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1. FERRITIC/MARTENSITIC STEEL DEVELOPMENT

1.1 Stability of Nanoprecipitates in Fe-Base Model Alloys — 1
L. Tan, Y. Katoh, and L. L. Snead (Oak Ridge National Laboratory)

The stability of VN, TaC, and TaN under thermal, stress, and radiation conditions is being investigated. Isothermal aging experiments at 600 and 700°C for 100, 1000, and 5000 h have been completed. VN and TaC showed similar resistance to thermal aging at 600 and 700°C. TaC may be slightly more resistant. Further study is in progress including TaN particles. The samples have been subjected to creep tests at 600°C and 170 MPa for TaC and TaN and 100 MPa for VN. Unlike VN and TaC, TaN was not resistant to the creep, which was broken into small pieces. Irradiation experiments, using Fe^{2+} ions at 500°C for 20 and 200 dpa and neutron at 300, 500, and 650°C for up to about 20 dpa, are in progress. Post-irradiation examination will be pursued.

1.2 Recent Observations of Helium Effects on Cavity Evolution in Tempered Martensitic Steels and Nanostructured Ferritic Alloys — 5
G. R. Odette, T. Yamamoto, and Y. Wu (University of California - Santa Barbara), S. Kondo and A. Kimura (Kyoto University)

Additional dual ion (Fe^{3+} and He^{+}) beam irradiation (DII) was performed at 500°C on previously irradiated alloys up to a nominal dpa and He levels of 80 dpa and ≈ 3400 appm, respectively. The irradiations were performed at dual ion beam facility, DuET, located at Kyoto University in Japan. The actual dpa, He and He/dpa vary with depth in the sample. The alloys studied include a normalized and tempered martensitic steel, (TMS) F82H mod.3 and a nanostructured ferritic alloy (NFA), MA957. TEM observations have been performed at a location where total dpa and He levels are estimated to be ≈ 220 dpa and ≈ 3400 appm He. These same locations had been previously irradiated to ≈ 70 dpa and ≈ 900 appm He. Cavity evolutions during the incremental irradiation were distinctly different in the two alloys. In F82H the number density of the cavities (N) remained at ≈ 5 x $10^{22}/m^3$ while average diameter (d) of all cavities grew from 3.5 to 4.9 nm, with corresponding increases in the void fraction of cavities from 67 to 87% (defined as d > 2 nm) and in growth of the average d of voids (d_v) from 3.9 to 5.3 nm. The cavity volume fraction (f) in F82H increased from 0.23% to 0.43%. In the case of MA957, the number density of the cavities increased by about a factor of 4 reaching N ≈ 4.4 x $10^{23}/m^3$; this is very similar to the typical number density of nm-scale oxide features in the alloy. The average d of cavities in MA957 also increased from 1.38 to 1.80 nm, including 22% that are larger than 2 nm. However, it is not known if these cavities are bubbles or voids. The cavity f in MA957 increased from 0.016% to 0.16%. Note the highest dpa and He irradiation conditions exceed the end of life conditions of even an aggressive fusion demonstration reactor.

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2. ODS AND NANOCOMPOSITED ALLOY DEVELOPMENT

See also Sections 1.2 and 8.3.

2.1 Development of ODS FeCrAl for Fusion Reactor Applications — **10**
B. A. Pint, D. T. Hoelzer, D. Shin, J. O. Kiggans, Jr., and K. A. Unocic (Oak Ridge National Laboratory)

Capsule testing was completed on six cast FeCrAl alloys for 1,000h at 700°C. The alloys with 3%Al all showed mass losses similar to 9Cr steel under these conditions while those with 5%Al all showed little or no mass gain. In all cases, a LiAlO2 reaction product formed but it was thinner for the 3%Al alloys and the surface was rougher. For the oxide stability, the thermodynamic model of HfO2 -Y2 O3 was combined with the other two constituent pseudo-binaries of Al2 O3 -Y2 O3 and Al2 O3 -HfO2. Isothermal and isoplethal data from the experimentally assessed phase diagram of Al2 O3 -Y2 O3 -HfO2 were used to adjust the ternary model parameters. Diffusion couple experiments at 1250° and 1650°C showed that Ti was very reactive with Al2 O3 and Y2 O3. Much less reaction occurred with HfO2 and ZrO2.

