[3] A. Meldrum, L. A. Boatner, R. C. Ewing, Phys. Rev. Lett., 88, 2(2001)025503.

[3] J. M. Leger, P. E. Tomaszewski, A. Atouf, et al., Phys. Rev. B, 47,21(1993)14075.

[4] D. Simeone, J. L. Bechade, D. Gosset, et al., J. Nucl. Mater, 281(2000)171.

[5] K. E. Sickafus, H. J. Matzke, Th. Hartmann, et al., J. Nucl. Mater., 274(1999)66.

[6] K. H. Park, Y. Katoh, H. Kishimoto, et al., J. Nucl. Mater, 307(2002)1187.

5 - 4 Phase Transitions and He Bubble Evolution in Ti_3AlC_2 under Sequential He Ion Implantation and Fe Ion Irradiation

Pang Lilong, Tai Pengfei, Zhang Linqi, Niu Lijuan, Wang Zhiguang, Chang Hailong, Shen Tielong, Cui Minghuan, Huang Sihao, Qi Le, Gao Xing, Wei Kongfang and Ma Zhiwei

Ternary $M_{n+1}AX_n$ phase, where M stands for an early transition metal, A is an A-group element, and X is either C or N, has exhibited the combination properties of ceramics and metals. Their excellent performance leads them to be a very promising candidate for applications involving extremely harsh nuclear environments, acting as a candidate pump impeller and bearing materials for lead cooled fast reactor, and fuel pellet coatings and accident tolerant fuel coatings (ATFCs). However, radiation damage in structural materials and accumulation of He introduced either by radiation or by transmutation through the (n, α) nuclear reaction, are known to cause the degradation of the mechanical properties of materials, thereby threatening the safe operation of reactor. Ti_3AlC_2, as typical materials of the MAX phase family, has received a great deal of research interest, because it has excellent resistance to irradiation and high tolerance for He.

Ion implantation or irradiation experiments were carried out on the material terminal of 320 kV multi-discipline research platform for highly charged ions in IMP, CAS, and Heavy Ion Research Facility in Lanzhou (HIRFL). Ti_3AlC_2 samples were irradiated by energetic Fe ions and He ions in the sequence and reverse order.

The obtained results show there are some large differences between the two irradiation sequences. In the sequential (Fe+He) irradiation, it is found that two types of ions created their own relatively independent irradiation effects in the material, with a weak interaction between them. In sequential (He+Fe) irradiation, however, the observation is quite opposite. Compared with the single Fe ion irradiation or sequential (Fe+He) irradiation, the (He+Fe) irradiation maintains the higher content of original α phase, as shown in Fig. 1. It indicates that the pre-implanted He significantly suppresses the phase transitions caused by the following Fe ion irradiation. The following Fe ion irradiation was also found to promote the evolution of the pre-formed He bubbles. It can cause not only the growth of He bubbles, but the re-solution of He bubbles, as shown in Fig. 2. This will improve the resistance to He bubbles induced damage for Ti_3AlC_2.

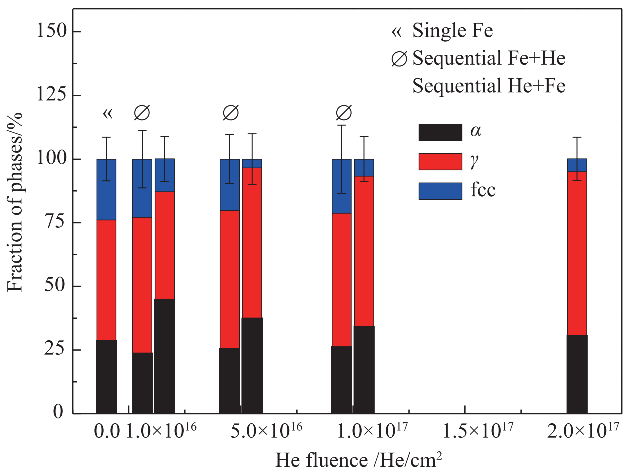

Fig. 1 (color online) The fraction of phases α, γ and fcc of the Ti_3AlC_2 samples with various irradiation conditions.

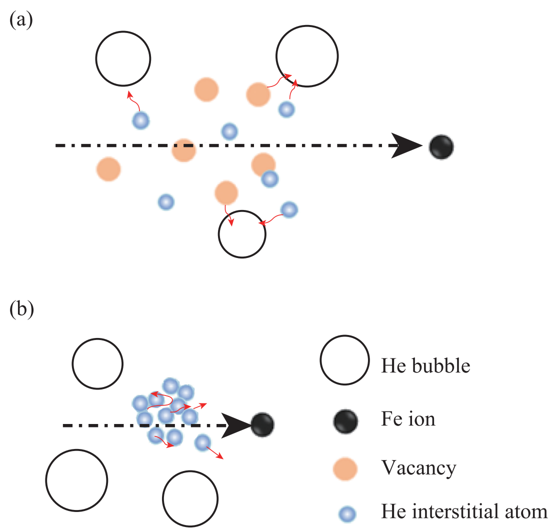

Fig. 2 (color online) Schematic illustration of the evolution mechanism of He bubbles driven by the following Fe ion irradiation. (a) The growth process of He bubbles, (b) The re-solution process of He bubbles.

