Irradiation Response of Fe-based Metallic Glass Under He Ions and H Ions Bombardment

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Abstract: The changes in structure, surface morphology of metallic glasses $Fe_{80}Si_7B_{13}$ before and after the irradiation of He ions or He and H ions were investigated, also the bubbles formed in the metallic glass were discussed. The results show that after the 300 keV He^{2+} irradiation, a series of crystallization occurred in metallic glass $Fe_{80}Si_7B_{13}$.The subsequent H ions irradiation decreased the size of bubbles while increased the number density of bubbles in the Fe-based metallic glass.

Keywords: ion irradiation, nano-crystalline, metallic glass.

1. Introduction

The materials applied to the fusion devices need to sustain the irradiation of high-energy neutrons and plasma flow as well as thermal irradiation [1]. During the irradiation of high-energy neutrons, a large number of He ions and H ions are generated by the (n, α) and (n, p) reactions [2].Because He ions and H ions coexist in the fusion device and both of them react on the materials, so the irradiation behaviour of the materials under the irradiation of He ions and H ions is worth substantial attention.

Among numerous kinds of metallic glasses, Fe-based metallic glass is considered to show a good resistance to the irradiation damage due to its wide super-cooled liquid region, relative high crystallization initial temperature, good glass forming ability, and ultra high strength.

In this study, the behaviour of metallic glass $Fe_{80}Si_7B_{13}$ against the irradiation of He ions and H ions was observed, and discussed the changes in structure, surface morphology.

2. Experimental Methods

The metallic glasses $Fe_{80}Si_7B_{13}$ with the width of 10mm and thickness of 35um used in this study were prepared by melt-quench method. The ion irradiation experiment was carried out on the 320kV highly charged ion research platform at institute of modern physics, Chinese academy of sciences. The detailed irradiation parameters are listed in **Table 1**. And the He ions irradiation was prior to the H ions irradiation. The beam spot size was 15×15mm, the beam intensity was 10uA, and the vacuum degree was keep in the level of 10-6pa.

Table 1. Detailed irradiation parameters.

Ions	Energy of ions	Fluences of ions
He	300 keV	4×10^{17}ions/cm^2
		1×10^{18}ions/cm^2
		1.6×10^{18}ions/cm^2
He	500 keV	1×10^{18}ions/cm^2
H	250keV	5×10^{17}ions/cm^2

The phase structure of the unirradiated and irradiated samples was analysed by X-ray diffraction (XRD), and the changes on microstructure of samples were studied by transmission electron microscope (TEM). The surface morphology and root-mean-square (RMS) roughness of samples was characterized by scanning electron microscope (SEM) and atom force microscope (AFM), respectively.

3. Main Results

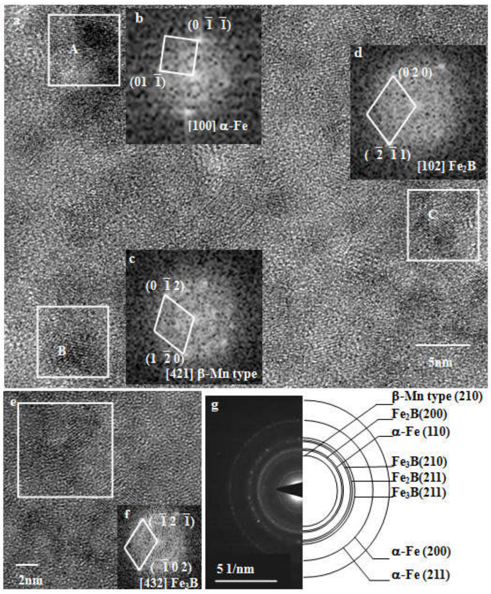

Fig.1. (a)The cross-section HRTEM image and images of different crystallization areas (b) the corresponding FFT pattern of the white box A in (a) (c) the corresponding FFT pattern of the white box B in (a) (d) the corresponding FFT pattern of the white box C in (a) (e) white box A : Fe_3B phase ([432]) (f) the corresponding FFT pattern of the white box in (e) (g) the corresponding SAED pattern of the He bubbles layer of the metallic glass $Fe_{80}Si_7B_{13}$ irradiated by He ions up to a fluence of 1.6×10^{18}ions/cm^2.