2.2 Characterization of 14W NFA Micro-Alloyed with Y, Ti, Hf, and Zr — **15**
Y. Wu, V. Ravula and G. R. Odette (University of California - Santa Barbara)

Nanostructured ferritic alloys (NFAs) have applications in advanced fission and fusion reactors and are strengthened and made irradiation tolerant by a high number density of Y-Ti-O nanofeatures (NFs) that are very stable up to 1000ºC [1]. We briefly report preliminary results on the effects of various additions of Y, Ti, Hf and Zr to a baseline NFA composition of 14Cr, 3W and 0.3 Y_2O_3 (wt.%) on the microstructure and strength of NFAs. These alloys were characterized by microhardness (μH) and transmission electron microscopy (TEM) measurements. Alloys with additions of Ti (≈ 0.47 at.%) plus Hf (≈ 0.13 at.%) or Y(≈ 0.25 at%) had the highest μH and smallest grain sizes after hot consolidation at 1150°C. The corresponding hardness was lower in alloys alloyed with Zr (≈ 0.25 at. %) and Ti. The μH was lowest in alloys with Hf and Zr but without Ti; Hf again resulted in higher μH in this case than Zr. The alloy alloyed with Hf but without Ti had larger grains than those alloyed with either Hf or Y and Ti.

The alloys with Ti and Hf or Y added had extremely small grain sizes, especially for the consolidation temperature of 1150°C. The average NF size (<d>), number density (N) and volume fraction (f) ranged from 2.8 to 3.9 nm, 1.3 to $1.7 \times 10^{23}/m^3$ and 0.7 to 1.8 %, respectively. The NF oxides appear to be consistent with pyrochlore structures observed in reference NFA MA957, which are Y_2Ti_2O7 in this case. The NFs in alloys without Ti appear to contain large quantities of Cr.

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2.3 Characterization of the Final Precursor Alloy to a Larger Best Practice Heat of 14YWT — 20

N. J. Cunningham, Y. Wu, G. R. Odette, D. Gragg, and K. Fields (University of California - Santa Barbara), D. T. Hoelzer (Oak Ridge National Laboratory), S. A. Maloy (Los Alamos National Laboratory)

We describe our characterization of a new, extruded and cross-rolled nanostructured ferritic alloy (NFA) designated 14YWT-PM2 (PM2). Atomized Fe14Cr powders containing Y, Ti, and W were milled for 40 h with FeO, extruded at 850°C, and cross-rolled at 1000°C. The consolidated alloy was characterized by transmission electron microscopy (TEM) and atom probe tomography (APT), as well as by various mechanical property tests. A summary of the TEM, APT, and mechanical testing results are shown in Table 1. PM2 contains a high number density of N = 8.4±2.6x10^{23} m^{-3}, small <d> = 1.75±0.35 nm Y-Ti-O nanofeatures (NFs). The balance of the microstructure consists of: a) a fine, nearly unimodal size distribution of grains with approximately equiaxed cross sections, that are moderately extended in the extrusion direction, with an average effective diameter d_g ≈ 424 nm; and, b) a high dislocation density of r ≈ 1.2x$10^{15}$$m^{-2}$. Larger Ti oxi-nitride precipitate phases are also observed. The corresponding μH = 401±15 kg/mm^2, is consistent with yield and ultimate strengths of 1125 and 1298 MPa, respectively. The cleavage fracture toughness of PM2 increases in the temperature regime from ≈ -200 to -100°C up to a ductile tearing upper shelf transition at ≈ 80 MPa√m. A limited number of strain rate jump creep tests also showed high strength, comparable to that of the strongest NFA, in spite of the formation of edge cracks and possible necking during loading.

In addition, milled powders annealed at 850ºC, 1000ºC, and 1150ºC were characterized by small angle neutron scattering (SANS) and TEM. They also contained a high number density of NFs with increasing <d> and decreasing (N) and volume fraction (f) with increasing temperature.

3. CERAMIC COMPOSITE STRUCTURAL MATERIAL DEVELOPMENT

See also Sections 8.1 and 8.2.

