Helium Ion Irradiation Experiments Using Controlled Energy Degrader

著者	Masuyama T., Hasegawa A., Abe K.
journal or publication title	CYRIC annual report
volume	1992
page range	64-68
year	1992
URL	http://hdl.handle.net/10097/49694

I. 14. Helium Ion Irradiation Experiments Using Controlled Energy Degrader.

Masuyama T. , Hasegawa A. and Abe K.

Department of Nuclear Engineering, Tohoku University

Introduction

Light ion accelerators, which can produce ion beams with enough ranges (larger than 100μA), are utilized to study mechanical property changes under fusion reactor conditions[1)] Coexisting of displacement damage and transmuted helium by fast neutron irradiation is a characteristic condition of fusion reactor. Three types of irradiation mode by accelerator have been used to study the influence of displacement damage and helium on the mechanical property changes in metals and alloys (Fig. 1).

Type I: Light ion(proton and α) beams penetrate the specimen. Since the range of ions is fairly larger than the specimen thickness, almost uniform distribution of displacement damage is produced in the specimen(Fig. 1(a)). Using this irradiation mode, the correlation of yield stress changes among light ions, fusion neutrons was studied[2)].

Type II: Helium ions are bombarded into the specimen. Since the range of ions is fairly smaller than the specimen thickness, displacement damage and helium atoms distribute in the specimen(Fig. 1(b)). The depth profile of microhardness was measured along the implanted direction and the effects of helium and displacement damage on the microhardness were studied[3)].

Type III: Helium ions are implanted to the specimen. Since various ion-ranges are produced by an energy degrader and implanted to the specimen, uniform helium distribution along the implanted direction is obtained by this mode(Fig. 1(c)). The influence of preimplanted helium on creep rupture behavior was studied[4)] with this mode. This report describes the development of a tandem type energy degrader with stepping motors and a computerized control system for advanced type III irradiation mode.

Tandem type energy degrader

The tandem type energy degrader system was installed in the material irradiation chamber at 32 course of CYRIC. Irradiated particle is α(^{4}He). Accelerating energy was 36 MeV. The ranges of 36 MeV-α in some candidate materials for fusion reactor are as follows[5]; Steel:195 μm, Vanadium:272 μm, Mo:213 μm. The ranges are large enough to study mechanical properties.

Figure 2 shows schematic diagrams of the tandem type energy degrader. The degrader was set in front of sample stage. It consists of two rotating disks. The disks have a diameter of 200 mm and are made of titanium. One disk is a energy degrader and the other is a multipurpose disk. Figure 3 shows schematic illustration of control system of the energy degrader. The degraders are rotated by stepping motors which are controlled by personal computer. Each degrader can be controlled by different rotating mode.

The first degrader is located on the multi-purpose disk. There are a beam profile monitor, a transmitted beam window and a degrader window area on the disk. Aluminum foils were used for energy degrading materials. Projected range of 36 MeV-α particles in aluminum is 525μm[5]. The window of the first degrader has five sections with aluminum foils from 0, 6, 7, 8, 9 μm thickness and rotates reciprocally. The second degrader is on the other disk. It is a wheel type degrader and it has 105 sections with aluminum foils from 0 to 520 μm thickness in 5 μm steps. The wheel rotates one direction. Combining two degraders it has 525 sections with aluminum foils from 5 to 529 thickness in 1 μm steps and 1 section without foil.

In the present arrangement, second degrader decides the depth of main helium-peaks and the first degrader extends effectively the width of the main peaks. Figure 4 shows estimation of depth profiles[5] in helium distribution by second degrader and by combination of first and second degrader. Thickness step of aluminum foils by 1 μm is small enough to produce uniform distribution of helium in specimens(Mo, V or steel). A merit of the tandem type arrangement is to use commercial type aluminum foils to obtain the uniform helium distribution. Results of mechanical property change by this helium implantation technique were presented else where[6]

Application

In the case of helium implantation experiments, the ratio of helium concentration to displacement damage (He/dpa) is fixed. In the case of 36 MeV-α implantation to vanadium, He/dpa is about 10000. In order to change the He/dpa parameter with a single-beam(a particle) irradiation apparatus(ex. CYRIC), type-I and type-III mode should be combined by the computer-controlled tandem degrader. Figure 5 shows a schematic illustration of the combined mode. Displacement damage is produced by penetrating beam though the part without foils on the degrader and helium is implanted by penetrating beam though the degrader foil area. The He/dpa ratio will be able to varied by changing the durations of the implant mode(typeIII) and the penetrate mode(type-I) by means of stepping motor control system.

