§3. Effect of Neutron Irradiation on Tritium Behaviors in Fusion Materials

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Understanding of tritium behavior (diffusion, trapping, desorption, etc.) in neutron-irradiated materials is indispensable for evaluation of tritium balance in fusion reactors. The objective of this work is to discuss up-to-date results of ion-irradiation experiments and theoretical studies in Japanese universities for planning of neutron-irradiation experiments in Japan-US joint project TITAN and interpretation of data form the project. Attention is focused on tungsten due to lack of data on irradiated samples.

It is known that defects such as vacancies and dislocations in tungsten act as strong trapping sites against hydrogen isotopes. Indeed, Fukumoto et al.[1] have reported that deuterium retention reached 1 at.% after irradiation to 4.8 dpa at 200 ^{o}C. One of the purposes of Task 2-1 in TITAN project is to clarify whether neutron irradiation led to similar increase in tritium retention. Tungsten samples are irradiated in High Flux Isotope Reactor (HFIR) in Oak Ridge National Laboratory (ORNL), and then tritium retention in the irradiate samples are examined with a linear tritium plasma device called TPE (Tritium Plasma Experiment) in Idaho National Laboratory (INL). On the other hand, it is also well known that exposure of tungsten surface to hydrogen plasma results in formation of blisters and a large amount of hydrogen is retained in blisters. In TITAN project, the influence of blisters has to be minimized to observe clearly the effects of neutron irradiation in the bulk of samples.

We have decided, through the discussion in this work, to prepare the samples for neutron irradiation by slicing rods of pure tungsten. In the samples thus prepared, grains are elongated in perpendicular direction to the surfaces, and tritium implanted from the surface cannot be accumulated in grain boundaries to form blisters. Rods of pure tungsten (99.99 % and 6 or 3 mm diameter) were supplied under stress-relieved and recrystallized conditions by A. L. M. T. Co., Japan. Disk type specimens (0.2 mm thickness) were prepared from these rods. Both surfaces were polished with diamond powders (9 and 3 μm) and colloidal silica (0.04 μm). Finally, the samples were heated in vacuum at 900 ^{o}C (stress-relieved conditions) or 1300 ^{o}C (recrystallized conditions) to remove damage induced by polishing. Fig. 1 shows the samples thus prepared together with the rods. Larger samples (ϕ6 mm) are used for tritium retention experiments, and smaller ones (ϕ3 mm) are for microstructure observation. Non-irradiated samples under stress-relieved and recrystallized conditions were exposed to deuterium plasma with TPE in TITAN project. Blisters were observed after exposure, but their size was small and density was low. The amount of retained deuterium showed the dependence on microstructure of samples, indicating influence of blisters was sufficiently small.

Conditions of neutron irradiation are also discussed. Microstructure of irradiated tungsten is known to be sensitively dependent on irradiation temperature; the structure consists of small dislocation loops at ≤ 400 ^{o}C and formation of voids occurs at higher temperatures.[2] In order to separate the trapping effects of different types of defects, we decided to irradiate the samples at three temperatures: 80, 300 and 650 ^{o}C.

Irradiation matrix in TITAN project Task 2-1 is summarized in Table 1. Samples of pure Ni under cold-rolled conditions (10% strain) and recrystallized conditions were also prepared for fundamental investigation on defect-tritium interactions. Several disks of F82H and those with tungsten coating prepared by vacuum spray method are also irradiated for preliminary study. These samples have been sent to ORNL. The irradiation at 0.1 dpa and 80 ^{o}C was completed in January 2009.

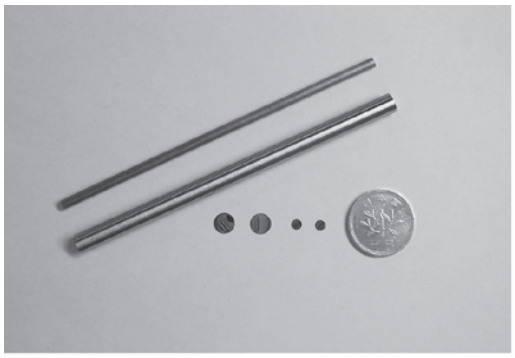

Fig. 1. Tungsten disk samples for neutron irradiation in HFIR.

Table 1 Irradiation matrix of TITAN project Task 2-1

Dose (dpa)	0.1	1.2			9.6	
Temp. (^{o}C)	80	80	300	650	300	650
W-SR (ϕ6)	6	8	4	4	4	4
W-SR (ϕ3)	6	6	3	3	3	3
W-RX (ϕ6)	0	4	4	4	4	4
W-RX (ϕ3)	0	3	3	3	3	3
F82H (ϕ6)	0	0	0	0	2	0
W-F82H	0	0	0	0	3	0
Ni-RX (ϕ6)	6	6	4	0	0	0
Ni-RX (ϕ3)	4	5	3	0	0	0
Ni-CR (ϕ6)	6	6	4	0	0	0
Ni-CR (ϕ3)	4	5	3	0	0	0

SR: stress-relieved, RX: recrystallized, CR: cold-rolled

1) Fukumoto M. Et al.: J. Nucl. Mater.: **390-391** (2009) 572-575.
2) V. Barabash, G. Federici, J. Linke, C. H. Wu, J. Nucl. Mater.: **313-316** (2003) 42-51.