3.1 Determination of Interfacial Mechanical Properties of Ceramic Composites by the Compression of Micro-Pillar Test Specimens — 34

C. Shih, Y. Katoh, K. J. Leonard, H. Bei, and E. Lara-Curzio (Oak Ridge National Laboratory)

The interfacial debond shear strength and the coefficient of internal friction between the fiber and pyrocarbon interface of a SiC fiber reinforced CVI SiC matrix composite are determined using a novel method, which involves micro compression of micro sized pillars containing an inclined fiber/matrix interface. The interfacial debonds shear strength and the coefficient of internal friction was determined to be 100 MPa and 0.73, respectively. This new test method with simple geometry showed high data reproducibility; moreover, the results fit the proposed Coulomb fracture criterion well. The determined interfacial properties are compared with those determined from fiber push out tests.

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3.2 Process Development and Optimization for Silicon Carbide Joining and Irradiation Studies — 42
T. Cheng, J. O. Kiggans, Jr., Y. Katoh, and L. L. Snead (Oak Ridge National Laboratory)

The candidate joint materials for the ongoing work to evaluate the neutron irradiation effects on chemically vapor-deposited (CVD) SiC includes bonds produced by the NITE (nano-infiltration and transient eutectic-phase) – like transient eutectic phase processes, diffusion bonding utilizing active titanium or molybdenum inserts, calcia-alumina (CA) glass/ceramics, and Ti-Si-C MAX phase through displacement reaction. During the present reporting period, joint specimens were successfully produced through the active metal insert methods and the NITE-like process, and then evaluated for as-fabricated properties.

4.0 HIGH HEAT FLUX MATERIALS AND COMPONENT TESTING

4.1 High-Heat Flux Testing Using Plasma Arc Lamps of Low-Level Irradiated Materials — 55
A. S. Sabau, E. Ohriner, Y. Katoh, and L. L. Snead (Oak Ridge National Laboratory)

The high-heat flux testing facility using Plasma Arc Lamps was demonstrated at ORNL for W samples during a visit of the Japanese delegation of a PHENIX planning workshop. The second generation test section, which was designed by taking into account safety and materials compatibility requirements in order to handle the testing of low levels irradiated tungsten articles, was fabricated. The test sections were assembled and all the steps during the high heat flux runs were tested, including the air evacuation, backfill with Ar, and Ar pressure monitoring during the high heat flux testing, demonstrating the readiness of the new facility for irradiated samples.

4.2 Effect of Ti and TiC Additives on Sintering Behavior of Nano W — 60
X. Wang and Z. Zak Fang (University of Utah)

Ti and TiC were added as grain growth inhibitors during sintering of nano W alloys. The sintering of nano W, W-1Ti, W-1Ti-0.5TiC, W-1TiC powders were investigated to understand the effect of Ti and TiC addition on grain growth and densification. The results show that both Ti and TiC can effectively prevent W grain growth during sintering. However, the additives also adversely affect densification. The combinations of Ti and TiC appear to have promise to be used for achieving high density while retaining nanoscale grain size.

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4.3 Effects of B, C, N, O, P and S Impurities on Tungsten Σ27[110]{552} and Σ3[110]{112} Grain Boundaries — 67
W. Setyawan and R. J. Kurtz (Pacific Northwest National Laboratory)

Density functional theory was employed to investigate the effects of B, C, N, O, P and S impurities on the properties of W Σ27[110]{552} and Σ3[110]{112} grain boundaries (GBs). Careful search of interstitial sites near the interfaces resulted in 19 and 9 unique interstices in Σ27 and Σ3 respectively. By using the segregation energy as a weighing factor, the average intergranular fracture energies were calculated. It was found that B, C, N and P increase the cohesion of Σ27 by 10.1, 8.9, 4.1 and 2.5% respectively, while O (0.6%) and S (2.7%) embrittle the GB. In Σ3, only C was found to strengthen the interface by 1.2%, while B, N, O, P and S decrease the intergranular cohesion by 1.7, 1.6, 11.2, 18.4 and 19.4% respectively. The impurity content in this study was 1.37 atoms/nm^2.