The defect microstructure are influenced not only by the parameters of displacement damege (dpa) and He/dpa, but also by the details in the combination of displacement damage and helium atoms, that is, the cascade damage distribution and helium production rate etc. Therefore, the foil arrangement and the rotation cycle of degrader should be important parameters in this application.

Acknowledgments

The authors express thanks to T. Takahashi, K. Komatsu and T. Nagaya for making experimental apparatus and to staffs of CYRIC for beam experiment.

References

1) Ullmaier H., Radiation Effects, vol.**101** (1987) p.147
2) Abe K., Nagase F. and Morozumi S., J. Nucl. Mater., **179-181** (1991) 1088.
3) Abe K., Hasegawa A. and Morozumi S., Radiation Effects, **101** (1987) 237.
4) Schroeder H. and Batfalsky P., J. Nucl. Mater., **122/123** (1984) 1475.
5) Ziegler J. F., Biersack J. P. and Littmark U., The Stopping and Range of Ions in Solids, Pergamon Press (1985)
6) Masuyama T. et al., Proc. of the Int. Conf. on Evolution in Beam Applications, Takasaki, Japan, Nov.5-**8** (1991) p.729

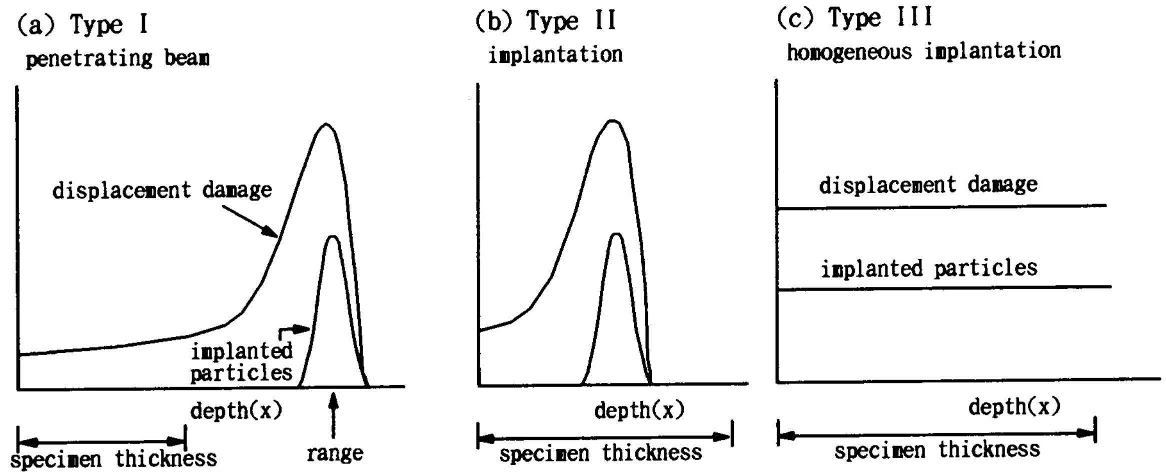

Fig. 1. Three types of irradiation mode to study mechanical properties utilizing light ions.

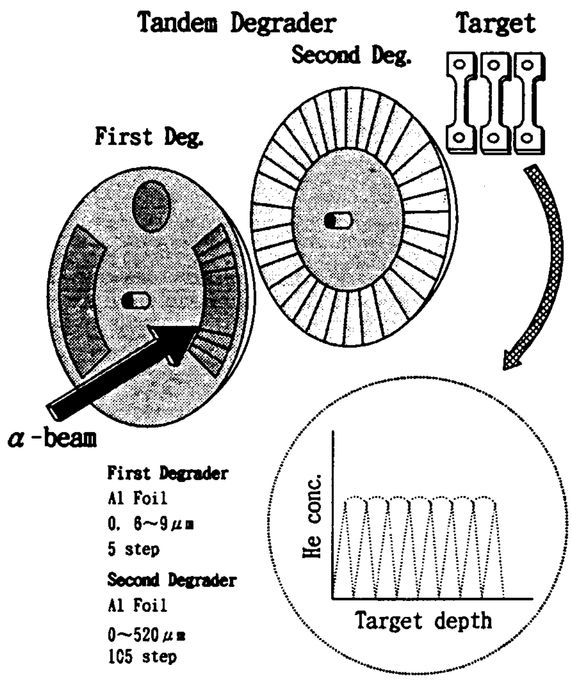

Fig. 2. Schematic diagrams of the tandem type energy degrader.

