

§5. Deuterium Retention in Tungsten Oxide under Low-Energy Deuterium Exposure

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Tungsten is one of candidates for plasma facing materials in the nuclear fusion project under progress. Oxide (WO_3) layers exist naturally on metal surfaces and are highly anticipated due to O_2 gas introduction for tritium removal. Thus, deuterium (D) retention in oxide layers and thermal release are important for designing the devices. In this work, we have studied D-retention in WO_3 under D_2 plasma exposure and thermal release of D [1], and in W for comparison.

WO_3 films were prepared by oxidation of W sheet in air at 550 °C for 50 min. According to X-ray diffraction, the films are polycrystalline with the crystal structure of orthorhombic or monoclinic. Rutherford backscattering spectroscopy (RBS) shows nearly stoichiometric composition with the film thickness of $\sim 0.5 \mu\text{m}$. The films were exposed to D_2 plasma under AC discharge and DC discharge (NAGDIS-II). The amount of D was analyzed by using nuclear reaction analysis (NRA), $\text{D}(^3\text{He},\alpha)\text{H}$ with ^3He -energy of 0.7 MeV. Since the depth resolution of the NRA is poor ($\sim 0.4 \mu\text{m}$), only total amount of D is concerned.

Fig. 1(a) shows D-retention in WO_3 and W versus applied voltage (V =effective voltage) under AC discharge. The former does not seem to saturate up to $V=2.5 \text{ kV}$, while the latter saturates at $V\sim 1.5 \text{ kV}$. D-retention saturates at 10 and 5 min in WO_3 and W at $V=1.5 \text{ kV}$. At this voltage, D-retention in WO_3 is $1.4 \times 10^{17} \text{ cm}^{-2}$ and is larger by an order of magnitude than that of $0.2 \times 10^{17} \text{ cm}^{-2}$ in W. The maximum energy of D at $V=1.5 \text{ kV}$ is 1.06 keV, assuming that D_2 breaks two D's upon incidence on sample surface. The diffusion length at room temperature during the discharge time of 10 min is estimated to be $0.65 \mu\text{m}$ [2] and this is comparable with the film thickness. Thus, D's are more likely to be distributed throughout the film beyond the projected range of 12 nm [3], resulting in D_xWO_3 with $x=0.15$. The discharge current was 1.4 mA at 1.5 kV, thus the D-uptake efficiency is $\sim 4\%$. D-retention under AC-discharge at $V=1.5 \text{ kV}$ is comparable with that under DC-discharge at 100 eV, shown in Fig. 1(b), indicating that the effective energy under AC-discharge is smaller by an order of magnitude than DC-discharge.

Thermal desorption spectroscopy (TDS) shows that D_2 -desorption takes place at ~ 180 and 450 °C from

WO_3 and $200\text{-}400 \text{ °C}$ from W. Desorption of H_2 , H_2O , HD, D_2O and HDO have been observed, indicating intermixing between H and D, and remaining origin of H in question. When samples were kept in desiccator at room temperature, D-retention decreased to half of the initial value at 12 and 5 days in WO_3 and W.

The temperature rise of the sample during AC- and DC-plasma discharge is estimated to be less than 200 °C . The diffusion length in W for 10 min at room temperature and 200 °C [4] is estimated to be $\sim 0.6 \text{ nm}$ (smaller than the projected range of 10 nm) and $\sim 1 \mu\text{m}$, respectively. More accurate measurements are desired for more accurate estimation of the diffusion length, especially in W. Furthermore, NRA measurements of depth distribution of D are under consideration.

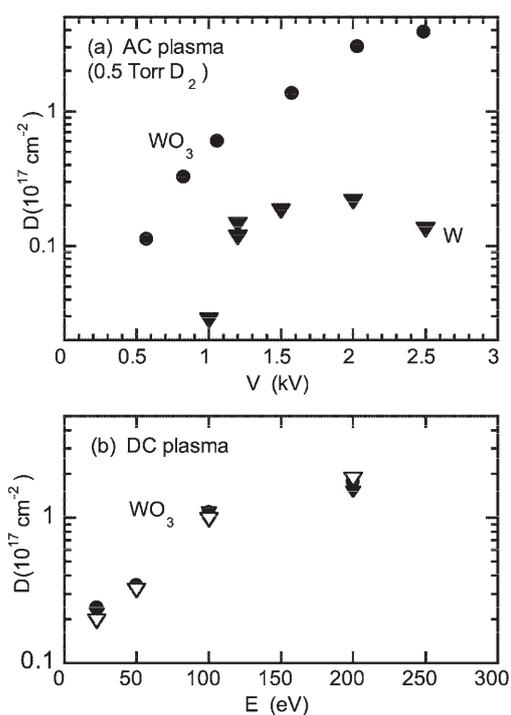


Fig. 1(a) Voltage (V) dependence of D-retention in WO_3 (●) and W (▼) under AC plasma discharge (0.5 Torr D_2). Discharge time is 10 and 15 min for WO_3 and W. (b) Dependence of D-retention in WO_3 on the D ion energy under DC-plasma discharge for ~ 10 min.

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