5. MAGNET AND DIAGNOSTIC SYSTEM MATERIALS

5.1 Irradiation Response of Next Generation High Temperature Superconducting Rare-Earth and Nanoparticle-Doped $YBa_2Cu_3O_{7-x}$ Coated Conductors for Fusion Energy Applications — 73
K. J. Leonard, T. Aytug (Oak Ridge National Laboratory), A. Perez-Bergquist, W. J. Weber (University of Tennessee), A. Gapud (University of South Alabama)

The pre-irradiation electrical and microstructural characterization of three advanced high temperature superconductors has been completed and is discussed in this report. These conductors represent three distinct ways in which increased performance and improved flux pinning have been achieved through means of rare earth and nanoparticle doping. The $GdBa_2Cu_3O_{7-x}$ conductor primarily utilizes stacking fault and anti-domain defects in its structure to enhance magnetic flux pinning in the B//ab direction. Disperse $(Dy,Y)_2O_3$ nano-particles dominate the microstructure of the $(Y,Dy)Ba_2Cu_3O_{7-x}$ conductor which also shows enhanced B//ab pinning. The Zr-doping of $YBa_2Cu_3O_{7-x}$ produces c-axis aligned $BaZrO_3$ nanoparticles to produce enhanced B//c pinning and a reduced field dependence of the critical current density. Irradiation experiments using 25 MeV Au ions will begin at the start 2013, from which the response behavior of these advanced conductors will be evaluated.

5.2 High Neutron Dose Irradiations of Dielectric Mirrors — 84
K. J. Leonard, G. E. Jellison, Jr., and L. L. Snead (Oak Ridge National Laboratory), A. P. K. K. Nimishakavi (University of Tennessee)

Our experimental work to date on HfO_2/SiO_2 and Al_2O_3/SiO_2 dielectric mirrors indicate an impressive irradiation resistance. However, with increasing dose, chemistry and crystallinity changes in the film layers of the mirrors result in decreases in reflectivity of the HfO_2/SiO_2 mirror following post irradiation annealing. This contribution discusses the recent microscopy work on the 0.1 dpa-irradiated mirrors to assess the causes in optical property changes. Further work has been initiated this year for higher irradiation dose experiments to determine the upper neutron irradiation dose and thermal limits of the

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HfO_2/SiO_2 and Al_2O_3/SiO_2 mirrors. At the time of this writing, irradiation capsules have completed $1x10^{21}$ and $4x10^{21}$ n/cm^2 (E>0.1 MeV) exposures at 448 K, corresponding to approximately 1 and 4 displacements per atom (dpa). Post irradiation examination of the high dose mirrors will begin at the start of 2013.

6. FUSION CORROSION AND COMPATIBILITY SCIENCE

6.1 Additional Characterization of V-4Cr-4Ti and MHD Coatings Exposed to Flowing Li — **91**
B. A. Pint and K. A. Unocic (Oak Ridge National Laboratory)

Additional results are presented on the characterization of a dual layer (Y2 O3 /V) MHD coating exposed to flowing Li at ~688°C. This coating was exposed at the highest temperature and had the largest volume of a "new" phase formed at the V-4Cr-4Ti substrate-Y2 O3 interface. Extensive analytical transmission electron microscopy has not definitively identified the phase, partly because it is unstable under the electron beam. However, it is assumed to be LiYO2 that formed due to Li ingress along the substrate-V overlay coating interface.

6.2 Compatibility of Materials Exposed to Isothermal Pb-Li — **95**
B. A. Pint, K. A. Unocic, and S J. Pawel (Oak Ridge National Laboratory)

Isothermal capsule experiments were completed on coated and uncoated Grade 92 (9Cr-2W) specimens for 5,000 h in Pb-Li to determine the long-term stability of the coating at 600° and 700°C. Thin ~50**µ** m Alrich diffusion coatings showed similar low mass changes at both temperatures. However, extensive Al loss was observed after 5,000h at 700°C. In contrast, a thicker diffusion coating where intermetallic aluminide phases formed showed a mass loss after 5,000h at 700°C due to partial spallation of the aluminide coating outer layer. Characterization of the 5,000h specimens is still in progress. These results indicate that (1) Al-rich coatings greatly reduce dissolution at 700°C in Pb-Li but do not prevent it and (2) the effectiveness of coating strategies to improve compatibility are limited. In order to further evaluate the coating concept and wrought and oxide dispersion strengthened (ODS) FeCrAl alloys, plans are being made to build a Pb-Li thermal convection loop of Fe-9Cr or FeCrAl tubing.