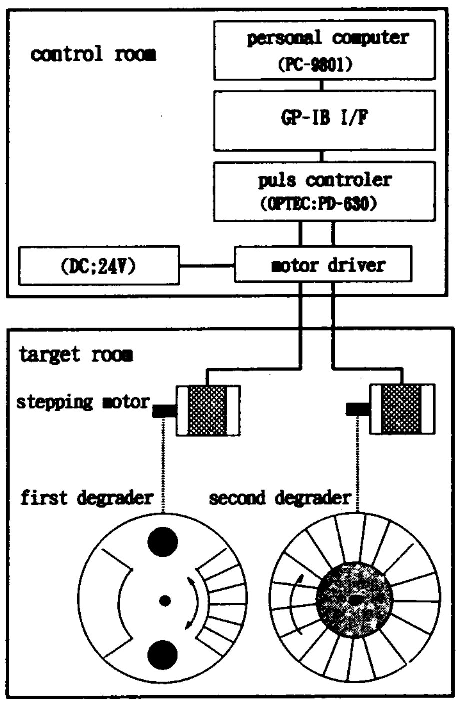

Fig. 3. Schematic illustration of control system of the tandem type energy degrader.

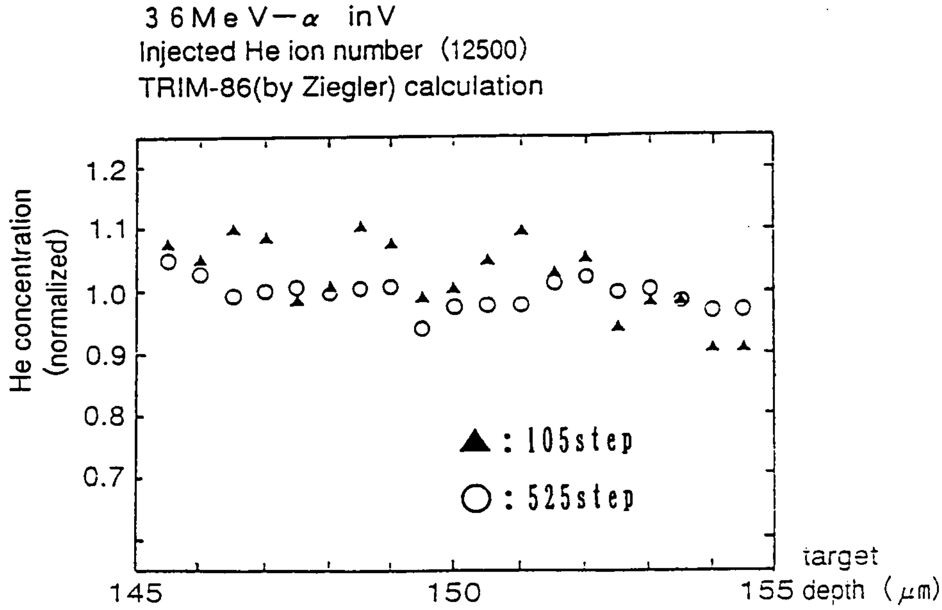

Fig. 4. Estimation of depth profile in helium concentration by TRIM-85 code. Typicalexample at depth between 145 and 155mm in vanadium.

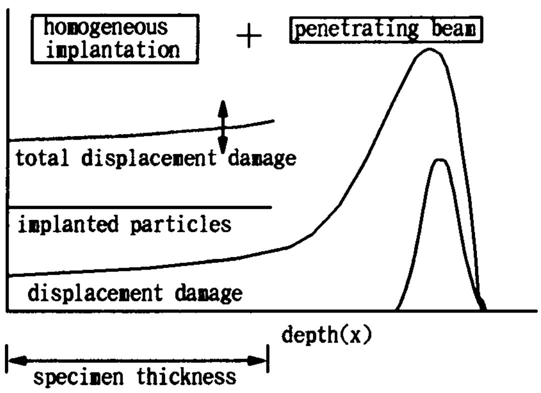

Fig. 5. Combination of penetration mode and implant mode to change the ratio of helium concentration to displacement damage.