

Achieving high-performance with SOFC ceramic anodes

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Introduction

Most solid oxide fuel cell (SOFC) anodes consist of a mixture of Ni and an ion-conducting ceramic material, such as yttria-stabilized zirconia (YSZ). Performance with these ceramic-metallic (cermet) composites can be outstanding in H₂ and syngas (a mixture of CO and H₂); however, Ni-cermet suffer from several limitations. Ni-cermet can be severely damaged due to carbon formation in the presence of dry hydrocarbons [1], they are sensitive to the presence of sulfur in the fuel [2], and cannot tolerate being oxidized during start-up and shut-down cycles [3]. The lifting of these limitations could speed the commercialization of this technology.

One class of materials that has been extensively investigated as an alternative to Ni-cermet is conductive ceramics [4]. Ceramic anodes are attractive due to properties such as stability against carbon-fiber formation in dry hydrocarbon fuels, insensitivity to oxidation and reduction cycles, excellent thermal stability, and in some cases sulfur tolerance. Unfortunately, the performance of most ceramic anodes is modest compared to Ni-cermet and must be operated at higher temperatures to produce comparable power densities. For example, most ceramic anodes are operated above 1173 K, whereas good power densities (>500 mW/cm²) are routinely achieved below 973 K with Ni-YSZ cermet.

In this work, we propose an approach in which a ceramic based anode is separated into two distinct layers, a thin functional layer near the electrolyte to perform the electrochemical reaction and a separate conducting layer for current collection. We will demonstrate that excellent performance can be achieved with a Pd-doped ceria in YSZ functional layer and a conduction layer made from LST (La_{0.3}Sr_{0.7}TiO₃). The anode concept is flexible and should allow various materials to be used in the functional and the current-collector layers.

Materials and Methods

The approach for cell fabrication involved synthesis of the electrodes by impregnation of porous YSZ and has been described elsewhere [5, 6]. The dense YSZ electrolyte layer was 75 μm thick, the thickness of the porous YSZ layer for the cathode was 300 μm, and the thickness of the porous YSZ for the anode ranged from 10 μm to 100 μm. The LST current-collecting layer was applied as a glycerol slurry of LST powder and subsequently fired to 1823 K. The cathode side was impregnated to a final loading of 40-wt% LSF (La_{0.8}Sr_{0.2}FeO₃) and the anode side was impregnated with nitrate salts to loadings of 40 wt% ceria and 1 wt% Pd.

Results

Fig. 1a) shows V-i polarization curves that demonstrate reasonable power densities in humidified H₂, 339 mW/cm² at 973 K and 653 mW/cm² at 1073 K, can be achieved at

intermediate temperatures, even using a relatively thick YSZ electrolyte. The impedance spectra in Fig. 1b) indicate that the cell losses are dominated by ohmic losses, which arise primarily from the 75 μm electrolyte. The cells were also tested in humidified CH₄ resulting in power densities approaching those observed with humidified H₂, 208 mW/cm² at 973 K and 539 mW/cm² at 1073 K. Because the concept is flexible, we suggest that high performance can be achieved with other materials providing the catalytic activity and conductivity.

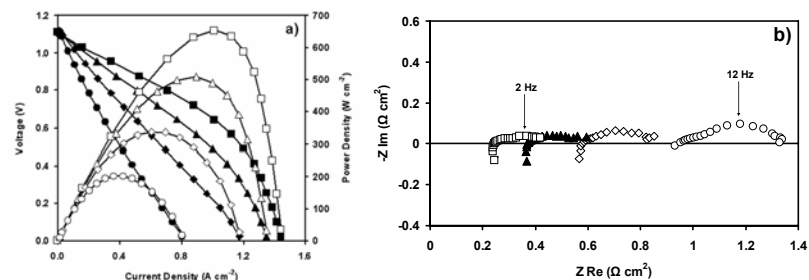


Figure 1. (a) V-i polarization curves and (b) impedance spectra on a 12 μm Ce-Pd-YSZ anode with a LST current collector in humidified H₂ (3% H₂O). Data are shown for the following temperatures: circles, 923 K; diamonds, 973 K; triangles, 1023 K; squares, 1073 K.

References

1. S. McIntosh and R. J. Gorte, *Chem. Rev.*, **104**, 4845 (2004).
2. Y. Matsuzaki and I. Yasuda, *Solid State Ionics*, **132**, 261 (2000).
3. G. Rietveld, P. Nammensma, and J. P. Ouweltjes, in *Solid Oxide Fuel Cells VII (SOFC-VII)*, H. Yokokawa and S. C. Singhal, Editors, PV 2001-16, p. 125, The Electrochemical Society Proceedings Series, Pennington, NJ (2001).
4. S. Tao, and J. T. S. Irvine, *Chem. Rec.*, **4**, 83 (2004).
5. R. J. Gorte, S. Park, J. M. Vohs, and C. H. Wang, *Adv. Mater.*, **12**, 1465 (2000).
6. S. Park, R. J. Gorte, and J. M. Vohs, *J. Electrochem. Soc.*, **148**, A443 (2001).