TLS 7-19

DOE/ER-0046/9

Damage Analysis and Fundamental Studies

Quarterly Progress Report
Jan-Mar 1982

May 1982

U.S. Department of Energy
Assistant Secretary for Energy Technology
Office of Fusion Energy
Washington, DC 20545

CONTENTS

	Page
Foreward	iii
Figures	xi
Tables	xvi
CHAPTER 1: IRRADIATION TEST FACILITIES	1
1. RTNS-II Irradiations and Operations (LLNL)	3

A letter of understanding between the U.S. DOE and Japan Monbusho (Ministry of Education, Science and Culture) was signed on February 9, 1982, to implement joint utilization and support of the RTNS-11 facility. Irradiations were done on a total of fourteen different experiments this quarter. Approximately five weeks of unscheduled outage occurred due to problems with the 50-cm target seal.

CHAPTER 2: DOSIMETRY AND DAMAGE PARAMETERS	7
1. Room-Return Neutron Flux Measurements at RTNS-II (ANL)	9

Neutron activation measurements have been used to determine the neutron flux and energy spectrum in the RTNS-II target room both near the target and at distances of 5, 15, 30, 120 and 380 cm (the backwall). The room-return neutron flux and spectrum appears to be constant throughout the room; it is 1% of the total flux at 18 cm, 3% at 30 cm and 31% at 120 em.

2. RTNS-II Fluence Mapping and Helium Generation Cross Sections (RIES)	16

Neutron fluence contours have been calculated for the high-flux region of the RTNS-11 sample irradiation volume, and the cross section of elemental lead has been determined for 14.8-MeV neutrons.

CONTENTS (Cont'd)

3. Helium Accumulation Neutron Dosimetry for the Omega West Reactor (RIES and ANL) 22

Neutron energy spectrum unfolding using combined helium accumulation and radiometric measurements has been demonstrated for the neutron environment of the Omega West Reactor.

4. Combined Helium Accumulation and Radiometric Dosimetry for Be(d,n) Neutron Spectra (ANL and RIES) 27

Neutron energy spectrum unfolding using combined helium accumulation and radiometric measurements has been demonstrated for a Be(d,n) neutron environment.

5. Neutron Dosimetry Measurements for the HFIR-CTR32 Irradiation (ANL) 32

The maximum fluence in the HFIR-CTR32 irradiation was 4.80 X 10^{22} n/cm^2 (1.24 X 10^{22} n/cm^2 above 0.1 MeV). The status of all other fission reactor dosimetry is summarized.

It is pointed out that displacements from the $^{59}Ni(n,\alpha)^{56}Fe$ reaction, neglected in previous calculations, may be significant.

6. The Impact of the $^{59}Ni(n,\alpha)^{56}Fe$ Reaction on Damage Calculations for HFIR (HEDL) 41

Greenwood and Smither have recently shown that the contribution of the $^{59}Ni(n,\alpha)^{56}Fe$ reaction to displacement damge has been overlooked. When included in calculations of HFIR-induced displacement levels, the displacement level is increased significantly and the helium/dpa ratio correspondingly reduced. This additional contribution to the damge rate is nonuniform both in time and space.

7. Solid and Gas Transmutation Production Code Development (HEDL) 50

The computer code REAC and its associated libraries have been expanded and used to determine transmutations in INTOR, UWMAK-1, FMIT, HFIR and FMIT spectra.

CONTENTS (Cont'd)

8. Primary Recoil Energy Spectra for the (n,γ) Reaction (ANL) 55

A detailed analysis was made of the recoil energy spectrum from multiple y-ray cascades following thermal neutron capture in iron. The new analysis gives the same average recoil energy per neutron capture as the simpler approximation that assumes that each gamma ray corresponds to an individual recoil event; however, the spectra are quite different in some cases.

9. On the Use of Thresholds in Damage Energy Calculations (ORNL) 69

It is pointed out that there is an inconsistency in the use of a displacement threshold with the damage energy model that is part of the standard procedure for expressing radiation effects exposures. A simple correction to the model is presented. Relative damge energies for fission and fusion reactor spectra are unaffected but the correction may influence correlations involving low energy primary recoil spectra (as for light ions).

10. Channeling in High Energy Displacement Cascades (HEDL) 78

High energy cascades generated with the MARLOWE code were analyzed using computer graphics. Channeling events occur frequently in high energy cascades, but they have little effect on the overall size and shape of cascades.

