§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 from the project. Attention is focused on tungsten (W) due to lack of data on irradiated samples.

In TITAN project, disk-type samples of W and Ni are irradiated by neutron in High Flux Isotope Reactor (HFIR) in Oak Ridge National Laboratory (ORNL), and retention of hydrogen isotopes is examined with linear plasma machine TPE in Idaho National Laboratory (INL). The samples irradiated in January 2009 at coolant temperature (50 ^{o}C) for 0.025 dpa (W) and 0.1 dpa (Ni) were transported from ORNL to INL in November 2009. In INL, the samples were first examined visually and radionuclides formed by neutron irradiation were identified by γ-spectrometry. It was found by γ-spectrometry that ^{188}W and ^{188}Re are major γ emitters in the W samples. The radioactivity of these nuclides was evaluated to be ca. 7 MBq in one samples in December 2009; ^{188}Re should be in secular equilibrium with ^{188}W. The visual examination showed that the surfaces of W samples were covered by black contaminant (Fig. 1), although the samples were kept in sealed Mo envelopes during irradiation. One of W samples was exposed to deuterium plasma by TPE at ca. 200 ^{o}C and flux of 5.0×10^{21} D m^{-2}s^{-1} for 2.0 h (fluence 3.6×10^{25} D m^{-2}). After exposure to deuterium plasma, the black contaminant completely disappeared from the exposed surface, indicating this black matter is the layer of W oxides. The cause of oxide formation was considered to be a leak in Mo envelopes resulting in reaction between samples and coolant water. Although the contaminant remained on side and backside, preliminary thermal desorption spectrum was measured as shown in Fig. 2.

Under the framework of this collaboration, the radioactivity of ^{188}W and ^{188}Re was compared with the value obtained by calculation with FISPACT-2001 code in NIFS (by Dr. T. Tanaka). The values evaluated with the code agreed well with those obtained by γ-spectrometry. In addition, the calculation indicated the presence of ^{181}W and ^{185}W. These nuclides are β-emitter and cannot be detected by γ-spectrometry. Characterization of radiation defects by a positron annihilation technique is planned to be carried out in Japan. Discussion in this collaboration derived tentative conclusion that the presence of these radionuclides would not severely disturb the analysis. Interpretation of the thermal desorption spectrum was also the matter of consideration. Characteristic points of spectrum from neutron-irradiated samples are: (1) burst-like desorption observed in the low temperature region (＜100 ^{o}C), and (2) continuation of desorption in the temperature range above 500 ^{o}C. The burst-like desorption was ascribed to deuterium release from oxide layers on the side and backside. The desorption in the high temperature region was attributed to the trapping effects by defects created by neutron irradiation. The influence of contaminant remaining at the side and backside on the spectrum was not fully understood, and it was recommended to repeat the measurements after complete removal of contaminant from all surfaces. The method to remove contaminant was also discussed. Careful comparison of desorption spectra from neutron- and ion-irradiated samples would provide information on the capability of ion-irradiation techniques to simulate the effects of neutron irradiation. The conditions to prepare ion-irradiated samples were dissected.

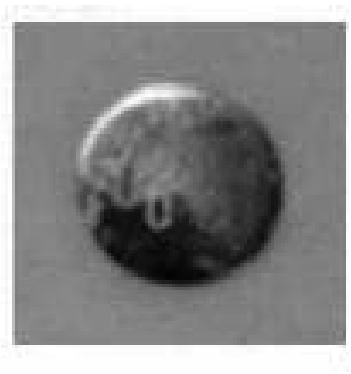

Fig. 1. Photo of W sample irradiated by neutron in HFIR at 50 ^{o}C for 0.025 dpa..

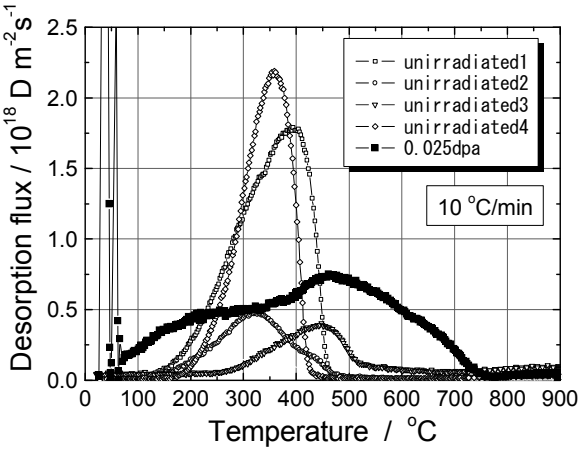

Fig. 2. Preliminary data on deuterium desorption from W sample irradiated by neutron at 50 ^{o}C for 0.025 dpa and exposed to deuterium plasma by TPE at ca. 200 ^{o}C. Spectra from unirradiated tungsten samples are also shown.