

vacancy case. The DFT results calculated with VASP for bcc iron are shown in Fig. 2. The results for bcc Fe are similar to W. One possible reason for these results is elastic interaction between defects and strain field, leading to the change of elastic formation energy of these defects.

Since the strain field affects the formation of defects, the critical displacement energy should also be affected. One case is shown in Fig. 3. The critical displacement energies decrease with strain for [100] and [110] directions, which can be explained by strain effect on formation energy as shown in Figs. 1 and 2.

Based on above results, one conclusion can be given that when the materials work under compressive condition in reactor, the lifetime would be extended. Thus, the materials with pre-compression stress may be one of good candidates for radiation-resistance application.

References

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3 - 8 Thermal Desorption and Surface Modification Induced by Helium Implantation in Tungsten

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Plasma-facing materials (PFMs) for a fusion reactor suffer hydrogen/helium plasma bombardment, neutron irradiation and high temperature, *etc.* Tungsten is a promising candidate PFM due to its low sputtering yield for the light elements, high thermal conductivity, high mechanical strength, and high melting point. Helium could be introduced by helium bombardment and neutron irradiation and trapped in tungsten at different sinks. It is possible that the trapped helium atoms re-emit to the core plasma due to thermal desorption which affects the safety. In this work, the thermal desorption behavior of helium implanted into tungsten at different temperatures was investigated.

The tungsten specimens with high purity of 99.99% were implanted with 100 keV helium ions at room temperature (RT), 400, 600 and 800 °C. Helium implantation experiments were performed at 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. The beam was swept at two directions of X and Y in order to get a uniform beam. The mean flux was about 4.7×10^{13} ions/(cm²s). The fluence was 1.0×10^{18} ions/cm². After implantation, He desorption behavior was investigated by Thermal Helium Desorption Spectroscopy (THDS) and Scanning Electron Microscope (SEM) was used after THDS test to identify the surface modification. In the thermal desorption process, the temperature increased first with a ramp rate of 2 K/s to 175 °C, then with a ramp rate of 3 K/s to 900 °C, kept 100 s at the temperatures of 175 and 900 °C and at last cooled down to RT.

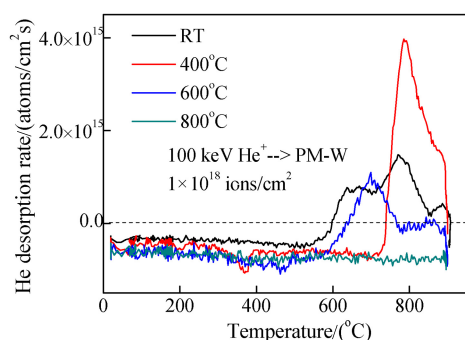


Fig. 1 (color online) THDS of specimen implanted with 100 keV He⁺ to 1×10^{18} ions/cm².

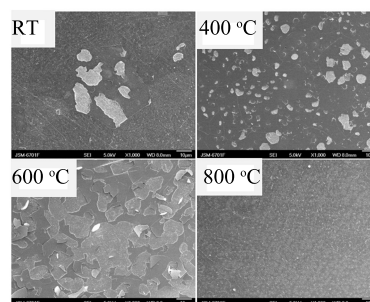


Fig. 2 Surface modification of specimens implanted with 100 keV He⁺ to 1×10^{18} ions/cm² after THDS test, implantation temperatures are indicated in each figure.

Thermal helium desorption spectra are shown in Fig. 1. It should be illustrated that the He desorption rates below zero are considered as background, *i.e.* zero, and only those data above zero will be discussed. When the implantation temperature was RT, helium desorption started at about 598 °C and four peaks appeared below 900

°C. The initial temperatures for thermal helium desorption were 740 and 640 °C for the specimens implanted at 400 or 600 °C, respectively and both of them were higher than the implantation temperatures. There was only one desorption peak (785 and 700 °C, respectively) below 900 °C in both cases. The THDS results of the specimen after 8 keV He⁺ implantation at 600 °C to a fluence of 1×10^{18} ions/cm² gives a desorption peak temperature of 700 °C^[1] which is the same with the temperature in our study. The initial temperature for thermal helium desorption, the temperature at the peak, the desorption rate at the peak and the total desorption in the case of 400 °C were all higher than those in the case of 600 °C. No helium desorption observed for the specimen implanted at 800 °C.