7. MECHANISMS AND ANALYSIS

7.1 Progress on Developing an Atomistic Equation of State for Helium in Iron — **100**
R. E. Stoller and Y. N. Osetskiy (Oak Ridge National Laboratory)

A large series of molecular dynamics simulations have been completed to map out the pressure-temperature relationship for helium in iron to provide the basis for fitting of a new equation of state for helium bubbles. The behavior of helium is described by the three-body Fe-He potential developed at ORNL under the fusion program.

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7.2 Atomistic Studies of Helium Bubble Nucleation at Grain Boundaries in α–Fe — **103**
L. Yang, F. Gao, H. L. Heinisch, and R. J. Kurtz (Pacific Northwest National Laboratory)

Experimental results and atomistic calculations demonstrate that GBs act as sinks to trap He atoms in α-Fe. The nucleation and growth of He bubbles at GBs are likely to determine the extent of embrittlement which is potentially one of the most serious material problems related to the development of fusion power. The nucleation of He bubbles in the bulk and at GBs in α-Fe has been previously studied [1-3] using molecular dynamics with our newly developed Fe-He potential [4]. It was found that the evolution of the GB configurations, the accumulation of He atoms and the nucleation of He bubbles all depend on the He concentration, temperatures and the GB configurations. In the bulk of α-Fe, the computational results showed that complexes consisting of a dislocation loop with helium-vacancy (He-V) clusters are formed at high He concentrations [2]. In order to understand the formation and evolution of interstitial dislocation loops due to the growth of He bubbles in the helium-rich vacancy-poor situation, the clustering of He and the growth of He bubbles at two GBs in α-Fe is currently being investigated. It has been found that within the S3 GB, when the size of a He cluster is large enough, a 1/2 <111> dislocation loop is formed, accompanied by the emission of the dislocation loop. However, in the S73b GB the sequential insertion of He atoms induces the emitted self-interstitial atoms (SIAs) to rearrange at the core of the inherent dislocation, leading to the propagation of the dislocation along the [-1 -1 12] direction. The small He bubbles form longitudinal shapes along the dislocation line in the S73 GB, a shape commonly observed at GBs in experiments.

7.3 Theory of a Quodon Gas with Application to Precipitation Kinetics in Solids Under Irradiation — **108**
V. I. Dubinko and R. V. Shapovalov (NSC Kharkov Institute of Physics and Technology), S. Y. Hu, Y. L. Li, C. H. Henager, Jr., and R. J. Kurtz (Pacific Northwest National Laboratory)

The difference in the ability to absorb point defects by extended defects is a main driving force of microstructural evolution under irradiation [3]. Another driver for radiation-induced microstructural evolution is based the forced atomic relocations resulting from nuclear collisions, a.k.a. ballistic effects [4] that have been taken into account for the explanation of the dissolution of precipitates under cascade damage. Later on it was recognized that the so-called “thermally activated” reactions may be strongly modified by irradiation resulting in the radiation-induced production of Schottky defects [3, 4-8], which has essentially the same physical nature as the ballistic effects, but, in contrast to the latter, it operates under both cascade and non-cascade damage conditions, including sub-threshold electron irradiation that does not produce stable Frenkel pairs. The underlying mechanisms for these processes are based on the interaction of extended defects with unstable Frenkel pairs, focusing collisions (a.k.a. focusons) and with lattice solitons. The latter can be mobile, and these are referred to below as quodons, which are stable quasi-particles that propagate one-dimensionally and transfer energy along the close packed directions of the lattice. Quodons may have more technological significance than focusons due to much

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longer propagation ranges expected from the nonlinear theory and demonstrated experimentally [8, 9]. This points to the necessity of the modification of the chemical rate theory to account for the quodon-induced energy deposition to the reaction area. Accordingly, the rate theory of microstructure evolution in solids has been modified to account for the production of Schottky defects at surfaces of extended defects due to their interaction with the radiation-induced lattice excitations [3, 5-8]. The modified theory predictions include important phenomena, which have not been properly understood before, such as irradiation creep [5, 6], radiation-induced annealing of voids [3, 7], saturation of void growth under high dose irradiation and void lattice formation [8].

8. MODELING PROCESSES IN FUSION SYSTEM MATERIALS

8.1 Molecular Dynamics Modeling of Atomic Displacement Cascades in 3C-SiC — 115
G. D. Samolyuk, Y. N. Osetskiy, and R. E. Stoller (Oak Ridge National Laboratory)

A set of atomic displacement cascades was simulated using popular SiC Tersoff interatomic potentials. The types of created defects and their dynamics were analyzed. The validity of existing interatomic potentials was investigated by comparison of typical point defect diffusion barriers obtained using these potentials with first principles results.

