Solid Oxide Fuel Cells based on Metal Electrodes

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Introduction

Solid oxide fuel cells offer an attractive means of energy conversion due to the high fuel efficiency and low pollutant emissions possible with this technology. However, commercial introduction of these systems has been delayed due to the high cost ($/kW) relative to entrenched power generation technologies. Accordingly, many developers are pursuing various cost reduction strategies to bring the system cost down into the realm of commercial viability. These include of reduction of system operating temperature, simplification of stack design, lower cost power electronics, and increased system integration. The work within our group is largely focussed on strategies to increase stack reliability and reduce cost through the use of metal-based electrodes.

The U.S Department of Energy's Solid State Energy Conversion Alliance (SECA) has targeted a cost of $400/kW for SOFC power generating systems. This system cost is considered to be competitive with existing power generation technologies. Since the fuel cell stack is only one component of the SOFC system, the SECA cost goal dictates stack costs that at a fraction of that value. Shown in Figure 1 is are calculated values for allowable stack costs given system target of $400/kW; at reasonable power densities the SOFC stack cost must be on the order of 5¢/cm^2. Such aggressive cost targets precludes the use of exotic raw materials, costly seals, and/or complex cell processing or stack fabrication.

Discussion

Among the strategies for SOFC cost reduction is the lowering of cell operating temperature through the use of a thin electrolyte membrane supported on a porous electrode support. Typically a YSZ membrane is co-fired onto a Ni-YSZ support, and the air electrode is deposited in a later step. The use of Ni-YSZ as the structural support has a number of drawbacks including the high cost of thick Ni-YSZ electrodes, and the need to maintain a reducing atmosphere on stack cool-down to avoid oxidation of the Ni to NiO. This can be remedied somewhat by co-firing of the YSZ membrane onto the LSM air electrode, however, for the case of a tubular geometry the power density suffers from the low electronic conductivity of the LSM tube. The LBNL group is developing a novel SOFC structure based on the co-firing of a thin ceramic electrolyte film on a porous metal alloy support. Ideally, the metal alloy support is based on commercially available alloy in order to keep cost to a minimum. This concept is outlined schematically in Figure 2.

Suitable alloys for metal supported SOFCs include those compositions that form highly adherent, electronically conductive scales in oxidizing environments, identical requirements to those for metal interconnects. The co-firing of the metal support/ceramic film structure is accomplished in reducing atmospheres as is commonly done for sintering porous metal structures. The thermal expansion coefficients of the metal support and ceramic electrolyte film can be matched through appropriate choice of the alloy composition and/or by including a ceramic phase in the support. Fabrication of a variety of metal-supported thin-film ceramic SOFCs is currently underway at LBNL. Shown in Figure 3 is a YSZ membrane co-fired on a Inconel/YSZ support. The electrolyte membrane is dense and 15 μm in thickness. Preliminary electrochemical tests of such structures have shown good performance. This approach may also be beneficial for alternative ceramic membrane applications including electrolytic oxygen separation, oxygen permeation, and syn-gas production.

Acknowledgment

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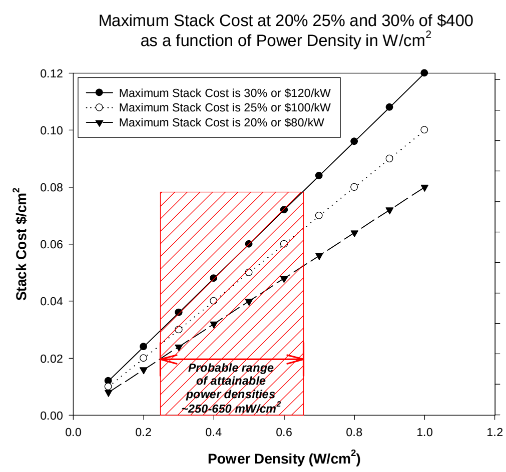

Figure 1. Allowable SOFC stack costs.

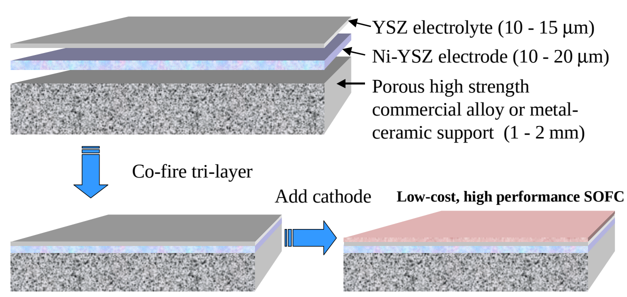

Figure 2. Metal supported thin-film SOFC

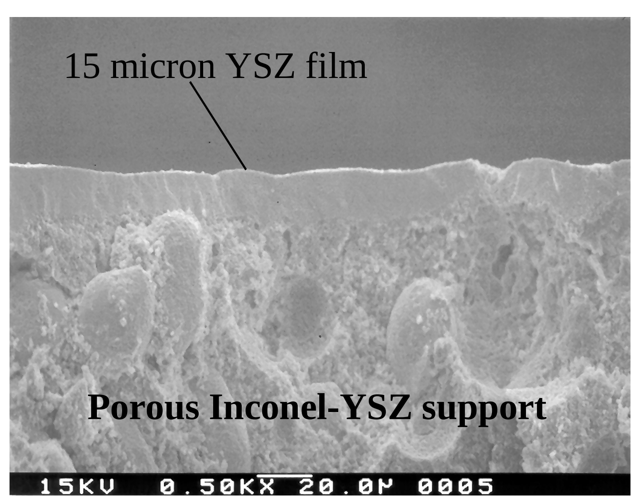

Figure 3. Thin YSZ electrolyte co-fired onto Inconel/YSZ support.