11. Cascade Quenching and Short-Term Annealing (HEDL) 86

The stochastic computer code ALSOME was used to simulate cascade quenching. Exaggerated values of defect mobilities and critical reaction distances for recombination and clustering were used until the number of defect pairs was reduced to the value determined from resistivity experiments at 4K. Normal mobilities and reaction distances were then used during short-term annealing to

Page

simulate Stage 111 recovery. The number of free vacancies depends strongly on the clustering criteria used during the quench. Preliminary results for 30-keV copper cascades are in good agreement with some experimental data.

12. 14-MeV Neutron Irradiation of Copper Alloys (U. of Wisconsin) **93**

Application of an unsaturable trap model to resistivity data on Cu and Cu alloys irradiated with 14-MeV neutrons at room temperature implies that at least 12% of the defects originally created survive the cascade event.

A review of the effect of clustering on resistivity reveals that, to a first approximation, the resistivity of a small cluster Id < 30 Å) may be equated to the sum of the resistivities of the individual defects.

CHAPTER 3: FUNDAMENTAL MECHANICAL BEHAVIOR 103

1. **Yield Strength-Microhardness Comparisons in 14-MeV Neutron-Irradiated Vanadium and Titanium (PNL)** **105**

Yield strength and microhardness measurements have been made on vanadium and titanium specimens following irradiation at 25°C with 14-MeV neutrons up to 2 x 10^{22} n/m^2. The yield strength increase in both materials followed a $(\phi t)^{0.5}$ fluence dependence. Microhardness of the vanadium increased with irradiation to 6 x 10^{21} m^{-2} and remained constant thereafter. Microhardness in the titarium showed a small increase only at the highest fluence. These results suggest that yield strength-microhardness correlations in irradiated metals may be limited to specific materials and neutron ftuences.

CONTENTS (Cont'd)

2. Critical Flaws in Fusion Reactor Materials (PNL) 116

Critical leak rate, fatigue and environmentally induced sub-critical crack growth and unstable crack growth flaw sizes for austenitic and ferritic stainless steels are compared. The critical leak rate flaw size is about 0.2 mm, the threshold flaw sizes for fatigue and corrosion fatigue sub-critical crack growth of 316 SS and HT-9 range from 0.2 to 2 mm, and the flaw sizes for unstable crack growth of irradiated 316 SS and HT-9 are 4 mm and 50 mm, respectively. These results suggest that the threshold for sub-critical crack growth in fatigue is a critical property.

3. Local Displacement Fields in Irradiated Materials (U. of Virginia) 135

In microtensile samples irradiated to high doses, cavities form which can be used as internal markers. From measurements of the elongation or displacement of these markers, a displacement map of the strain field in front of a crack tip can be constructed.

CHAPTER 4: CORRELATION METHODOLOGY 145

1. On the Correlation of Yield Strength Changes in 316 Stainless Steel Irradiated with High Energy and Fission Reactor Neutrons (HEDL) 147

A simple defect production function, based on the production of lobes in computer simulated cascades, correlates the changes in yield strength of SA 316 stainless steel irradiated with 14-MeV and fission neutrons much better than damage energy.

2. The Influence of Dislocation Density and Radiation on Carbon Activity in AISI 316 (U. of Wisconson and HEDL) 153

The interaction of carbon and dislocations induced by cold-working of AISI 316 is not as large as previously estimated by the authors,

Page

although it still may be sufficient at low irradiation temperatures to prolong the transient regime of swelling. A possible high temperature mechanism is based on the stability of carbide nuclei in a rapidly evolving dislocation network.

3. Microchemical Examination of Annealed AISI 316 (DO-Heat) Irradiated In HFIR (HEDL) 160

When a new and simple examination technique involving X-ray analysis of large areas of extraction replicas was applied to specimens irradiated in HFIR, the level of nickel and silicon segregated into precipitates was found to correlate with the level of swelling. The high level of nickel (29 wt.%) found in the precipitates of annealed AISI 316 (DO-heat) irradiated to 47 dpa at 550°C agrees with the level found independently by Garner and Porter in comparable specimens of a different heat of 316 irradiated in EBR-II.

4. Factors Influencing the Swelling of 300 Series Stainless Steels (HEDL and ANL-West) 170

It appears that the major effect of nickel content, temperature and displacement rate on swelling of 300 series steels is to alter the duration of the transient stage. Since the constant swelling rate stage is insensitive to temperature, this implies that swelling may not be very sensitive to the density of temperature-sensitive microstructural components or to helium.