SEM observation results after THDS test were shown in Fig. 2. Extensive exfoliation was observed, and the area of exfoliation increased with increasing implantation temperature from RT to 600 °C. Outside the exfoliation zones, small holes appeared for the RT case, while no holes for 400 and 600 °C cases. No significant surface modification after THDS test was observed for the specimen implanted at 800 °C.

The results indicated that helium desorption was detected for the specimens observed obvious surface modification. The diversity of surface modification for the RT specimen was in agreement with the multiple peaks, which indicated that helium release was controlled by different mechanism. The surface modification of only exfoliation for the 400 and 600 °C specimens was in agreement with the only one peak, which indicated helium release was controlled by one mechanism.

Reference

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3 - 9 Mechanical Properties Studies on High-energy Kr-ion Irradiated Corrosion Layer Fe₃O₄

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The RAFM (Reduced Activation Ferritic/Martensitic) steel is considered as one of the promising candidate structural materials for LFRs (Lead alloy-cooled Fast Reactors) and ADS (Accelerator Driven Sub-critical system), and its compatibility with liquid metal and radiation-resistant properties have been extensively studied because of the requirements of reliability and safety of the blanket^[1]. A number of corrosion experiments of RAFMs (Eurofer 97, T91 and 316L, *etc.*) in liquid LiPb alloy have been investigated, and the corrosion results show that these Fe-based steels suffered more serious corrosion attack from 480 to 550 °C, and the corrosion layer is made of the oxide layer (Fe₃O₄ and Cr_xFe_{3-x}O₄) at steels' surface. Generally speaking, during the stage degeneration of material, the formation of corrosion layer is one of the important features of the process^[2]. Cracking, blistering, embrittlement and other changes in materials may be induced by corrosion layers, and the corrosion layers have independent compositions, structures and radiation-resistant properties with distinguished from the alloy matrix. In a word, in order to further clarify the applicability of Fe-based structural materials in nuclear facilities, we should study not only the RAFM steel itself but also its corrosion layer (Fe₃O₄, mainly). So we report on modifications of mechanical properties of Fe₃O₄ corrosion layer irradiated with high-energy ion.

The static corrosion experiments of T91 and RAFM steel specimens in liquid PbBi (Pb-44.5 at%) at 450 °C and irradiation experiment of Fe₃O₄ at RT with 2.03 GeV Kr²⁶⁺ ions were performed in IMP (Institute of Modern Physics, Chinese Academy of Sciences, Lanzhou)^[3].

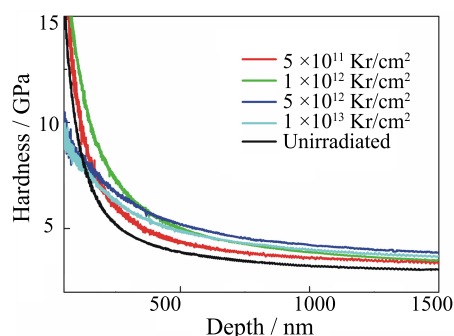


Fig. 1 (color online) Nano-hardness profiles of the unirradiated sample and the samples irradiated with different fluences at RT.

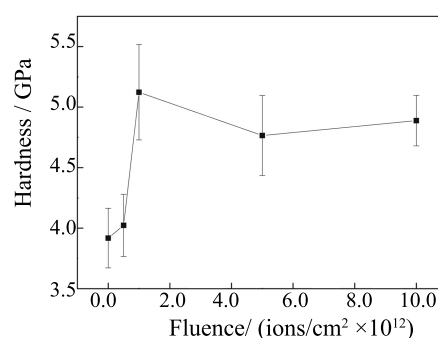


Fig. 2 (color online) The dependence of nano-hardness on the Kr²⁶⁺ ion fluence for Fe₃O₄ films.