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ScienceDirect
Journal of the European Ceramic Society 30 (2010) 2145–2146
www.elsevier.com/locate/jeurceramsoc

Guest Editorial

The manuscripts in this issue are based on presentations at the Workshop on Aerospace Materials for Extreme Environments that was held August 3–5, 2009 in St. Louis, Missouri, United States. This was the third in a series of workshops sponsored by the United States Air Force Office of Scientific Research.[1] The purpose of the workshop was to discuss the current status and latest technical progress of fundamental research on ultra-high temperature materials. The workshop featured invited speakers from academia, industry, and government laboratories from around the world. The agenda included 28 presentations and 23 posters that were focused on the basic science of processing, microstructure development, properties, and modeling of ultra-high temperature materials.

Ultra-high temperature materials have been categorized based on wide-ranging criteria such as melting temperature (>∼3000 °C), upper temperature limit for continuous use (>1600 °C), or chemical family (refractory transition metals, carbon, plus carbides, borides, and nitrides of early transition metals). To be included in this workshop, materials had to be potential candidates for transition into future hypersonic air or space vehicles. Some of the likely applications for these ultra-high temperature materials include leading edges, acreage thermal protection systems, scramjet flow-path components, and rocket propulsion components.

Historically, ultra-high temperature materials were investigated in the U.S.S.R. and the U.S. from the late 1950s through the early 1970s as part of the original space race. Fundamental research on ultra-high temperature materials was largely dormant until a recent resurgence that began in the late 1990s. Since that time, research groups have been established in Italy, China, Ukraine, the U.S., and other countries. As an indication of the increase in the level of research worldwide, data available on Scopus indicates that publications on the topic of "ultra-high temperature ceramics" increased from ∼5 in 2000 to 74 in 2008 while published papers on the compound zirconium diboride increased from ∼80 in 2000 to more than 200 in 2008.

The Workshop on Aerospace Materials for Extreme Environments included sessions on "Mechanical and Physical Properties," "Processing, Synthesis and Structure," and "Oxidation and Environmental Response." Some of the significant accomplishments that are reported in the manuscripts in this issue include in situ measurement of mechanical properties at temperatures above 2000 °C, a crystal chemical approach to synthesis of ultra-refractory ternary carbides, and diagnostics for material behavior in plasma environments similar to those encountered in hypersonic flight and/or atmospheric re-entry. Taken together, the manuscripts and presentations point to the tremendous challenge associated with modeling, predicting, and controlling the behavior of structures with complex, hierarchical, and/or engineered architectures that are composed of materials with dissimilar physical and chemical properties.

Despite the significant progress reported in the manuscripts in this issue, discussions at the workshop pointed to several outstanding areas where additional research efforts are needed. In particular, research is needed to understand coupled thermal and mechanical behavior including the development of methods to monitor and predict highly correlated properties in extreme environments. Novel compositions and chemistries are also relatively underreported and new compositions with microstructures tailored for improved elevated temperature strength and creep resistance in addition to improved resistance to oxidation would greatly enhance future capabilities. Hopefully, future workshops will report on progress made in these and other areas.

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[1] Manuscripts from the other two workshops were published in the Journal of Materials Science, 39(19), October 2004 and the Journal of the American Ceramic Society, 91(5), May 2008.

doi:10.1016/j.jeurceramsoc.2009.11.009

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Available online 16 December 2009