TABLE OF CONTENTS

1.0 VANADIUM ALLOYS *1*

1.1 OPERATION OF A V-4CR-4TI THERMAL CONVECTION LOOP WITH Li AT 700°C—ORNL Loop Team: B. A. Pint, S. J. Pawel, M. Howell, J. L. Moser, G. Garner, M. Santella, P. F. Tortorelli, and J. R. DiStefano (Oak Ridge National Laboratory) **2**

The loop experiment ran for 2,355h from March to June 2007 with a maximum temperature of 700°±10°Cand was stopped due to an unplanned power outage. After initial heating, the vacuum system ran at<1x10-5Pa, well below the level where significant oxidation of V-4Cr-4Ti is expected. Temperature control and monitoring was an issue and somewhat unusual temperature gradients were observed. Characterization of the exposed material will be conducted after the loop is drained and the specimens are removed in October 2007.

2.0 CERAMIC COMPOSITE MATERIALS *6*

2.1 SUBCRITICAL CRACK PROPAGATION STUDIES IN HI-NICALON AND HI-NICALON TYPE-S FIBER SiC/SiC COMPOSITES USING COMPACT TENSION SPECIMENS—C. H. Henager, Jr. (Pacific Northwest National Laboratory) **7**

The potential use of SiC composites in fusion energy systems is well documented and studied. One of the main issues for the use of this material, other than radiation stability, is the long term crack growth stability problem or static fatigue issue compounded by environmental interactions. In ceramics this requires environmental crack growth studies under constant load and the properties of composites, while improved relative to monolithic ceramics, are nevertheless known to be strongly time and temperature dependent, especially with regard to crack growth. There are strong environmental interactions but also thermally-induced crack propagation rates are not well known. As fiber types evolve and weave structures are modified some of the basic crack growth data is required to understand failure in these materials and to provide design guidelines. Specimen geometry is critical since much data has been obtained using small specimens such as single-edge notched beams due to high materials costs. SENB bars in bending are attractive from a material conservation viewpoint but may not be attractive when geometrical and stress state effects are raised. The need for larger and more uniformly stressed samples is an important consideration. The use of CT specimens, even subscale, is a perceived improvement over SENB tests. This study is designed to show comparisons between data sets of similar materials tested in both geometries.

3.0 FERRITIC/MARTENSITIC STEELS AND ODS STEELS *11*

3.1 MECHANICAL PROPERTIES OF UNIRRADIATED AND IRRADIATED REDUCED-ACTIVATION MARTENSITIC STEELS WITH AND WITHOUT NICKEL COMPARED TO PROPERTIES OF COMMERCIAL STEELS—R. L. Klueh, M. A. Sokolov, and N. Hashimoto (Oak Ridge National Laboratory) **12**

Tensile and Charpy specimens of four normalized-and-tempered martensitic steels were irradiated to 23-33 dpa at 376–405ºC in the Experimental Breeder Reactor (EBR-II). The steels were the ORNL reduced-activation steel 9Cr-2WVTa and that containing 2% Ni (9Cr-2WVTa-2Ni), modified 9Cr-1Mo (9Cr-2WVTa), and Sandvik HT9 (12Cr-1MoVW). Two tempering conditions were used for 9Cr-2WVTa and 9Cr-2WVTa-2Ni: 1 hr at 700ºC and 1 h at 750ºC. The 9Cr-1MoVNb and 12Cr-1MoVW were tempered 1 h at 760ºC. These heat treatments produced tempered-martensite microstructures for all steels except 9Cr-2WVTa-2Ni tempered at 750ºC, where, a duplex structure of tempered and untempered martensite

formed. Based on changes in tensile and Charpy impact properties, the results demonstrated the superiority in strength and ductility of the 9Cr-2WVTa reduced-activation steel over the commercial steels. Comparison of the mechanical properties after irradiation of 9Cr-2WVTa-2Ni and 9Cr-2WVTa steels indicated a favorable effect of nickel that could lead to development of a heat treatment for improved irradiation resistance.

