§7. Helium Retention and Thermal Desorption Properties of V-4Cr-4Ti Alloy (NIFS-HEAT2)

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Vanadium alloy is an attractive structural material used for fusion reactor because of its low induced radioactivity and good thermal and mechanical properties at high temperatures. The vanadium alloy, V-4Cr-4Ti, may be a promising material because it shows excellent mechanical tolerance to neutron damage and low helium and hydrogen production rate during 14 MeV neutron irradiation. The first wall of V-alloy is exposed to helium ions with different energies during helium glow discharge cleaning and helium ash resulting from fusion reactions. Therefore, it is important to investigate the He retention property of the V-alloy after He ion irradiation. In this study, the helium retention property of V-4Cr-4Ti alloy (NIFS HEAT2) was examined by using an ECR ion irradiation apparatus. Ion energy of helium was taken at 5 keV, which the projected range of He ion in the sample is ~27 nm. Helium ions were irradiated in the V-alloy after annealing at 1373 K for 1 hr at room temperature with high flux (~10^{18} He/m^2/s) and high fluences (up to 1×10^{22} He/m^2), i.e. this fluence corresponds to ~90 dpa, which is comparable with that of α-particles of the operating condition of DEMO reactor. Subsequently, the retained deuterium or helium was measured by thermal desorption spectroscopy, TDS.

From SEM observation, it was found that a lot of blisters with the size of 01~0.5 μm were observed on the irradiated sample, and after heating at 673 K, no significant changes were observed on the surface, but after heating at 1473 K, many blisters ruptured and pinholes were observed. Thermal desorption spectra of helium after helium ion irradiation are shown in Fig.1. Many desorption peaks were observed in the TDS spectra. These peaks were divided into three groups, i.e. Peak I was the desorption around 500K, Peak II at 826~896 K, and Peak III at temperature higher than 1100 K. The activation energies of Peak I, II, and III were obtained as 1.50, 2.35~2.59, and 3.59~4.16 eV, respectively. From these activation energies, it was found that the He desorption of Peak I, II, and III corresponded to the dissociation energies of He_nVX type defect cluster, that of He_nV_5X cluster, and the rupture of the blister and internal bubbles [1]. Here, n denoted the number of helium atom (n>1), V vacancy, and X impurity atoms, such as C, N, or O. The total amount and amounts corresponding to Peak I, II, and III are shown in Fig. 2. The amount of retained helium of Peak III and II was saturated at low fluence, while that of Peak I was gradually saturated at higher fluence. The total amount of retained He was saturated at the fluence of ~$5\times10^{21}/m^2$ and the value was 2.75 $\times10^{21}$ He/m^2, corresponding to the concentration of 1.4 (He/V). Distribution of fine precipitates consisted of Ti-O-C complex in V-4Cr-4Ti alloy was drastically changed by the final annealing temperature [3,4]. Theses precipitates might act as a sink for He. Additional experiments were conducted to investigate the effect of final annealing temperature on the He retention. Smallest retention of He was observed in the sample with annealing at 1373 K after polishing.

It is reported that the origin of the bubble and blister was He_nVX [1]. Therefore, if the V-alloy would be kept at operational temperature (V-alloy blanket; 673~923 K [2]) during both discharge cleaning and ion implantation, the amount of desorbed He for the Peak I would_significantly decrease and the amount of retained He would be small. Desorption and retention behaviors of He examined in this study could be useful for wall conditionings of first wall of the V-alloy for the blanket

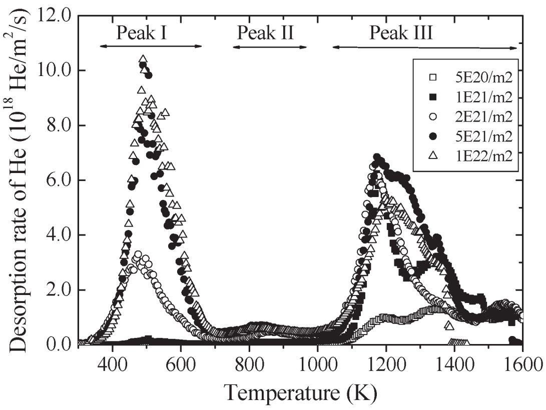

Fig.1 Thermal desorption spectra of helium after helium ion irradiation at room temperature. Ramp rate is 1 K/s.

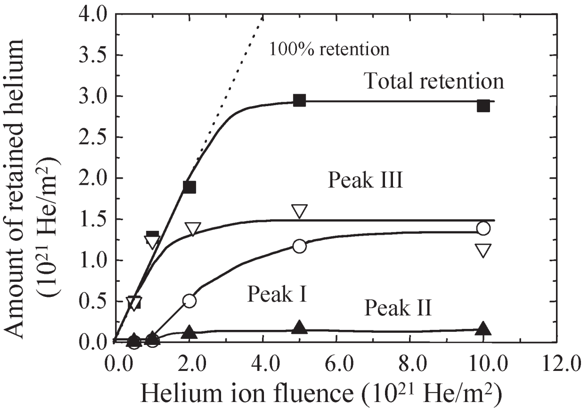

Fig.2 Amount of retained helium in the V-alloy (NIFS HEAT2) as a function of helium ion fluence

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