College of Engineering
Department of
Mechanical & Industrial Engineering

The Robert W. Courter Seminar Series

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1263 Patrick F Taylor Hall

Solid Oxide Fuel Cells
For Clean and Efficient Power Generation

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Solid oxide fuel cells (SOFCs) electrochemically convert chemical energy of a fuel (such as natural gas) into electricity at temperatures from about 550 to 1000^{0}C. These cells, based on an oxide ion conducting electrolyte such as stabilized-zirconia, offer a clean, low-pollution technology to generate electricity at high efficiencies. The most important need to commercialize SOFC technology on a mass scale is to significantly reduce the overall cost of SOFC-based power systems, while maintaining adequate performance and performance stability with time. Reduction of cell operation temperature enables use of low-cost metallic interconnects and a decrease in maintenance costs. However, at lower temperatures, greater ohmic loss due to reduced ionic conductivity of the electrolyte and reduced catalytic activity of the electrodes result in lower cell performance. To improve cell performance at lower temperatures, employing advanced materials, including nanomaterials and nanostructures with improved ionic conductivity for the electrolyte and mixed ionic-electronic conductivity for the electrodes, has been investigated. However, 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. This overview focuses on the designs, materials, processing, and performance of solid oxide fuel cells including the possible use of nano-grained and nano-porous materials for the electrolyte and the electrodes, respectively. Recent progress in the deployment of power generation systems built with various design solid oxide fuel cells and their operating experiences, as well as challenges in reducing cell and system costs, are summarized and discussed. SOFCs can also be operated in reverse operating mode for hydrogen and syngas production through electrolysis of steam and mixtures of steam and carbon dioxide; interest in solid oxide electrolysis has greatly increased during the last decade. Application of solid oxide cells for electrolysis is also discussed in this overview.

* Dr. Singhal worked as a Battelle Fellow and Director, Fuel Cells at PNNL from 2000 to 2013 and provided senior technical, managerial, and commercialization leadership to the laboratory's extensive fuel cell and clean energy programs. Before that, he worked for over 29 years, initially as a scientist and later as Manager-Fuel Cell Technology at the Westinghouse Electric Corporation. He has authored 100 scientific publications, edited 17 books, received 13 patents, and given over 350 plenary, keynote and other invited presentations worldwide. Dr. Singhal has served as an Adjunct Professor in the Department of Materials Science and Engineering at the University of Utah, and a Visiting Professor at the China University of Mining and Technology-Beijing (under the China's 1000 Talent Program) and the Kyushu University-Japan. Dr. Singhal is a member of the U.S. National Academy of Engineering; a founding member and Past President of the Washington State Academy of Sciences; a Fellow of four professional societies (American Ceramic Society, The Electrochemical Society, ASM International, and American Association for the Advancement of Science); and a senior member of the Mineral, Metals & Materials Society (TMS).