§16. Microstructure Observation and Deuterium Trapping Property in Ion Irradiated Ferritic Steel

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In fusion thermonuclear reactors the trapping and release characteristics of hydrogen isotopes and helium will influence plasma parameters, tritium inventory in the first wall and tritium permeation to the coolant. It is well established that hydrogen isotopes may be trapped at particular defect sites, such as vacancies, dislocations, grain boundaries and precipitates. However, trapping property of cavity formed by irradiation is still unknown.

Fe-9Cr specimens used in the present work were prepared by arc melting method. After rolled to 0.06mm thick, the specimen was annealed at 1023K for 2 hours to reduce dislocations. The specimens were irradiated with 8keV-deuterium ions up to the fluence of $3x10^{22}$ D_2^+/m^2, and successively thermal desorption of D_2 and HD under the constant heating rate (1K/s) was measured using quadruple mass spectroscopy. Transmission electron microscopy observation was also carried out to know the relation with microstructure.

Typical microstructural evolution in Fe-9Cr at 300 K under irradiation with 8 keV D_2^+ ions is shown in Fig. 1. Interstitial type dislocation loops appeared at first and increased their density with increasing fluence. The density saturated at the fluence level of around $1.0x10^{20}$ions/m^2, while size of each loop continued to increase. Above a fluence of $3x10^{21}$ions/m^2, average size of the loop becomes about 10 nm, and the loops piled up as tangled dislocations. No cavity was observed at the fluence of $3x10^{22}$ ions/m^2.

In the case of deuterium ion irradiation at 573K and 673K, are shown in fig. 2, 3-dimensional cavities were observed. The size of cavity increases with increasing irradiation temperature. At 673K irradiation, self-organized ordering cavities can be observed in several regions. The axes of the void ordering are parallel to those of the host crystal.

Fig. 3 shows thermal desorption spectra of deuterium from Fe-9Cr irradiated with 8 keV-D_2^+ ions at 300K and 573K. The desorption stage of 300K-irradiation and 573K-irradiation shows the greatly different feature. For 300K-irradiation, deuterium desorption stage were formed below 550K at any fluence. Total amount of the trapped deuterium for irradiations of $3.0x10^{21}$ions/m^2 is $1.2x10^{18}D_2/m^2$. For 573K-irradiation, no desorption stage were formed at lower fluencies ($<3.0x10^{21}$ions/m^2), and new desorption stage formed between 650K and 1100K at higher fluencies ($>1.0x10^{22}$ions/m^2). Total amount of the trapped deuterium for irradiations of $3.0x10^{22}$ions/m^2 is $6.8x10^{17}D_2/m^2$; about 0.007% deuterium were trapped by irradiation. The deuterium desorption stage in such a high temperature region essentially differs from what has been observed by previous research in any transition metals. It is considered to be a result that deuterium atoms were re-combinated to D_2 molecules at the surface of cavity, and recombination efficiency is considerably low.

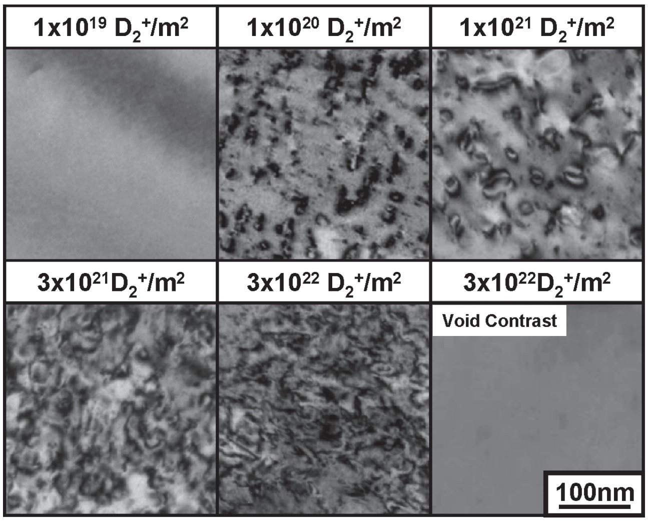

Fig.1 Microstructural evolution in Fe-9Cr at 300 K under irradiation with 8 keV D_2^+ ions

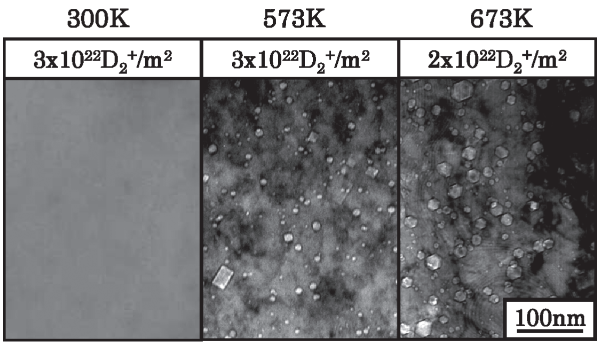

Fig.2 Temperature dependence of Microstructural in Fe-9Cr at higher dose.

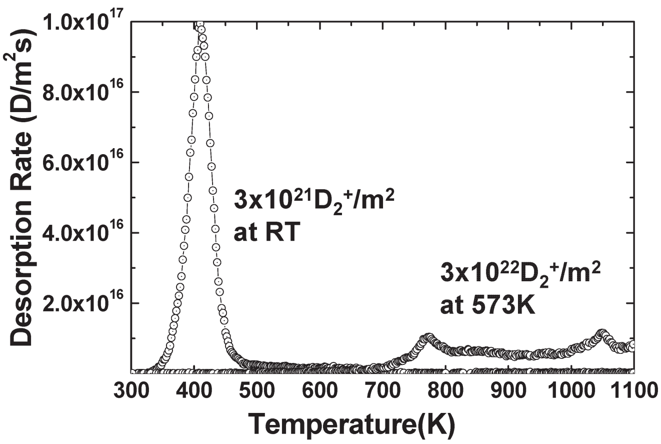

Fig.3 Temperature dependence of Microstructural in Fe-9Cr at higher dose.