MECHANICAL PROPERTY EVALUATION OF REACTOR MATERIALS BY ION BOMBARDMENT SIMULATION

M.Shimada
Nuclear Engineering Laboratory, TOSHIBA Corporation

Abstract

To induce radiation damage in the materials, it has been widely known to use ion bombardment simulation technique especially in the regime of void swelling. A few MeV metallic ions, such as Ni^{+} 1) or few tens of MeV of C^{++} 2) or Ni^{6+} 3) are the examples. As those ions penetrate, at most, a few micrometers beneath the target surface, the electron microscopic observation is the major possible postirradiation evaluation method.

In this work, two experiences will be presented, where by using higher accelerating energies and lighter ion species, the bombarding ion can penetrate through the target materials, leaving only radiation damage within the materials.

1. Creep under irradiation

The creep in-reactor may differ from the thermal creep behavior because of the co-occurance of damage production and plastic deformation. There is, in reality, an observation that the creep rate under irradiation is several times faster than the thermal creep rate4).

There are, however, some difficulties in carrying out irradiation creep in-reactor under well controlled experimental conditions from the point of facility capability as well as economical allowability. For these reasons, the ion irradiation simulation technique has been applied to irradiation creep.

3.5 MeV protons were irradiated to zirconium alloy (Zircaloy-2) at a rate of 6×10^{-7} dpa/s at 325°C and the correlation between stress and creep rate was studied. The elongation during irradiation was measured by LVDT 9Linear Variable Differentioal Transformer) of which sensitivity is 5×10^{-6} cm.

As a result, it was shown that the creep rate is proportional to the applied stress and that even under no stress, the elongation (irradiation growth) was observed.

2. Ductility loss in iodine environment5)

To study mechanical property of irradiated materials, 52 MeV alpha particles were irradiated to dumbbell shaped specimens at 340°C up to 4×10^{18} α/cm^2 by Harwell VEC cyclotron. The overall dimension is 33mm long by 0.4mm thick; the reduced gauge section is 18mm long by 2.5mm wide. Prior to the irradiation, three different kinds of heat treatment were given to the specimens. In some cases, 100 MPa of stress was applied during irradiation. Post-irradiation tensile test was performed at a strain rate of 6.4×10^{-4}/min in argon gas or 4 Torr. of iodine gas environment at a temperature of 350°C.

In both test environment, the ductility loss began to appear from the $4x10^{17}\alpha/cm^2$ dosage. And the ductility loss appeared more prominent in iodine environment indicating the occurrence of stress corrosion cracking. The ductility loss was also affected by preirradiation heat treatment, where 580°C annealed specimen showed the most resistant charactor. The stress applied during irradiation enhanced the ductility loss and lowered the on-set dosage of ductility loss compared to the stress free irradiation.

As shown by the above examples, the ion bombardment has many usefull advantages in oerforming irradiation experiment in elaborate conditions in a short duration. Besides radio-activity induced by ion bombardment is very much lower than by reactor irradiations.

References

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