3.2 THE THERMAL STABILITY OF NANOSTRUCTURED FERRITIC ALLOYS—P. Miao, G. R. Odette, T. Yamamoto, and D. Klingensmith (University of California, Santa Barbara) **25**

The excellent tensile and creep strength and the potential for managing radiation damage make nanostructured ferritic alloys (NFAs) promising candidates for high temperature applications in spallation proton, advanced fission, and fusion neutron environments. The thermal stability of NFAs is critical for such applications, hence, this has been investigated in a series of aging experiments on MA957 at 900˚C, 950˚C, and 1000˚C for times up to 8000 h. Optical and transmission electron microscopy (TEM) studies for 3000 h aged MA957 showed the fine scale grain and dislocation structures are stable up to 1000°C. TEM and small angle neutron scattering (SANS) showed that the nm-scale solute cluster-oxide features (NFs), that are a primary source of the high strength of NFAs, were stable at 900°C and coarsened only slightly at 950˚C and 1000˚C after 3000 h aging. Porosity that developed during high temperature aging was minimal at 900°C and modest at 950˚C, but was much larger after 1000°C. Microhardness for the 3000 h aged MA957 was basically unchanged after the 900°C aging and decreased only slightly (≤ 3%) after aging at 950˚C and 1000˚C. However, the hardness was significantly reduced after 8000 h aging at 1000˚C.

4.0 COPPER ALLOYS ***34***

No contributions.

5.0 REFRACTORY METALS AND ALLOYS ***35***

No contributions.

6.0 AUSTENITIC STAINLESS STEELS ***36***

6.1 INFLUENCE OF SILICON ON SWELLING AND MICROSTRUCTURE IN RUSSIAN AUSTENITIC STAINLESS STEELS IRRADIATED TO HIGH NEUTRON DOSES—S. I. Porollo, S. V. Shulepin, Yu. V. Konobeev (State Scientific Center of Russian Federation, Institute of Physics and Power Engineering), and F. A. Garner (Pacific Northwest National Laboratory) **37**

Void swelling and microstructural development of EI-847 austenitic stainless steel were investigated by destructive examination of fuel pin cladding irradiated in three fast reactors located in either Russia or Kazakhstan. The tendency of void swelling to be progressively reduced by increasing silicon concentration appears to be a very general phenomenon, whether observed in simple single-variable experiments on well-defined materials or observed in multivariable, time-dependent irradiations conducted on commercially-produced steels over a wide range of irradiation temperatures, neutron spectra and dpa rates. The role of silicon on microstructural development is expressed both in the solid solution and via its influence on formation of radiation-induced phases that in turn alter the matrix composition.

7.0 MHD INSULATORS, COATINGS, INSULATING CERAMICS, AND OPTICAL MATERIALS ***52***

7.1 TRANSFORMATION OF Al_2O_3TO $LiAlO_2$ IN Pb-17Li AT 800°C—B. A. Pint and K. L. More (Oak Ridge National Laboratory) ***53***

A FeCrAl substrate was pre-oxidized at 1000°C to thermally grow an external Al_2O_3 scale and then isothermally exposed to Pb-17Li for 1000h at 800°C to determine if this layer would protect the under lying alloy from dissolution. After exposure, a small mass gain was measured, indicating that the layer did inhibit dissolution. However, characterization of the external layer determined that it had transformed to $LiAlO_2$ with an increased thickness and a much larger grain size than the original layer. This observation has implications for the use of Al_2O_3 as a tritium diffusion barrier.

8.0 BREEDING MATERIALS ***58***

No contributions.

9.0 RADIATION EFFECTS, MECHANISTIC STUDIES, AND EXPERIMENTAL METHODS ***59***

9.1 PREDICTION OF STRUCTURAL AND ELECTRONIC PROPERTIES OF Y-Ti-O COMPLEX OXIDES USING AB-INITIO CALCULATIONS—Y. Jiang, J. R. Smith, and G. R. Odette (University of California, Santa Barbara) **60**

