

RES

DOE/ER-0046/25



Damage Analysis and Fundamental Studies

Quarterly Progress Report
January-March 1986

May 1986

U.S. Department of Energy
Office of Energy Research
Office of Fusion Energy
Washington, DC 20545
B&R No. AT-15-O2-03-04

CONTENTS

| | <u>Page</u> |
|---|-------------|
| Foreword | |
| CHAPTER 1: IRRADIATION TEST FACILITIES | |
| 1. <u>RTNS-II IRRADIATIONS AND OPERATIONS (LLNL)</u> | 2 |
| Irradiations were performed on seven different experiments during this quarter. The sixth U.S./Japan Steering Committee meeting was held February 6 and 7, 1986, at RTNS-II. | |
| CHAPTER 2: DOSIMETRY AND DAMAGE PARAMETERS | |
| 1. <u>EXPERIMENTS IN THE OMEGA WEST REACTOR (ANL)</u> | 5 |
| Dosimetry results are reported for fusion-fission correlation experiments in the Omega West Reactor (Los Alamos National Laboratory). Three short irradiations were performed from August to October 1985 with neutron fluences between $5.2-54 \times 10^{18} \text{ n/cm}^2$. | |
| 2. <u>DEVELOPMENT OF THE SPECOMP COMPUTER CODE (ANL)</u> | 8 |
| A new computer code, SPECOMP, is being developed to calculate displacement damage for compounds. In LiAlO_2 , for example, the code yields 20-40% more damage in the compound than would be expected from a combination of elements using SPECTER. | |
| 3. <u>MEASUREMENTS OF ^{91}Nb, ^{94}Nb, AND ^{95}Nb FROM Mo BY 14.5-14.8 MeV NEUTRONS (ANL)</u> | 10 |
| The production cross section for ^{94}Nb (20,300y) is about 56 mb from ^{94}Mo and 7.9 mb from natural Mo near 14.6 MeV. The production cross section of ^{91}Nb (700 y) from natural Mo is about 45 mb. These data can be used to calculate the production of these isotopes in a fusion reactor. | |
| 4. <u>HELIUM PRODUCTION IN MIXED SPECTRUM REACTOR-IRRADIATED PURE ELEMENTS (ROCKWELL INTERNATIONAL)</u> | 12 |
| Helium generation measurements have been made for several Fe, Cu, Ti, Nb, Cr, and Pt samples irradiated in ORR and HFIR. Discrepancies with the ENDF/B-V Gas Production File are found for Cu, Ti, Nb, and Cr. | |
| CHAPTER 3: REDUCED ACTIVATION MATERIALS | |
| 1. <u>PROSPECTS FOR REDUCED ACTIVATION ALLOYS (HEDL, ORNL)</u> | 20 |
| The framework is described within which the development of alloys exhibiting reduced activation is being pursued in the U.S. and a brief survey is made of the current status and future prospects of this effort. Although the work is at an early stage, there is evidence for optimism. | |
| 2. <u>SWELLING OF Fe-Mn AND Fe-Cr-Mn ALLOYS AT HIGH NEUTRON FLUENCE (HEDL)</u> | 28 |
| At exposure levels approaching 50 dpa, the swelling rate of simple Fe-Cr-Mn and Fe-Mn alloys and of commercial Fe-Cr-Mn base alloys decreases below 1%/dpa. | |
| 3. <u>ELECTRON IRRADIATION STUDIES OF Fe-Cr-Mn AND Fe-Cr-Ni ALLOYS (HEDL)</u> | 31 |
| Study of the elemental segregation that occurs at grain boundaries during electron irradiation confirms that iron and chromium segregate at microstructural sinks in Fe-Cr-Mn alloys while nickel segregates in Fe-Cr-Ni alloys. Solute additions can be used to suppress the segregation process. | |

