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重水素プラズマ曝露したタングステンにおける表面化学状態変化と重水素滞留挙動

Study of correlation between deuterium retention behavior and surface chemical state in deuterium plasma exposed tungsten

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Tungsten will be used as a plasma facing material (PFM) in D-T fusion reactors. The PFM was exposed to D-T plasma and the hydrogen isotopes were implanted into the PFM. In addition, a deposition layer was formed by impurities like carbon and oxygen during plasma operation, which led to cause higher hydrogen isotope retention in PFM. It is important to elucidate fundamental tritium retention and transport behaviors in tungsten under well-controlled condition for understanding fuel recycling in actual conditions. In this study, the deuterium plasma exposure to tungsten of different grain boundary samples was performed to clarify the deuterium retention behavior and the formation of the deposition layer on the tungsten surface during deuterium plasma operation at room temperature as a preliminary experiment. The deuterium retention for the plasma-exposed tungsten was evaluated by TDS (Thermal Desorption Spectroscopy), and the chemical states of the impurity deposition layer were measured by XPS (X-ray Photoelectron Spectroscopy).

Disk-type of stress-relieved polycrystalline tungsten (Stress-relieved), recrystallized polycrystalline tungsten (Recrystallized) and single crystal tungsten (Single crystal), which were purchased from Allied Material Co. Ltd., were used for all experiments. The samples size were 10 mm diameter and 0.5 mm thickness. The samples were preheated at 873 K for 30 minutes into the plasma exposure system to remove the impurities. The D^+ plasma exposure was carried out at room temperature with the D^+ ion energy of 100 eV. The ion fluence was set to be (1.2-1.8) × 10^{25} D^+ m^{-2}. After the plasma exposure, TDS measurements were performed from R.T. up to 1173 K with a heating rate of 0.5 K s^{-1} to investigate the deuterium desorption and retention behaviors. The chemical state and the thickness of the impurity deposition layer on the samples were evaluated by XPS with using Ar^+ sputtering technique.

The D_2-TDS spectrum for Stress-relieved sample consisted of two desorption stages at 400 K and 550 K. The desorption stage at 400 K was attributed to the desorption of deuterium adsorbed on the surface from the previous results. The deuterium retention as the desorption stage at 550 K was increased with increasing ion fluence. The irradiation defects would hardly formed in tungsten sample during plasma exposure according to SRIM (Stopping Range of Ion in Mater) code calculation, it was considered that these deuterium retentions were caused by the trapping of impurity deposition layer and/or grain boundary. Figure compares the D_2-TDS spectra for Stress-relived, Recrystallized and Single crystal samples. The deuterium retention of Recrystallized was 2.45 × 10^{19} D^+ m^{-2}, it was the largest among these samples. The highest deuterium retention was derived for the Single crystal sample. The Single crystal has no grain boundary, and the grain boundary of Recrystallized was different from the Stress-relieved. In addition, the impurity deposition layers were formed, and these chemical states and depth profile were the same with each other. The impurity desorption layers were consisted of WO_3 on the surface. This presentation would be discussed about the effects of sample chemical state and/or grain boundary on the deuterium desorption behavior.

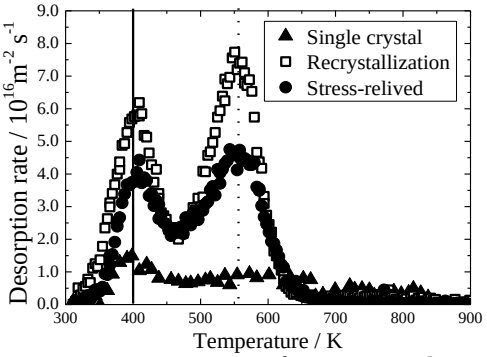

Fig D_2 TDS spectra for W exposed to deuterium plasma