Our objective is to develop a fundamental understanding of the identity and character of nm-scale features (NFs) in nanostructured ferritic alloys (NFAs), especially at the smallest sizes. The NFs' features are believed to be responsible for the very high creep strength and radiation damage resistance of NFAs. Atom probe tomography studies have indicated that the NFs have Ti + Y to O ratios greater than 1 and Ti to Y ratios much greater than 1. These elemental ratios are inconsistent with the known complex oxide phases in the Ti-Y-O system, which include complex cubic pyrochlore $Y_2Ti_2O_7$ and orthorhombic (at lower temperatures) Y_2TiO_5. Both of these phases have been observed in transmission electron microscopy studies of NFAs, but generally in a size range that is larger than the smallest, and very likely, non-equilibrium NFs. There are also a number of other open questions including the basic thermokinetics of NF precipitation and coarsening; and the basic characteristics of NFs, such as elastic properties and interface structures, that mediate their interactions with dislocations. Since it is difficult, if not impossible, to fully address many of these questions with direct experimental measurements, we have developed a multiscale modeling approach that will complement a range of characterization techniques that are needed to obtain reliable answers.

9.2 THE FORMATION AND STABILITY OF HE-VACANCY CLUSTERS WITHIN DISPLACEMENT CASCADES IN α-Fe—F. Gao, H. L. Heinisch and R. J. Kurtz (Pacific Northwest National Laboratory) **67**

Molecular dynamics (MD) methods have been utilized to study the formation of vacancy clusters created by displacement cascades in α-Fe containing concentrations of substitutional He atoms varying from 1-5%. These He concentrations are not necessarily intended to represent specific conditions within a fusion reactor (average end-of-life He concentrations in the first wall are expected to be on the order of 0.15%), but they provide an opportunity to investigate the effects of substantial amounts of He on cascade processes and microstructure development under damage producing conditions.

9.3 MODELLING THERMODYNAMICS OF ALLOYS FOR FUSION APPLICATION—A. Caro, P. Erhart, M. Serrano de Caro, B. Sadigh (Lawrence Livermore National Laboratory), E. Lopasso (Centro Atomico Bariloche, Argentine), D. Farkas (Virginia Polytechnic Institute), S. G. Srinivasan and C. Jiang (Lawrence Livermore National Laboratory) 72

Atomistic simulations of alloys at the empirical level face the challenge of correctly modeling basic thermodynamic properties. In the periods reported previously we develop a methodology to generalize many-body classic potentials to incorporate complex formation energy curves. Application to Fe-Cr allows us to predict the implications of the ab initio results of formation energy on the phase diagram of this alloy and to get a detailed insight

into the processes leading to precipitation of α' phase under irradiation. In particular in this period we report on the consequences of the negative heat of formation at low Cr composition on the short range order SRO existing in the α phase. We elaborate a simple description of SRO on a two-phase alloy and compare the predictions with experiments. We provide a key to rationalize a diversity of experiments on SRO versus annealing time or irradiation dose.

9.4 EFFECT OF MASS OF THE PRIMARY KNOCK-ON ATOM ON DISPLACEMENT CASCADE DEBRIS IN α-IRON—A. F. Calder, D. J. Bacon, A. V. Barashev (The University of Liverpool), and Yu. N. Osetsky (Oak Ridge National Laboratory) **80**

Results are presented from molecular dynamics (MD) simulations of displacement cascades created in α-iron (Fe) by primary knock-on atoms (PKAs) with energy from 5 to 20 keV and mass chosen to represent C, Fe and Bi. Molecular Bi_2 has also been simulated using two Bi PKAs, and PKA-Fe interaction potential has also been varied. Four effects are reported. First, the PKA mass has a major effect on cascade damage while the interaction potential has little if any. Second, the total number of point defects produced in a cascade decreases with increasing PKA mass. This fact is not accounted for in models used conventionally for estimating damage. Third, interstitial loops of ½<111> type and both vacancy and interstitial loops of <100> type are formed, the latter being observed in MD simulation for the first time. The probability of <100> loop appearance increases with increasing PKA mass as well as energy. Finally, there is a correlation between production of large vacancy and interstitial clusters in the same cascade.

