Hot Materials, Hotter Impact

by Eric Wuchina and Eric Wachsman

The interdisciplinary nature of ECS is uniquely reflected within the High Temperature Materials (HTM) Division. Here, scientists and engineers are concerned with the chemical and physical characterization of materials, the kinetics of reactions, the thermodynamic properties and phase equilibria of systems, the development of new processing methods, and ultimately, the use of materials in advanced technology applications at high temperatures. High temperature materials provide the basis for a wide variety of technology areas, including energy, electronic, photonic, chemical, and structural applications. While some applications involve the use of these materials at high temperatures, others require materials processed at high temperatures for use at room temperature. The value of a cross-cutting technology such as high temperature materials to a wide variety of technical arenas is reflected by the number of science and engineering disciplines involved in the study of processing and properties of these materials, including: ceramic science, chemistry, chemical engineering, electrical engineering, mechanical engineering, metallurgy, and physics. The diversity of research and development ranges from experimental observations to predicting behavior, from scientific principles to engineering design, and from atomic scale models to performance while in use.

The focus of the HTM Division has expanded significantly from its origins in 1921 in high temperature materials chemistry and corrosion to encompass high temperature electrochemical systems such as solid oxide fuel cells, ionic membranes, sensors, and the science and technology of chemical vapor deposition and related processes. The mission of the HTM Division is to stimulate education, research, publication, and exchange of information related to both the science and technology of high temperature materials, which include ceramics, metals, alloys, and composites. While seeking to fulfill its mission, a continuing goal of the Division is to help ensure the development of new materials and processes to overcome the limitations that currently hold back advances in technology.

In this issue, we highlight three areas of interest to the membership: ultra-high-temperature ceramics, solid oxide fuel cells, and other solid-state ionic devices. For extreme environment applications (T > 2000°C in oxidizing atmospheres), the limitations of current ceramic materials for hypersonic leading edge and engine applications has led to a renewed interest in ultra-high temperature ceramics with melting temperatures over 3000°C and the ability to retain structural integrity at temperatures over 2000°C in oxygen-containing environments. A brief description of research activities in this arena will provide the readers with some ideas of the challenges faced by the community and advances made.

Solid oxide fuel cells are becoming an increasingly important technology in the U.S. and abroad. The need for clean, efficient, and silent stationary power generation with the capability to reach remote locations is obvious, and the use of SOFCs for residential and automotive applications continue to expand; the need for new materials, fabrication processes, and design and testing of cell and stack components is reflected in the increased attendance in the ECS SOFC symposia, with the most recent SOFC X generating over 300 papers and 570 attendees.

Solid-state ionic devices are critical components of advanced technology, from batteries and fuel cells to membranes and sensors for automotive and chemical applications, and are thus not only a major focus of the HTM Division, but most of the other Divisions in the Society as well. The development of these devices hinges on an understanding of the basic science and mechanisms of ion transport through solids, interfacial phenomena, developing, along the way, new materials to improve performance, and optimize device design.

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Related High Temperature Materials Division Symposia

International Symposium on Solid State Ionic Devices—Solid state electrochemical devices, such as batteries, fuel cells, membranes, and sensors, are becoming more and more important for our technologically driven lifestyles. The development of these devices involves common research themes such as ion transport, interfacial phenomena, and device design and performance. The intent of this symposium is to bring together researchers in all fields of solid state ionics. This continuing symposium is a forum for current advances in solid state ion conducting materials, regardless of the class of materials or whether the solid state is amorphous or crystalline, and the design, fabrication, and performance of devices that utilize them.

Topics covered include modeling and characterization of defect equilibria, ionic and electronic transport, interfacial and electrocatalytic properties of ion conducting ceramics, novel synthesis and processing of thin films, membranes, and nanostructured materials or devices; the effect of nanostructures on ionic transport and catalytic activity; electrode kinetics, interfacial phenomena, and electrode microstructure pertaining to chemical sensors, fuel cells, gas separation membranes and reactors, solid-state battery and microbattery electrodes.

The lead symposium organizer is E. D. Wachsman, University of Florida (e-mail: ewach@mail.mse.ufl.edu). The next symposium in this series (SSID-VI) will be held at PRiME 2008 (a joint international meeting of ECS and the Electrochemical Society of Japan) in Honolulu, HI, October 12-17, 2008.

International Symposium on Solid Oxide Fuel Cells (SOFCs)—This continuing symposium series provides an international forum for the presentation and discussion of developments related to solid oxide fuel cells based on zirconia or other oxide electrolytes. Topics addressed include materials for cell components. (e.g., electrolyte, electrodes, and interconnection); fabrication methods for complete cells and components; cell design, electrochemical performance and modeling; stacks and systems for residential and automotive applications; and field tests of SOFC demonstration systems.

This symposium started in 1989 at the ECS fall meeting in Hollywood, Florida and has since become the leading symposium in the field of solid oxide fuel cells. The symposium is held every two years, rotated among USA, Europe, and Japan, and co-sponsored by the SOFC Society of Japan.

The lead symposium organizer is S. C. Singhal, Pacific Northwest National Laboratory (e-mail: singhal@pnl.gov). The next symposium in this series (SOFC-XI) will be held at the 216th ECS Meeting in Vienna, Austria, October 4-9, 2009.

International Symposium on Ionic and Mixed Conducting Ceramics—This continuing symposium series made its debut at the ECS fall 1991 meeting in Phoenix and has provided a rich forum for the international research community to share and discuss the forefront activities that are ongoing in the exciting field of ionic and mixed conducting ceramics. Some of the specific themes include ionic transport in solid electrolytes, mixed conduction in ceramics, thermo- and chemo-mechanical properties of mixed conductors, hydrocarbon conversion by ceramic electrochemistry, electrocatalytic phenomena, electrode reactions involving ceramic cells, ceramics-based fuel cells and batteries, and thin film ceramic membranes.

The lead symposium organizer is M. Mogensen (e-mail: mogens.mogensen@risoe.dk). The next symposium in this series (IMCC VI) returns to its origin and will be held at the 213th ECS Meeting in Phoenix, AZ, May 18-23, 2008.