TABLE OF CONTENTS

Annealed 316SS was irradiated at 90°C and 290°C in RTNS-II and in CWR. Radiation induced microstructures were examined by transmission electron microscopy. Very small dislocation loops of extremely high density were observed in dark field images. In the case of irradiations at 90°C and 290°C in RTNS-II and 90°C in CWR, the loop density increased moderately with dpa, roughly proportional to the square rwt of dpa, while that of 290°C irradiation at CWR showed stronger dpa dependence about 0.003 dpa, where the yield stress change also Increased strongly. The yield stress change was roughly proportional to the square root of the defect density, independent of irradiation temperature and neutron energy spectrum. The observed small dislocation loops are the origin of the yield stress change, with a Strength parameter estimated to be 0.2.

Micro-bulge testing was conducted on several Fe-Ni-Cr alloys irradiated as 0.3 mm thick disks to 10 dpa at 603 and 773 K in the Oak Ridge Research Reactor. Miniature tensile tests were performed on specimens of tha same alloys irradiated concurrently. Good correlation between the tensile yield strength and the bulge yield load was observed in unirradiated specimens; however, the correlation was not simple for irradiated specimens. Good correlation was also observed between the ultimate tensile strength and the maximum bulge load. While irradiation produced a significant reduction in total elongation in the tensile test, irradiation caused only a small decrease in the deflection corresponding to the maximum bulge load compared to that observed on thinner disks used in earlier experiments. The results suggest that the thinner disk is better suited for ductility evaluations than the thicker disk. The area bounded by the load-deflection traces of the bulge tests shows a systematic variation with both alloy composition and Irradiation condition which is not observed in the tensile data. It is anticipated that this parameter nay prove useful in the evaluation of material toughness.

The influence of helium on the microstructural evolution of irradiated metals is reviered. The review encompasses data from past work involving charged particle irradiations and neutron Irradiations in fission reactors, but emphasizes more recent results. Thls latter data was obtained from experiments in which either the reactor neutron spectrum or the isotopic content of the nickel in the irradiated alloys was tailored to yield a ratio of helium to displacement production (He/dpa ratio) that is near the value that will be obtained in a DT fusion reactor. Both the absolute level of helium present and the He/dpa ratio are shown to be important parameters. All major components of the irradiated microstructure — cavities, precipitates. and dislocations — are shown to be sensitive to helium as a result of either its direct influence on cavity formation, or its indirect effect on point defect and solute partitioning. The results emphasize the importance of careful experimental and theoretical analysis if data from fission reactor experiments are to be used in fusion reactor design. In particular, the effects of helium appear to be greatest during the swelling incubation period, the time of most practical interest for fusion reactor designers.

New concepts are reviewed which replace the conventional separation of microstructure evolution analysis into nucleation and growth. Classical nucleation theory is inadequate under fusion conditions (high helium-to-dpa ratios) and the usual "mean field" approximation of microstructural growth cannot account for cascade effects. A comprehensive theory of microstructure evolution Under fusion conditions is formulated based on non-equilibrium statistical mechanics. Dynamic re-solution of helium gas in cavities is shown to result in continuous nucleation of helium-filled cavities. Microstructure evolution (e.g., dislocation loops and cavities) is modeled by kinetic rate equations for small size features and Fakker-Planck (F-P) equations for sizes larger than fed atomic dimensions. Semi-analytical and numerical methods are developed for the analysis of microstructure evolution and the results are compared to experiments. The problem of spatial self-organization of microstructures under irradiation is described in terms of a nwly developed Ginzburg-Landau-type equation and the results are also conpared to experiments.

Point-defect generation by energetic displacment events is known to take place when a lattice atom requires an energy several tines its lattice binding value. In this energy range, many-body effects are important and interatomic pair potentials generally give poor representations of atomic interactions. By applying our nerly developed molecular-dynamics code, CASC-MD, we investigate the influence of aany-body interatomic interactions on the generation Characteristics of p i n t defects. We use a composite interatomic potential Which assumes the pair-potential nature at high energles and the many-body nature, based on the embedded-atom formalism, at low energies. It is shown that many-body effects lead to lower directional sensitivity of the displacenent threshold surface. For a 60-eV collision cascade in Cu, it is shown that the length of the replacement collision sequence decreases from 6 lattice constants at low temperature [near 0 K) to 1.5 lattice constants near the melting point.

