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FOREWORD

This is the fifty-second in a series of semiannual technical progress reports on fusion materials science activity supported by the Fusion Energy Sciences Program of the U.S. Department of Energy. It covers the period ending June 30, 2012. This report focuses on research addressing the effects on materials properties and performance of exposure to the neutronic, thermal and chemical environments anticipated in the chambers of fusion experiments and energy systems. This research is a major element of the national effort to establish the materials knowledge base for an economically and environmentally attractive fusion energy source. Research activities on issues related to the interaction of materials with plasmas are reported separately.

The results reported are the products of a national effort involving a number of national laboratories and universities. A large fraction of this work, particularly in relation to fission reactor irradiations, is carried out collaboratively with partners in Japan, Russia, and the European Union. The purpose of this series of reports is to provide a working technical record for the use of program participants, and to provide a means of communicating the efforts of fusion materials scientists to the broader fusion community, both nationally and worldwide.

This report has been compiled under the guidance of F. W. (Bill) Wiffen and Betty Waddell, Oak Ridge National Laboratory. Their efforts, and the efforts of the many persons who made technical contributions, are gratefully acknowledged.

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The high-heat flux testing facility using Plasma Arc Lamps was demonstrated at ORNL for W samples. The test sections were designed by taking into account safety and materials compatibility requirements in order to handle the testing of low level irradiated tungsten articles. An enclosure was designed and fabricated. Test sections for the high-heat flux testing using PAL of low-level radioactive sample were designed and fabricated. The test sections were assembled and proof-of-principle testing was conducted, demonstrating the readiness of the new facility for irradiated samples.

Density functional theory was employed to investigate grain boundary (GB) properties of W alloys. A range of substitutional solutes across the Periodic Table was investigated to understand the behavior of different electronic orbitals in changing the GB cleavage energy in the Σ27a[110]{525} GB. A number of transition metals were predicted to enhance the GB cohesion. This includes Ru, Re, Os, Ir, V, Cr, Mn, Fe, Co, Ti, Hf, Ta and Nb. While lanthanides, *s* and *p* elements were tended to cause GB embrittlement.

There are many claims in the literature regarding various approaches to *"ductilizing"* W that are difficult to assess, in part because different tests have been used to *"characterize"* the various alloys. Thus one objective of this work is to demonstrate the application of accepted fracture mechanics test methods, so as to provide a common toughness-based metric for comparing different W alloys and composites. A major challenge to testing monolithic W is pre-cracking a very brittle material. A variety of approaches to pre-cracking an elemental W plate were attempted. The most successful method was compression fatigue applied in the axial direction of a small, initially notched bend bar, with the crack in the (T-L) orientation. The linear elastic toughness was measured in 3-point bend tests and averaged K_{Ic} = 8.34±0.43 MPa√m.

A second testing challenge is associated with ductile phase toughened composites. In this case it is necessary to measure the toughness resistance curve associated with extensive stable crack growth. The resistance curve is expressed in terms of J_r/K_r-da curves. Ductile phase toughening (DPT) is largely due to the formation an intact bridging zone behind the tip of crack, which results in a increase in the remote load stress intensity needed for continued crack growth with increasing crack length, da. The main challenge in this case was measuring da as a function of the load (P) and load point displacement (d). We successfully characterized a K_r-da curve for a W-25%Cu heavy metal composite by

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