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Preface

Space nuclear reactors provide a uniquely harsh environment that places a high demand on system components. Space reactors must be designed to provide continuous or on-demand power with extremely high reliability and no possibility of repair or replacement. Reactor systems of interest include those proposed for use in nuclear electric propulsion, nuclear thermal propulsion, spacecraft power, and non-terrestrial surface power applications. This symposium was the first recent meeting dedicated solely to fuels and materials for space nuclear reactor systems. The papers included in the symposium had a strong technical focus and were primarily concerned with the fabrication or performance of fuels and materials proposed for use in space nuclear reactor systems. Fuel systems of interest included familiar fuels such as UO_2, cermet fuels, and nitride fuels. Materials of interest included primarily those proposed for core structural applications including fuel cladding, core internals, and reactor vessels. Because of the high operating temperatures expected in a space reactor, refractory alloys and other refractory materials are of particular interest for these systems. Performance issues addressed during the symposium included the behavior of these materials in a neutron flux, limiting material properties, and welding/joining.

The papers presented at the Space Reactor Fuels and Materials symposium represent the state of fuels and materials development and performance prediction as of 2006. Unfortunately, the principal project providing funding for research and development on space reactor technology was cancelled shortly before the symposium was held. The National Aeronautics and Space Administration (NASA) program to develop a space nuclear reactor for deep-space unmanned exploration, known as Project Prometheus (and in its earlier incarnation as the Jupiter Icy Moons Orbiter) was cancelled in late 2005 and most of the work funded by the program was finished during 2006. However, publication of work performed as part of this effort will benefit future researchers just as the present authors drew on earlier work from the SP-100, TOPAZ, and nuclear rocket programs as a starting point. Development of space nuclear reactor systems for power and/or propulsion is inevitable for any deep-space unmanned exploration that requires more than a few hundred Watts to power science payloads, or for rapid transits to Mars or the outer planets via direct nuclear thrust. Another possible application that is already being considered by NASA and others is surface power sources for manned outposts on the Moon or Mars. Programmatic priorities change over time, and when space nuclear reactors are once again considered for development, the issues addressed in these papers will be just as relevant as they were during Project Prometheus.

The papers are organized into three sections. The first addresses space reactor fuels, the second focuses on environmental effects such as thermal exposure and neutron irradiation on refractory alloys of interest for space reactor structural applications, and the third deals with practical issues of alloying and welding refractory alloys.

In the fuels section, the first paper by Higgs et al. explores the use of *in situ* neutron diffraction to investigate the evolution of the phase composition of oxide fuels. Oxides are the dominant fuel form for terrestrial reactors, and it makes sense that early space reactors would utilize this experience to reduce uncertainty. Understanding the thermodynamic behavior of the fuel and being able to predict reliably the composition of the fuel over time, particularly at high burnup, is necessary to evaluate the performance of a fuel for a demanding

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application such as space reactors in which removal of failed fuel is not possible. As Higgs et al. point out, their approach could also be used to investigate carbide or nitride fuels such as those described by Wheeler et al. in the second paper. Wheeler et al. focus on developing a fabrication process for producing ZrN as a surrogate for actinide nitride fuels. Uranium nitride was the fuel form selected for the SP-100 reactor that was under development during the late 1980s and early 1990s and is very attractive due to its high uranium density and high thermal conductivity. In the third paper by Haertling and Hanrahan, the authors examine the available thermal exposure and irradiation experience for refractory cermet fuels. Fuels of this type have been proposed for numerous space reactor systems, particularly those associated with nuclear propulsion. Much of the work described by Haertling and Hanrahan has not previously been available in the open literature, and their review will be very valuable to those interested in cermet fuels for future space reactor concepts.

In the section on environmental effects, the first paper by Leonard et al. provides an overview of thermal aging effects in a variety of refractory alloys. Because of their favorable high temperature properties and compatibility with molten metals, materials of this type have been considered in many space reactor systems from the nuclear rocket programs of the 1950s to the thermionic TOPAZ reactor and SP-100 of the 1980s and 1990s. While potentially attractive for use as fuel cladding, refractory alloys have also been proposed for use in heat exchangers, rocket nozzles, and fuel matrices. The second and third papers by Leonard et al. provide more detail on the thermal aging behavior of three alloys addressed briefly in the first paper, namely T-111, Mo–41Re, and Mo–47.5Re. Finally, in the fourth paper, Busby et al. address the low-fluence radiation response of Mo–41Re and Mo–47.5Re at space reactor relevant temperatures, including an assessment of the effects of radiation-induced segregation and transmutation. These issues are important for any structural material that will experience long service lifetimes and/or high fast neutron fluence.

In the section on refractory alloy development and welding, the first paper by Sakidja and Perepezko describes the synthesis and microstructural characterization of novel Mo–Si–B alloys designed to perform at high temperature while providing lower density than more traditional Mo-base alloys. Reducing mass is always a goal for any spacecraft, and space nuclear reactors are no exception. In the final paper, Xu et al. describe the development of a resistance spot welding technique for Mo–47.5Re. Joining is a critical feature of any space reactor design, and one that is sometimes overlooked. However, it is a subject that deserves some consideration before alloy selections are made, particularly for materials such as refractory alloys.

David Senor
Pacific Northwest National Laboratory,
902 Battelle Boulevard,
Richland, WA 99352, USA
E-mail address: david.senor@pnl.gov