Influence of Gd and Sm Doping on Atomic and Ionic Transport Properties of Novel Nanostructured Ceria-Zirconia Multilayers

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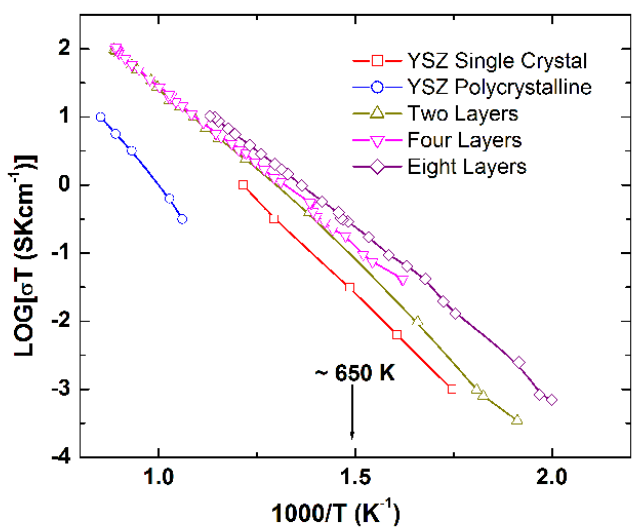
◆ Developing novel materials with enhanced ionic and atomic properties that function well at low temperatures is crucial for designing materials that can be used for fuel cells, catalysis (oxygen pumps), and sensor applications. Nanoscale oxide materials represent a class of promising materials that exhibit novel chemical, optical, electronic, and magnetic properties. ◆

This research will provide a fundamental scientific understanding of the nanoscale ionic and atomic transport phenomena in multilayer, oxide nanostructures. Nanoscale materials often display properties very different from the base coarse-grained bulk materials because of the size and quantum confinement effects; as a result, these materials have the potential to significantly improve the performance and durability of materials in several areas of national importance including environmental cleanup, energy production, and homeland security. In particular, nanostructured oxide electrolytes play a major role in fuel cell applications for clean energy production, especially at lower temperatures.

The goal of this project is to understand ionic transport processes in nanostructured oxide materials that may enable the synthesis of new types of electrolytes with enhanced ionic conductivity at low temperatures for electrochemical device applications. Increased ionic transport at low temperatures allows the use of a wide range of lower-cost materials for electrochemical devices such as solid oxide fuel cells. Atomic and ionic transport, which is crucial for many technological applications including catalysis and fuel cell technology, is also expected to be enhanced in nanostructured materials due to effects related to size, electronic structure, space charge, and multiple interface pathways.

We explored a novel approach to increase the ionic conductivity of gadolinia-doped high-quality ceria/zirconia multilayered structures by artificially introducing nanoscale interfaces that are parallel to the desired direction of high conductivity. Recently, such interfaces were discovered to dramatically increase the ion transport properties in the oxides due to the so-called redistribution of ions in the space-charge regions. We are gaining new insights into this phenomenon and the role of electronic structure in the enhanced transport properties as well as the process of nanoscale ion transport.

In FY 2003, the focus was on the growth and characterization of high-quality gadolinia-doped ceria/zirconia multilayer films. Oxygen ionic conductivity results from two-, four-, and eight-layer Gd_2O_3-doped ceria-zirconia are presented in the figure. For comparison, the oxygen ionic conductivity data from the polycrystalline and the single-crystal yttria-stabilized zirconia are also shown. In general, the high-quality films show significantly higher conductivity compared to the bulk polycrystalline yttria-stabilized zirconia. In addition, at low temperatures the eight-layered film shows higher oxygen ionic conductivity compared to the four- and two-layered film. Detailed experimental and modeling investigations are currently under way to understand the influence of multiple interfaces on oxygen ionic conductivity.



Arrhenius plots of oxygen ionic conductivity of eight, four, and two layers of gadolinia-doped ceria-zirconia multilayer thin films. The data from polycrystalline and single-crystal 8 mol% yttria-stabilized zirconia also are shown.