Both the He ion implantation and Fe ion irradiation actually inhibit each other's radiation damage to the material. This may play a positive role in reducing radiation damage to the Ti_3AlC_2 material, and also provides new insight into irradiation resistance of this material.

5 - 5 Helium Irradiation Induced Microstructural Damages and Mechanical Response of Al_2O_3-ZrO_2-SiC Composites*

Zhu Yabin, Chai Jianlong, Niu Lijuan, Shen Tielong and Wang Zhiguang

Numerous helium atoms would be produced in nuclear structural materials due to the (n, α) nuclear transmutation reaction. As a potential structural material, the Al_2O_3-ZrO_2-SiC composite was irradiated with 2.0 MeV He-ions and its structure and mechanical response were investigated.

X-ray diffraction analyzation gives that there are small shifts and broadening of the diffraction peaks, which denotes lattice expansion resulted from residual tensile stress related to the formation of defects and helium bubbles upon irradiation. TEM observations show that He bubbles with nanometer size can be observed in all irradiated regions for all samples, even in the near-surface regions where the expected He concentration is rather low (Fig. 1). The large number of grain/phase boundaries related to the refined grains is responsible for the formation of bubbles in the near-surface region which would accelerate the migration of implanted He-ions, as the mobility of He atoms at the boundary is higher than that within the grains. Moreover, the distribution of He bubbles in the Al_2O_3, ZrO_2 and SiC grains was obviously different: most of bubbles are uniformly distributed in Al_2O_3 grains and partly distributed

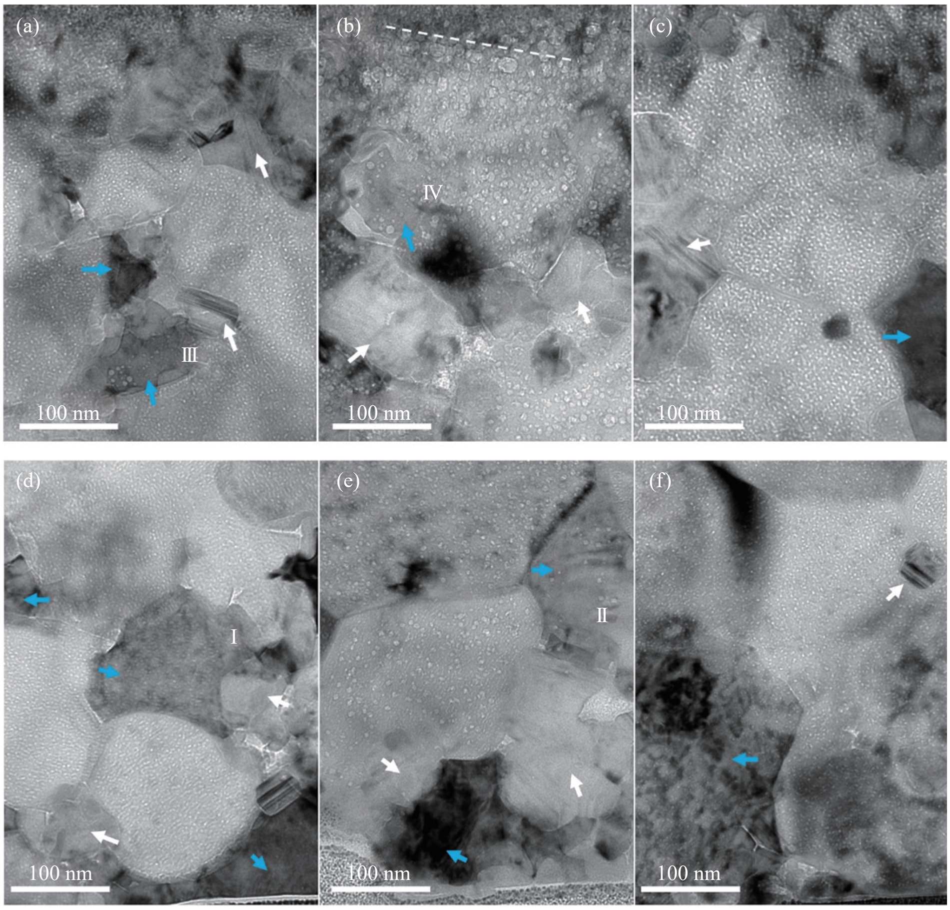

Fig. 1 (color online) Bright field under-focused (bubbles are with white contrast) TEM micrographs obtained from the He concentration peak regions of 800 ℃-1.72×10^{17} (a), 800 ℃-1.72×10^{18} (b), 300 ℃-1.72×10^{18} (c) and the near-surface regions of 800 ℃-1.72×10^{17} (d), 800 ℃-1.72×10^{18} (e), 300 ℃-1.72×10^{18} (f). The ZrO_2 and SiC grains are indicated by the light blue and white arrows. The dash line in (b) highlights a continuous band of large, interconnected bubbles at the He concentration peak region.