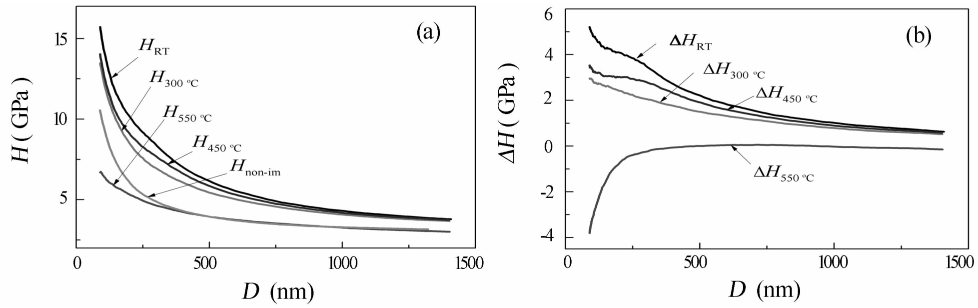

Fig. 2 Hardness H(a) and hardness increment ΔH(b) versus ion penetration depth D of SIMP-7 steel bombarded with 500keV helium ions to 1.0×10^{17} He/cm^2 at room temperature (RT), 300, 450 and 550 ℃.

Fig. 1 shows the hardness H(a) and hardness increment ΔH(b) of T91 steel versus the ion penetration depth D. The subscript index non-im, RT, 300, 450 and 550 ℃ denote the non-implanted sample, the samples implanted at RT, 300, 450 and 550 ℃, respectively. It is clear that the hardness decreases gradually with increasing the ion penetration depth and finally reaches to constants at depth above 1000 nm. In order to further investigate the change of hardness of T91 sample after He-ion implantation, we defined the hardness increment as $\Delta H = H - H_{non\text{-}im}$ that is shown in Fig. 1(b). Compared with the non-implanted T91 sample, ΔH decreases with the implantation temperature, indicating the recovery of irradiation damage at high temperature.

Both of SIMP and T91 steels do not show the increment of hardness with the decrease of temperature monotonously. The sample implanted at 550 ℃ shows the lowest hardness value among the samples, whereas the sample implanted at 450 ℃ shows the largest hardness value. The fact that most ferritic/martensitic steels under helium irradiation have the highest density of helium bubbles at 450 ℃[3] may explain that helium bubbles contribute more than other factors to the hardness of the steels.

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3 - 21 Positron Annihilation Study of Vacancy-type Defects in a F/M Steel under Helium Ion Implantation

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Positron annihilation technique (PAT) is sensitive to atomic-scale vacancy-type defects in solid. Thus it has become an indispensable implement in the study of defects in materials. In this paper, PAT was used to study the vacancy-type defects in a ferritic/martensitic (F/M) steel irradiated by 500 keV helium ions to a dose of 1.0×10^{17} cm^{-2} at room temperature (RT) and 450 ℃.

Fig. 1 shows the Sparameter for non-implanted sample and irradiated samples as a function of positron incident energy. The S parameter shows a remarkable difference between the samples irradiated at RT and 450 ℃. For the sample irradiated at RT, the value of S is larger than that of the non-implanted sample, meaning that extra vacancy defects have been induced by irradiation. For the sample irradiated at 450 ℃, the parameter S is found to be lower than that of irradiated at RT. For the sample irradiated at 450℃, the S parameter is smaller than that of non-implanted sample within 204 nm (corresponding to positron energy of 10 keV). The annihilation of vacancy-type defects by interstitials promoted by temperature play a minor role compared to the increase of defect density. But closer to radiation peak damage, because of the high concentration of vacancy-type defects, the S parameter is bigger than that of non-implanted sample.

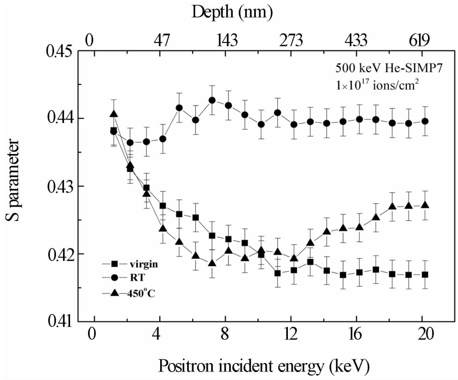

Fig. 1 The S parameter of irradiated samples as a function of the positron incidence energy.

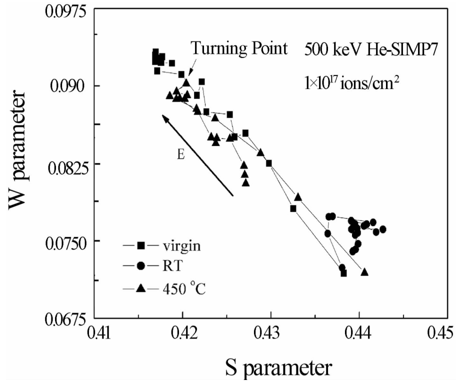

Fig. 2 S parameter of irradiated samples as a function of W parameter.

Fig. 2 shows the correlation between the S and the W parameters for non-implanted sample and irradiated samples. It is clear in the figure that, the well linearity of S-W plot shows only one-type defects in the non-implanted sample. For the sample irradiated at RT, the points in the S-W plot are not in the same line, indicating that different kinds of vacancy-type defects exist in the sample. For the case of irradiation at 450 ℃, the S-W Plot show two lines, indicating that two different kinds of vacancy-type defects exist in the sample possibly.

3 - 22 Structural Changes and Defects Evolution in Ti_3AlC_2 Induced by 500 keV He-ion Bombardments

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Due to its good damage tolerance, excellent physical properties such as remarkable mechanical properties and thermal stability, Ti_3AlC_2 has been considered as fuel cladding or structural materials used in accelerator-driven sub-critical systems (ADS) and Gas-cooled Fast Reactor (GFR).

Irradiation experiments with 500 keV He-ion were performed with different fluencies of 1×10^{16} ions/cm^2 to 1×10^{18} ions/cm^2 (irradiated sample will be referenced as sample 1E18 for concise and this notation applied to other samples) at room temperature (RT) under 320 kV multi-discipline research platform for Highly Charged Ions equipped with an ECR (Electron Cyclotron Resonance) ion source in the Institute of Modern Physics, Chinese Academy of Sciences (IMP, CAS), Lanzhou. On the basis of SRIM-calculations, penetration depth of He-ion is estimated to be about 1524 nm and the maximum damage at a depth of about 1278 nm is about 52.0 dpa. All the samples studied in this work were characterized by low-incidence X-ray diffraction and analyzed by Doppler broadening of Positron Annihilation Spectroscopy (PAS).

Fig. 1(a) gives XRD diffraction patterns of the virgin sample and all irradiated samples. For sample irradiated at the lowest dose, sample 1E16, changes in peak positions and peak broadening could not be detected. For 5E16 sample and higher damage levels, a continuous drop of peak intensity and increase of peak width is found. For 1E18 sample, very broad peaks of (1 0 3) and (1 0 4) appear, which is attributed to some loss of crystallinity. Shifts of the (1 0 2) and (1 0 5) peaks in the opposite direction should be noticed, which may be linked to an appearance of a new phase TiC_x but not be induced by an expansion of unit cell along *c* axis. Moreover, two new peaks corresponding to the (0 0 2) peak of TiAl and the (2 2 0) peak of Ti_3AlC appear and become stronger with an increasing fluence. That indicates an irradiation-induced segregation especially for atom C plays a vital role in resulting in the formation of new phases.