Overview

This publication contains the majority of the papers presented at the Twelfth International Symposium on Effects of Radiation on Materials, held in Williamsburg, Virginia on 18–20 June 1984. This biennial symposium series was begun in 1960 and has become a major international forum for the exchange and discussion of both the fundamental and technological aspects of behavior change in materials exposed to radiation environments. With a few exceptions contained in the last section, the data presented in these proceedings are primarily concerned with the response of metals to neutron or charged particle irradiation. As in the past, the performance of nuclear fuels is not included since this topic receives adequate treatment in other forums.

In the first section a significant amount of recent data on *Irradiation Creep of Structural Metals* is compiled, concentrating on both ferritic and austenitic alloys. Continuing a trend established earlier in this symposium series, there are several papers detailing the creep response of alloys to nonisothermal reactor histories. Two papers in this section concentrate on the microstructural origins of irradiation creep, with one demonstrating conclusively that creep deformation generates and is in turn sustained by the development of an anisotropic distribution of dislocation Burgers vectors.

The second section on *Microstructural Development* explores the changes in microstructure, microcomposition, and phase stability that accompany and cause macroscopic changes in physical properties or dimensions. A significant new observation is that irradiation can induce spinodal decomposition in some alloys which are not known to decompose by this mechanism in nonradiation environments.

In *Neutron-Induced Swelling* a large amount of data is shown that demonstrates that austenitic alloys tend to swell at a rate of ~1%/dpa following a transient regime. While this posttransient regime is very insensitive to composition, temperature, and other variables, the duration of the transient regime is quite sensitive to major element composition, particularly at relatively high irradiation temperatures. Minor elements such as titanium also exhibit a pronounced influence. There is a minimum transient period, however, of ~10 dpa that cannot be shortened by variations in composition or environmental variables. One new and surprising conclusion is that the application of compressive stress does not lengthen the transient duration as has been routinely assumed. Both compressive and tensile stresses were shown to equally influence void nucleation so as only to shorten the transient regime.

In the section on *Charged Particle Irradiation* the application of tensile stresses was confirmed to operate on void nucleation and the transient duration, but a correspondence between void and Frank loop development was also found. A number of papers explored the influence of helium on radiation-induced microstructural development, although some differences of opinion are expressed as to whether the influence of helium observed in the simulation will be representative of that experienced in the neutron environment. Several papers in this and the next section explore the possibility that the injected interstitial represented by the bombarding ion not only distorts the swelling response but also the effect of helium. One significant finding presented in this section is that highly focused electron beams cause segregation of alloy components and thereby create phase instabilities in a manner quite atypical of the neutron environment. Charged particle irradiation was also used to forecast that high-strength copper alloys may undergo a significant degradation in mechanical properties as a result of radiation-affected dislocation recovery and grain recrystallization.

In *Theory of Swelling* most papers focus on the nucleation stage of void formation, exploring the role of impurities, composition, and helium. One paper proposes a model for the formation of void lattices based on two-dimensional diffusion of self-interstitials and the shadowing effect of voids on the diffusion of interstitials in their vicinity.

The *Mechanical Properties* section contains a wide variety of papers. One group of papers explores the radiation-induced changes in fracture toughness of iron-based austenitic and ferritic alloys as well as that of various zirconium alloys. Another group of papers addresses fatigue behavior in thermal and fast reactors, while yet another group considers the microstructural origin of radiation-induced mechanical property changes. The data presented in the symposium both confirmed and extended the prevailing perceptions of the effect of radiation on mechanical properties; no significantly new or different phenomena were disclosed, however.

The *Pressure Vessel Steels* section of this conference has been growing at each meeting. A review was made of irradiation testing performed over the last 12 years on pressure vessel steels and their weldments. The studies of the last few years have confirmed the significance of chemistry control in governing irradiation resistance of ferritic steels. Copper has consistently shown up as the principal element over which control must be maintained. However, other elements such as nickel, when combined with copper, enhance copper's effect, and phosphorus and manganese were shown by some investigators to have a measurable influence. The discernment of the actual mechanisms involved for each of these elements is not made easy due to the inability to date to see clear evidence of radiation damage using electron microscopy. Field ion emission microscopy may offer promise over conventional transmission electron microscopy. The thought was also offered that boron is of significance due to its transmutation where thermal to fast neutron ratios are high.

Although the chemistry issue is not totally resolved, current damage trend curves do show a definitive relationship to the major contributory element, copper, especially at high fluences. The current status appears to be that the irradiation effects data have been exhaustively analyzed and correlation with postulated damage models is reasonably good. Further work is necessary to provide microstructural evidence of damage and establish relatively narrow bounds on alloy composition. The concentration of experiments on commercial pressure vessel alloys has not provided the range and variety of elements necessary to confidently establish these bounds, however. The concentration of effort on Charpy tests was also questioned and examination of other properties related to mechanical behavior, including microhardness changes, has been undertaken. The relation of the damage to fracture toughness has been more closely studied, but the significance of the upper shelf energy values provided by Charpy curves still escapes full understanding.

The annealing-out of radiation damage was reviewed in a number of papers. The likelihood of successfully "wet" annealing of pressure vessel damage for extended times at 650°F was shown to be relatively low. A higher temperature "dry" anneal is considered feasible but its cost-effectiveness and the treatment of the vessel nozzles and their attached piping remain as concerns.

In the *Irradiation Facilities* section only two of the papers presented were provided for these proceedings. These papers involve the Los Alamos Meson Physics Facility (LAMPF). The absent papers addressed the proposed Fusion Materials Irradiation Test (FMIT) Facility and the Materials Open Test Assembly (MOTA), an experimental test facility currently operating in the FFTF fast reactor in Richland, Washington.

The final section on *Other Radiation Studies* covers three papers that do not easily fit in the other categories. These are a modified method of helium introduction into alloys via the tritium trick, radiation damage aspects of a novel method for providing safe storage of Krypton-85 from fuel reprocessing, and radiation effects on resins and zeolites forming part of the waste stream from the clean-up effort at the Three Mile Island Nuclear Plant.

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