8.2 Thermal Conductivity of SiC/Si Composites 0- Porting PNNL EMTA ode for fusion Analyses — 118
C. H. Henager, Jr. and Ba Nghiep Nguyen (Pacific Northwest National Laboratory)

The study, measurement, prediction, and control of thermal conductivity of SiC/SiC composites are a critical issue for Fusion. Both high conductivity (first wall) and reduced conductivity (flow channel insert) materials appear to be required for specific fusion reactor applications so that low-activation goals are achieved. This study has applied an Eshelby-Mori-Tanaka approach (EMTA) implemented in PNNL EMTA software to predict thermal conductivities of SiC/SiC composites. The EMTA homogenization procedure is structured in three steps to capture the effects of the constituent materials including the fiber-coating layer on the thermal conductivities of the as-formed composites. The results show that when perfectly bonded to the fibers a thicker fiber coating layer with higher thermal conductivity than that of the fibers leads to increased thermal conductivities for the composite. EMTA can be effectively used to identify the interfacial thermal conductance by correlating the EMTA predicted thermal conductivities with the measured values. A reverse engineering procedure in EMTA is useful to determine the thermal conductivities of the constituents if the actual measured values are not available or is unknown.

8.3 Nanofeature-Dislocation Associations and a Fitted Long-Term Thermal Aging Pipe Diffusion Model for MA957 — 122
Y. Wu, N. J. Cunningham, G. R. Odette, and D. Klingensmith (University of California - Santa Barbara)

Nanostructured ferritic alloys (NFAs) have applications in advanced fission and fusion reactors and are strengthened by a high number density of Y-Ti-O nanofeatures (NFs) that

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are very stable up to 1000ºC [1]. Previously reported long and short-term aging studies from between 800ºC and 1400ºC on NFA MA957 for times up to 32.4 kh were used to develop a coarsening model in the form:

$$[d(t)^p - d_o^p] = [k_p(T)t]$$

Here t is the aging time and d is the average NF diameter starting at d_o. Simple models predict p ranging from 2 to 5, depending on the operative coarsening mechanism. Our data is most consistent with a pipe diffusion mechanism (p=5) [2]. However, a least square fit of all the data gives a higher p values of 6.26, possibly suggesting that combinations of complex phenomena operate during aging; for example, rather than random pipe diffusion processes, coarsening and other stages of NF evolution may involve highly correlated multispecies mechanisms.

In this short report we present TEM data for 1000ºC aging to 21.9 kh that provides strong support for pipe diffusion coarsening (p = 5), since most of the NFs are associated with dislocations. Additional aging studies at intermediate temperatures (1075ºC to 1200ºC) and times (<10 kh) are underway to help more accurately identify the coarsening mechanisms and kinetics.

9. IRRADIATION METHODS, EXPERIMENTS, AND SCHEDULES

9.1 Fusion Materials irradiation Test Facility (FMITS) at SNS — **127**
M. W. Wendell and P. D. Ferguson (Oak Ridge National Laboratory)

The impact of He and H transmutation products on material damage from 14.1 MeV neutrons is a critical unresolved issue which is being addressed by combining numerical models and specialized ion and neutron irradiation experiments. Because of the uncertainties associated with both modeling and ion irradiation experiments, there is a clear need for an accessible irradiation facility that can provide near prototypic levels of transmuted helium and hydrogen. The scientific understanding obtained would also enable more effective use of a future large-volume fusion engineering irradiation facility (such as IFMIF) when it becomes available.

A design study [1,2,3] for a fusion materials irradiation test station (FMITS) for installation at the Spallation Neutron Source (SNS) has been completed. Samples would be located within two horizontal tubes in front of the mercury target. For these specimen locations, the back-scattering neutron flux spectra should be close to the ITER fusion spectrum. The PKA spectra at the FMITS samples were also compared to those for ITER, and the results show good agreement. Material damage rates would be 1.6–5.5 dpa/yr for steel, and 1.8–3.4 dpa/yr for SiC.

9.2 HFIR Irradiation Experiments — **137**
Y. Katoh and J. L. McDuffee (Oak Ridge National Laboratory