| | | <u>Page</u> |
|---|--|-------------|
| CHAPTER 4: FUNDAMENTAL MECHANICAL BEHAVIOR | | |
| 1. | <u>MICROSTRUCTURE-MECHANICAL PROPERTY VARIATIONS IN HT-9 (UCSB)</u> | 37 |
| | Microstructures and mechanical properties of HT-9 specimens have been investigated as a function of heat treatments, and the data applied to the evaluation of micromechanical models of cleavage fracture. | |
| 2. | <u>APPLICATION OF HYDROGEN EMBRITTELEMENT MODELS TO THE CRACK GROWTH BEHAVIOR OF FUSION REACTOR MATERIALS (PNL)</u> | 57 |
| | Hydrogen induced crack growth rates of HT-9 have been estimated for three sources of hydrogen: the plasma, nuclear reaction, and aqueous corrosion. Based on this analysis, hydrogen induced crack growth is not considered significant for HT-9 during reactor operation but may be a problem during extended downtime if the temperature decreases to a value less than 100°C. | |
| 3. | <u>THE RELATIONSHIP BETWEEN J-INTEGRAL AND CRACK TIP OPENING DISPLACEMENT (HEDL)</u> | 68 |
| | Critical crack tip opening displacement ($CTOD_c$) values for SS304 and 55316 were used to test the relationship between $J_{Ic/0.95}$ and $CTOD_c$. Reasonable agreement was found between measured and calculated $CTOD_c$ using Wells' equation. | |
| CHAPTER 5: RADIATION EFFECTS MECHANISMS AND CORRELATIONS | | |
| 1. | <u>OWR/RTNS-II LOW EXPOSURE SPECTRAL EFFECTS EXPERIMENT (HEDL)</u> | 76 |
| | The status of the OWR/RTNS-II Low Exposure Spectral Effects Experiment is reviewed. Yield strength data for 316 stainless steel correlate well on the basis of displacements per atom (dpa), while those for copper and A302B steel do not. | |
| 2. | <u>APPLICATIONS OF A COMPOSITE MODEL OF MICROSTRUCTURAL EVOLUTION (ORNL, UCSB)</u> | 87 |
| | A comprehensive rate-theory-based model is used to compare alternate mathematical descriptions of the Frank faulted loop bias for interstitials. This calibrated model is also used to predict the swelling of an austenitic stainless steel DT fusion reactor first wall. | |
| 3. | <u>ION-INDUCED SPINODAL-LIKE COMPOSITIONAL MICRO-OSCILLATIONS IN Fe-35Ni AND ITS CONSEQUENCES ON PHASE STABILITY (U. OF WISCONSIN, HEDL)</u> | 98 |
| | When Fe-35Ni is irradiated with 5 MeV Ni^+ nickel ions at 625, 675 or 725°C spinodal-like micro-oscillations in composition develop similar to those observed in Fe-35Ni-7Cr earlier at 675°C. Upon cooling down from the irradiation temperature, however, the low nickel areas (>28%) transform to a cellular form of martensite. This transformation allows the visualization of the spatial relationships of the low nickel areas. | |
| 4. | <u>STABILITY DURING THERMAL ANNEALING OF MICRO-OSCILLATIONS DEVELOPED IN Fe-35.5Ni-7.5Cr DURING NEUTRON IRRADIATION (HEDL)</u> | 105 |
| | Compositional micro-oscillations which form in Fe-35.5Ni-7.5Cr during neutron irradiation at 593°C are stable during thermal annealing at 600°C for 24 hours. | |

CONTENTS (Cont'd)

| | <u>Page</u> |
|---|-------------|
| CHAPTER 6: FUNDAMENTAL STUDIES OF SPECIAL PURPOSE MATERIALS | |
| 1. <u>SWELLING OF COPPER-ALUMINUM AND COPPER-NICKEL ALLOYS IN FFTF/MOTA AT -450°C (HEDL)</u> | 110 |
| <p>The addition of Al and Ni to copper reduces swelling at low fluences, but, by increasing the saturation level relative to pure copper, may lead to increased swelling at high fluence.</p> | |
| 2. <u>THE EFFECTS OF LOW DOSES OF 14 MeV NEUTRONS ON THE TENSILE PROPERTIES OF VARIOUS COMMERCIAL COPPER ALLOYS (HEDL)</u> | 114 |
| <p>Miniature tensile specimens of high purity copper and five copper alloys were irradiated with D-T fusion neutrons in the RTNS-II to fluences up to 2.5×10^{18} n/cm² at 90 and 290°C. All the alloys sustain less irradiation-induced strengthening than pure copper. In contrast to pure copper, the effects of fission and fusion neutrons on the yield stress changes in the copper alloys correlate well on the basis of dpa.</p> | |