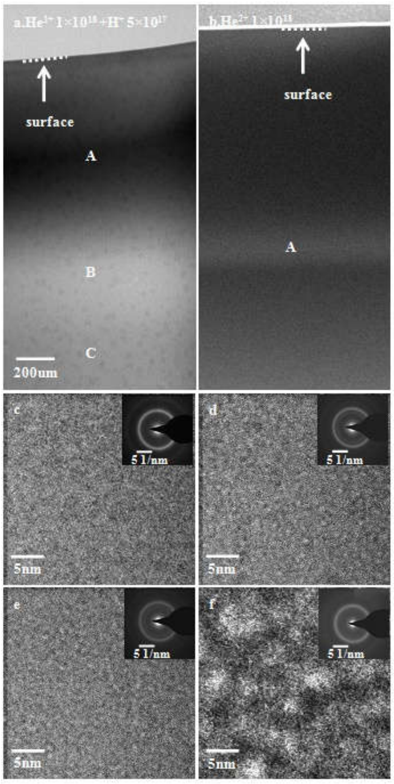

Fig.2. The TEM cross-sectional image of metallic glass $Fe_{80}Si_7B_{13}$ after a.the joint irradiation of He ions with the fluence of 1×10^{18} ions/cm^2 and protons with the fluence of 5×10^{17} ions/cm^2 b. the He ions irradiation with the fluence of 1×10^{18} ions/cm^2 c-e. The HRTEM images and the corresponded SAED patterns of different regions in Fig.3a: c. The region near the surface (A in Fig.3a) d. region which the ions passed through(B in Fig.3a) e. region at the end of the He ions range (C in Fig.3a) f. The HRTEM images and the corresponded SAED pattern of bubble layer in Fig.3b (E in Fig.3b)

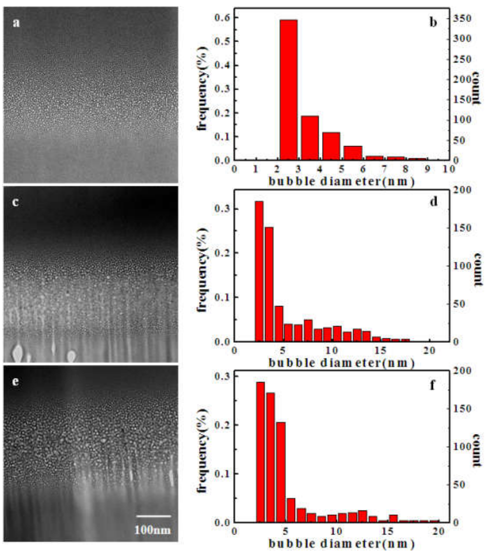

Fig.3. The HRTEM image of He bubbles layer in $Fe_{80}Si_7B_{13}$ metallic glasses irradiated by He ions with different fluences (a) 4×10^{17}ions/cm^2 (c) 1×10^{18}ions/cm^2 (e) 1.6×10^{18}ions/cm^2 and the corresponding size distribution of He bubbles in metallic glasses $Fe_{80}Si_{7.43}B_{12.57}$ irradiated by He ions with different fluences (b) 4×10^{17}ions/cm^2 (d) 1×10^{18}ions/cm^2 (f) 1.6×10^{18}ions/cm^2.

4.Conclusion

The results show that after the 300 keV He^{2+} irradiation, a series of crystallization occurred in metallic glass $Fe_{80}Si_7B_{13}$ in order of metastable β-Mn type phase → α-Fe phase and tetragonal Fe_2B phase → orthogonal Fe_3B phase, β-Mn -Mn type phase as well as α-Fe phase and Fe_2B phase with the fluence increased. Blisters and cracks appeared on the surface of tungsten under the irradiation fluence of 1×10^{18}ions/cm^2, however only when the fluence was up to 1.6×10^{18}ions/cm^2, could cracks and spalling appear on the surfaces of metallic glass. Numerous bubbles formed under the He ions irradiation in the metallic glass, When the irradiation fluence was 1.6×10^{18}ions/cm^2, several bubbles with the diameter of more than 20nm appeared, and the greatest diameter was up to 20.9 nm. While after the 500 keV He ions irradiation, the subsequent 250 keV H ions irradiation made the He bubble layer thickened due to the diffusion of bubbles, and the size of bubbles decreased while the number density increased in the Fe-based metallic glass.

5.Acknowledgement

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6.References

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