3 - 10 Helium Decoration of Vacancy-type Defects in Tungsten Induced by 200 keV He-ions

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Tungsten (W) has been selected as one of the potential candidate materials to cover some parts of the divertor in the future International Thermonuclear Experimental Reactor (ITER). The formation and accumulation of defects in tungsten induced by He is of great importance.

In this work, high pure polycrystalline tungsten samples were irradiated by 200 keV He^+ with a dose of 5×1016 He^+/cm^2 at room temperature (RT). After irradiation, un-irradiated and irradiated samples were probed by positrons in order to get the information about defect distribution. Measurements of Doppler broadening spectroscopy (DBS) were carried out in Beijing ^{22}Na slow positron beam line.

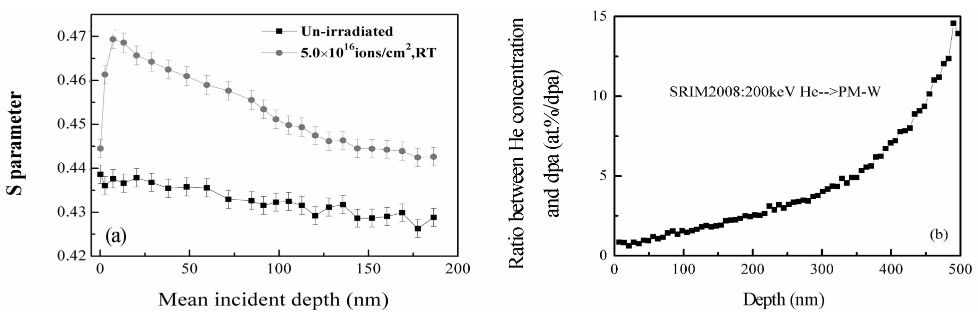

Fig. 1 Depth profile of (a) S parameter and (b) the ratio between He concentration and dpa induced by 200 keV He in W.

Fig. 1 (a) gives the curves for S-parameter versus positron's mean incident depth for the un-irradiated and irradiated samples. For the un-irradiated sample, S parameters are larger than ~0.43, which is larger than the S parameter in the lattice and indicates the presence of intrinsic vacancy-type defects. For the irradiated sample, S parameters are higher than those for the un-irradiated sample, which clearly indicates that positrons detect the presence of vacancy-type defects generated during irradiation of He in tungsten. This accords with the SRIM simulation result and indicates that the W atoms displacements can lead to the formation of vacancy-type defects which were also found in tungsten irradiated by 800 keV ^{3}He. The vacancy-type defects include mono-vacancies, di-vacancies, vacancy clusters, vacancy loops and microvoids etc, which will enhance the S parameters. The S parameter of the irradiated samples increases from the surface up to ~ 7.19 nm, which is too shallow compared with the damaged layer. Beyond the maximum value, S parameters decrease gradually when the mean incident depth increases. The trend of the decline can be interpreted on the basis of the He decoration of the vacancy-type defects. According to ratio between the He concentration and dpa shown in Fig. 1 (b), the estimated irradiation-induced defect concentration is well higher than the He concentration, which suggests that each introduced He atom can easily meet one vacancy. The injected He atoms with keV energies are trapped in irradiation-induced vacancies because of the very low migration energy (~0.3 eV or ~0.24 eV) of the interstitial He in tungsten at RT and the strong attractive interaction of He with vacancies in metal. Therefore, those vacancy-type defects such as dislocation/vacancy loops, mono-vacancy and vacancy clusters etc are all probably decorated by He, which makes for the formation of the He-vacancy (He-V) complexes with various sizes, HeiVj. Here, the suffixes denote the number of He atoms or vacancies. When the vacancy-type defects contain gas or compound, the formation probability of positronium effectively reduces by lowering the available positron-trap volume, leading to lower S parameters. Therefore, the He atoms in He-V complexes effectively reduce the low-momentum annihilation. The S parameters drop with depth mainly because the ratio between the He concentration and dpa increases from surface to ~300 nm.

In summary, vacancy-type defects induced by 200 keV He irradiation are detected in the damaged layer and they were decorated by He atoms.

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