Nanoscale Effects in Solid Oxide Fuel Cells

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ABSTRACT

Solid oxide fuel cell (SOFC) is an electrochemical device, based on an oxide ion conducting electrolyte, which converts chemical energy of a fuel (such as hydrogen or a hydrocarbon) into electricity at temperatures from about 550 to 1000°C. SOFC offers certain advantages over lower temperature fuel cells, notably its ability to use CO as fuel rather than being poisoned by it, and high grade exhaust heat for combined heat and power, or for combined cycle gas turbine applications. Siemens has successfully operated a 100 kW combined heat and power system for more than 30,000 hours with a voltage degradation of less than 0.1% per 1000 hours; in addition, individual cells have been tested for over 8 years with ability to withstand >100 thermal cycles.

The most important need to commercialize this technology is to significantly reduce the overall cost of SOFC-based power systems. Reduction of operation temperature enables use of low-cost metallic interconnects and a decrease in maintenance costs. However, at lower temperatures, greater ohmic loss due to a reduction in ionic conductivity (σ_i) in the electrolyte and reduced catalytic activity of electrodes results in lower cell performance. To improve cell performance at lower temperatures, employing nanoscale materials for the electrolyte and the electrodes has recently been considered. In this presentation, ionic transport in nanocrystalline electrolytes, with an emphasis on distinguishing intrinsic and extrinsic effects, is discussed with the use of space charge model, which predicts an enhanced conductivity. Maier and his colleagues[(1)] have provided experimental evidences, showing an increased σ_i of more than an order magnitude in nanoscale specimens by restructuring simple ionic crystals; in a typical electrolyte material, such as yttria stabilized zirconia (YSZ), enhanced oxygen diffusivity was observed in the interfaces of nanocrystalline YSZ; σ_i, therefore, is expected to increase based on Nernst-Einstein relationship. There exist, however, conflicting results with respect to whether or not σ_i increases in nanocrystalline YSZ films.

The size effect in Ni- based anode has been under scrutiny for a number of years because of other related research such as methane reforming. The size effect in the cathode and the seals is less well known and will also be discussed in this presentation, with an emphasis on the understanding of nano/microstructure-cathodic property relation. A crucial question that remains to be answered is whether the beneficial effect of employing nanoscale materials will persist even after long term cell operation at high temperatures, even though the initial performance may have indicated substantial enhancement.

[(1)] N. Sata, K. Eberman, K. Eberl, and J. Maier, *Nature*, **408**, 946-949 (2000).