodes are usually a compromise between electrochemical performance and stability. Recent work in our laboratory has demonstrated that it is possible to prepare SOFC anodes and cathodes from a wide range of materials by using low-temperature methods in which the electronically conductive component is added by impregnation with soluble salts to a porous matrix of the electrolyte material [1,2].

In the present study, cells were prepared by laminating multiple green tapes, including layers with pore formers for both the anode and cathode and a layer with holes for providing structural strength. The anode in this study was composed of $Cu_{0.7}Co_{0.3}$, CeO_2, and yttria-stabilized ZrO_2 (YSZ). The cathode was also prepared by impregnation with aqueous salts to a level of 35 wt% Sr-doped $LaCoO_3$ (LSCo). The electrolyte thickness was 25 microns. Cell strength was achieved using a YSZ layer with evenly spaced holes, laminated over the anode layer.

The performance of the $Cu_{0.7}Co_{0.3}$-CeO_2-YSZ|YSZ|LSCo-YSZ cell in H_2 and n-butane is shown in Fig. 1 for 973 and 1073 K. For operation using H_2, the open-circuit voltages (OCV) were close to the theoretical, Nernst potential of 1.1 V. It is also noteworthy that there is no curvature in the V-I curve at the OCV. Curvature in this region of the V-I curve for a SOFC is usually assigned to activation polarization, primarily within the cathode; however, the LSCo-YSZ cathode does not have to be polarized to exhibit high performance. The V-I curves show some curvature at the higher current densities. Maximum power densities of 590 mW/cm2 and 770 mW/cm2 were achieved at 973 K and 1023 K, respectively. For n-butane, the OCV were slightly lower than predicted by the Nernst potentials, ~1.12 V. The maximum power densities were also lower, 290 mW/cm2 at 973 K and 490 mW/cm2 at 1023 K, showing that the chemical oxidation reaction must partially limit performance.

In conclusion, we have demonstrated a new fabrication method for SOFC for direct utilization of hydrocarbon fuels. The method involved lamination of ceramic tapes prepared by tape casting with or without pore formers and a single step firing, followed by impregnation of nitrate solutions. By making composite electrodes in this way, separate calcination temperatures could be used for YSZ and the active electrode components. Utilization of perforated support layers allowed SOFC consisting of thin electrolytes and thin electrodes to be fabricated, providing flexibility in designing cell structure.

Acknowledgements

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References:

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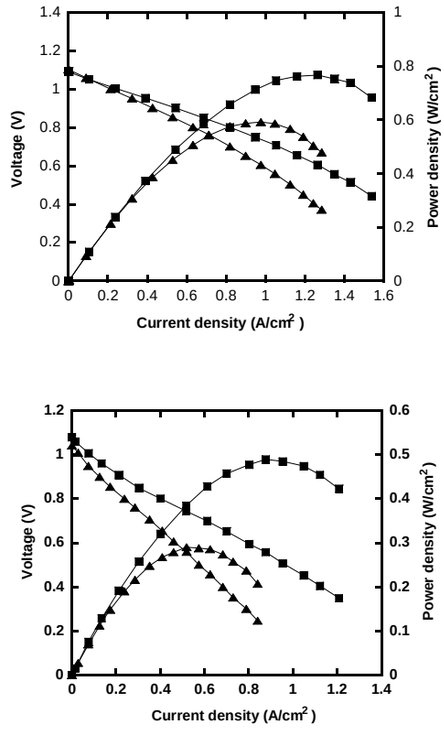

Fig. 1 Cell performance curves at 973 K (▲) and 1023 K (■) in H_2 (top curves) and n-butane (bottom curves).