9.5 EFFECT OF SIZE ON THE DESTRUCTION MECHANISMS OF STACKING FAULT TETRAHEDRA INDUCED BY GLIDING DISLOCATIONS IN QUENCHED GOLD—Y. Matsukawa (Argonne National Laboratory), Y. N. Osetsky, R. E. Stoller, and S. J. Zinkle (Oak Ridge National Laboratory) **89**

The destruction processes of stacking fault tetrahedra (SFTs) induced by gliding dislocations were examined by transmission electron microscopy (TEM) in situ straining experiments for SFTs with edge lengths ranging from 10 to 50 nm. At least four distinct SFT destruction processes were identified: (1) consistent with Kimura model for both screw and 60-degree dislocations, (2) stress-induced SFT collapse into a triangular Frank loop, (3) partial annihilation leaving an apex portion, and (4) complete annihilation. Process (4) was observed at room temperature only for small SFTs (~10 nm); however, this process was also frequently observed for larger SFTs (~30 nm) at higher temperature (~853 K). When this process was induced, the dislocation always cross-slipped, indicating only screw dislocations can induce this process.

9.6 A COMPRESSION ANVIL BEAM TEST METHOD TO MEASURE THE ARREST FRACTURE TOUGHNESS OF SEMI-BRITTLE MATERIALS WITH SMALL SPECIMENS—M. Y. He, G. R. Odette, and M. Hribernik (University Of California) **106**

Our goal was to design a specimen and test procedure that allowed the measurement of cleavage arrest (K_{Ia}) fracture toughness in very small oriented iron single crystals (< 10 mm). This was accomplished by incorporating iron single crystal slices into composite specimens. The test method described here is based on compression loaded, double-anvil beam fracture specimen, illustrated in Fig. 1. Conceptually, slow, uniform compression (σ) loading of a beam with a shallow fatigue starter crack (thick black line) in an double anvil fixture (shown in black) results in Poisson stresses normal to the crack faces, and elastic energy is released as the crack (thin black line) propagates. Composite specimens were fabricated by a sequence of diffusion bonding single crystal slices (light grey) to low alloy steel arms (darker grey), followed by a sequence of electro-discharge machining (EDM), fatiguing and final EDM to the pre-cracked bar configuration shown in Fig. 1. The mode I stress intensity factor (SIF), K_I, is a strong function of the crack depth **1**

(a/W). The SIF first increases to a maximum at a small a/W, and subsequently decreases very rapidly approaching 0 as a/W goes to 0.9 or less. The test is carried out by gradually increasing σ to the point where the crack initiates at σ_c and propagates until it arrests at a lower SIF $K_I = K_{Ia}$, terminating a substantial pop-in jump.

9.7 A CHEVRON NOTCHED WEDGE LOADED DOUBLE CANTILEVER BEAM TEST METHOD TO MEASURE THE INITIATION AND ARREST FRACTURE TOUGHNESS OF SEMIBRITTLE MATERIALS WITH SMALL SPECIMENS—G. R. Odette, M. Y. He, and M. L. Hribernik (University of California, Santa Barbara) **117**

Our goal was to design a specimen and test procedure that allowed the initiation and arrest of a crack in very small cleavage oriented iron single crystals (< 10 mm). This was accomplished by incorporating iron single crystal slices into composite specimens. The test method described here is based on a chevron-notched, wedge-loaded, double-cantilever beam specimen. Conceptually, slow insertion of the wedge, to load the beam arms, gradually increases the crack mouth opening displacement (Δ), and the corresponding stress intensity factor (SIF), K_I, up to K_{Ic}, thus initiating a propagating cleavage crack. However, due to the combination the wedge loading a double-cantilevered beam and chevron geometry, the K_I decreases very rapidly with increasing depth (a/W), and the crack arrests at a SIF $K_I = K_{Ia}$, after a short pop-in jump. Thus the crack can be grown in a series of short, and relatively stable, jumps. The initiation and arrest-re-initiation depths can be seen on the fracture surface.

10.0 DOSIMETRY, DAMAGE PARAMETERS, AND ACTIVATION CALCULATIONS 128

No contributions.

11.0 MATERIALS ENGINEERING AND DESIGN REQUIREMENTS 129

No contributions.

12.0 IRRADIATION FACILITIES AND TEST MATRICES 130

No contributions.