SIMULATION OF NEUTRON DAMAGE BY ION BOMBARDMENT

J. O. Stiegler

Existing neutron sources and reactors often have fluxes or spectra far removed from potential reactor conditions. For example, no operating neutron facility comes close to duplicating the environment expected in the first wall of a controlled thermonuclear reactor. This is the vacuum wall inside which the plasma is confined by a magnetic field. It must face an unmoderated current of 14.1-MeV neutrons born in the fusion process on the order of 10^{14} neutrons/cm^2-sec. Although fission reactors are available with higher fluxes, few of the neutrons have energies above a few MeV; and fluxes in operating 14.1-MeV neutron generators are at least two orders of magnitude too low to be useful. There is no evidence that the higher energy neutrons by themselves will change the form of the radiation damage. However, since cross sections for many transmutation reactions increase with increasing neutron energy and since many reactions have thresholds above 5 MeV, large differences between irradiation in fission and fusion reactors are expected in the rate of formation of transmutation products and in their possible interactions with the displaced atoms. This is illustrated in Table 1, which compares transmutation rates in a high flux fission reaction (EBR-II) and in a possible CTR. We can simulate the CRT situation by ion bombardment by irradiating, e.g., niobium with niobium ions to simulate the atomic displacements and by implanting hydrogen, helium, and zirconium in appropriate concentrations.

A second justification for ion bombardment simulation of neutron damage is economy of both time and dollars. Four or more years may elapse between the time a high dose neutron irradiation experiment is conceived and the time it is finally evaluated. Needless to say, the experiment design and construction costs and hot cell expenses for neutron irradiations are substantial. Ion currents available to us are high enough that damage equivalent to several years of neutron bombardment can be accummulated in a few hours. This allows rapid testing of ideas and screening of materials for potential reactor applications.

At ORNL we have equipped the 6-MV Van de Graaff with multiple ion sources to produce the displacement damage and to inject the "transmutation products." We have also constructed a high vacuum, high temperature chamber in which to conduct the irradiations. These units currently are being mated and should be operational in a few days. We know from work done elsewhere that from a qualitative viewpoint, ion bombardment will duplicate the damage produced by neutron irradiation. Because of the accelerated rate of production of the damage, quantitative differences are known to exist. During the next year we will establish the quantitative relationships between ion bombardment and neutron irradiation and then proceed to study the effects of transmutation products and metallurgical variables on the damage state. This program is being supplemented by work in the Solid State Division, including theoretical calculations of displacement rates and experimental measurements of relative displacement rates by different bombardment techniques.

Table 1

Comparison of Reactor Transmutation Rates[a]

Metal	Reactor	Helium (ppm/yr)	Hydrogen (ppm/yr)	Solid Products (%/yr)
Nb	CTR Wall[b]	270	890	1.4 (Zr, Mo, Y)
Nb	EBR-II Core	4	180	----
V	CTR Wall[b]	790	1500	$\sim$0.7 (Cr, Ti)
V	EBR-II Core	3.5	100	----

[a]Calculations by Don Steiner, Reactor Division.

[b]Wall loading of 10 MW/m^2.