The degree of sensitization of 25% cold-worked PCA irradiated at 60, 200, 330, and 400°C up to 7 dpa under spectrally tailored conditions in the ORR-MFE-6J/7J experiments was evaluated by the electrochemical potentiokinetic reactivation (EPR) test technique on miniaturized TEM disk-type specimens. Irradiation at 60°C to 7 dpa did not affect the reactivation behavior of PCA. The reactivation charge of PCA was increased by the Irradiation at 200, 330, and 400°C, as conpared with unirradiated Control specimens. and increased with increasing irradiation tenperature. Post-EPR examination of the specimen surfaces showed grain boundary etching for the specimen irradiated at 400°C, but not for the specimens irradiated at 330°C and below. This indicates that the intergranular stress corrosion cracking (IGSCC) susceptibility associated with chromium depletion along grain boundaries was not increased by the irradiation at temperatures below 330°C to this damage level. Localized attack across the grain faces was observed for all the specimens irradiated at 200, 330, and 400°C, which suggests the Occurrence of localized sensitization in the grain interior. The Investigation of the possibility of the localized sensitization in grain interiors and its effects on the corrosion behavior is in progress.

The FUBR-1B irradiation experiment in EBR-II has provided important information on the irradiation behavior of candidate lithium solid breeder materials in a high energy neutron Spectrum. The solid breeder materials include Li_2O, $LiAlO_2$, Li_2ZrO_3, Li_8ZrO_6 and Li_4SiO_4 pallets and $LiAlO_2$ spheres. The irradiation behavior of the materials was characterized for the temperature range from 400 to 900°C. The amount of tritium retained by the solid breeder materials, as well as swelling and physical stability, was detemined for specimens removed after the first period of irradlatlon.

LiAlO,. Li_2ZrO_3, and Li_8ZrO_6 exhibited excellent dimensional stability during irradiation while the dimensional stability of Li_2O was found to be dependent on the microstructure. The amount of retained tritium is compared to similar closed capsule experiments and extends the data to burnups as high as 1.6×10^{21} at/cc.

Temperature programmed desorption (TPD) measurements have started on the $LiAlO_2$-H_2 system. The sensitivity of the mass spectrometer that will detect the peaks was shown to be adequate for the measurements. Blank experiments to Characterize the behavior of the stainless steel sample tube in the measurements have revealed the evolution of N from the steel, a process facilitated by H_2. It is necessary to stabilize the sample tube so that it does not augment or distort the TPD peaks. The behavior of an unstabilized tube was demonstrated by means of a simulated TPD run. Stabilization consists of treating the tube with 990 ppm H_2 in helium at high temperature until undistorted simulated TPD runs are obtained. A $LiAlO_2$ sample was loaded in the apparatus: it came from the same batch of material that was used in an EXOTIC test. Prolonged drying of the sample in a He-H_2 stream is necessary, a finding that has important implications for many earlier reports on measurements of tritium release from irradiated samples where it was not demonstrated that the sample was adequately dry or that the apparatus did not affect the data.

Polycrystalline specimens of spinel ($MgAl_2O_4$) and alumina (Al_2O_3) were irradiated at room temperature and 650°C with either dual- or triple-ion beams in order to investigate the effects of simultaneous displacement damage and helium implantation on cavity formation. The cavities in alumina were aligned along the direction of the c-axis, with diameters ranging from <2 to 10 nm. The cavities in spinel were preferentially associated with dislocation loops and were of similar size as the cavities in alumina. Catastrophic amounts of Cavitation were observed at the grain boundaries in spinel when the displacement damage level exceeded a critical value (~20 dpa) in the presence of a fusion-relevant (~60 appm/dpa) helium environment.

A series of experiments have been planned to measure the dielectric properties of alumina in the presence of ionizing and displacive irradiation.

A stock of commercial, polycrystalline alumina with four different levels of purity (0.94, 0.976, 0.995, and 0.998) has been added to the Fusion Reactor Materials inventory. The material is in the form of 3/4 in. (0.998) and 1 in. (0.94) diameter rods and 2 in. by 2 in. bars (0.976 and 0.995).