Structural Thermal Stability of Fe-based and Ni-based Metallic Glasses under High-intensity Pulsed Ion Beam Irradiation

Xianxiu Mei[1], Xiaonan Zhang[1], Qi Zhang[1], , Gennady E. Remnev[2], Sergey K. Pavlov[2], Younian Wang[1]

[1] *Key Laboratory of Materials Modification by Laser, Ion and Electron Beams, Ministry of Education, Dalian University of Technology, Dalian, China*
[2] *National Research Tomsk Polytechnic University, Tomsk, Russia*

Abstract: HIPIB with different energy density and pulse number was used to irradiate Fe and Ni-based metallic glasses to study the structural thermal stability of the metallic glasses. After the irradiation with the impulses number of 300 and the energy density of 0.32J/cm^2, a large number of round holes and a few "bumps" appeared on the surfaces of the metallic glasses. After the irradiation, the metallic glasses kept amorphous, while the arrangement of atomic structure in the sub-surfaces of metallic glasses became more disordered.

Keywords: Metallic glass, High-intensity Pulsed Ion Beam, Thermal stability.

1. Introduction

Due to wide super-cooled liquid region, high glass transition temperature [1], low activation and other advantages, Fe-based and Ni-based metallic glass become a candidate for the irradiation-resistant material in the fusion reactor. The metallic glass $Fe_{80}Si_7B_{13}$ as well as $Ni_{62}Ta_{38}$ show good irradiation resistance under the irradiation of H^+ ions [2] and He^{2+} ions [3]. However, the structural thermal stability of metallic glass is the key to its application. The mechanism of thermal irradiation damage on metallic glass is not clear. It is necessary to study the structural thermal stability of metallic glass.

High-intensity pulsed ion beam (HIPIB) technology can generate the heating rate of 10^8-10^{11}K/s and the cooling rate of 10^8-10^9K/s on the material surface [4], resulting in melting, vaporization and even ablation of the material surface. It has been considered as an effective methods of surface modification for metallic material and have been widely studied [5]. In view of the unique characteristics of HIPIB such as high ion current, short pulse, high kinetic ion energy, HIPIB irradiation technology is worthy of being used to study the thermal irradiation damage of metallic glass.

In this study, HIPIB technology was used to irradiate metallic glass $Fe_{80}Si_7B_{13}$ and $Ni_{62}Ta_{38}$. The changes in the surface morphology, phase structure and properties of metallic glass before and after irradiation were analyzed. The thermal irradiation damage resistance and structural thermal stability of Fe-based and Ni-based metallic glass under HIPIB with instantaneous and highly thermal characteristics were investigated.

2. Experimental

The thickness of $Fe_{80}Si_7B_{13}$ and $Ni_{62}Ta_{38}$ metallic glass were 35 μm and the width of them was 10mm and 2mm , respectively. The irradiation experiment for metallic glass was performed on the TEMP-4M accelerator (high-power ion beam sources) in the Tomsk Polytechnic University. The ion beam was mainly consisted of 85% C^{n+} (predominantly C^+) and 15% H^+, the acceleration voltage was 200-240 kV, the pulse width was 90 ns and the pulse interval was 10 s. The experimental parameters were divided into two groups. For the first one,the energy density was 0.2-0.3 J/cm^2, the times of total pulses were 3, 10, 100 and 300, respectively. And for the second one，the number of pulses was 3 times, the energy density were 0.2-0.3 J/cm^2, 0.8-1.3 J/cm^2, 1.6-2.5 J/cm^2.

The phase structure of the metallic glass was studied by grazing incidence X-ray diffraction (GIXRD) and Transmission electron microscope (TEM). The evolution of surface morphology was characterized by scanning electron microscope (SEM). The surface reflectance of the metallic glass before and after irradiation was measured by ultraviolet spectrophotometer.

3. Main Results

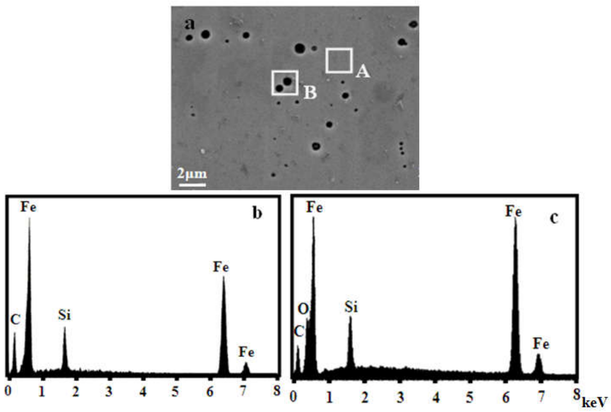

Fig.1. (a) Surface SEM images of Fe-based metallic glass after being irradiated for 300 times with the energy density at 0.2-0.3 J/cm^2. (b),(c): energy spectrums of A,B areas on the surface in Fig.2a

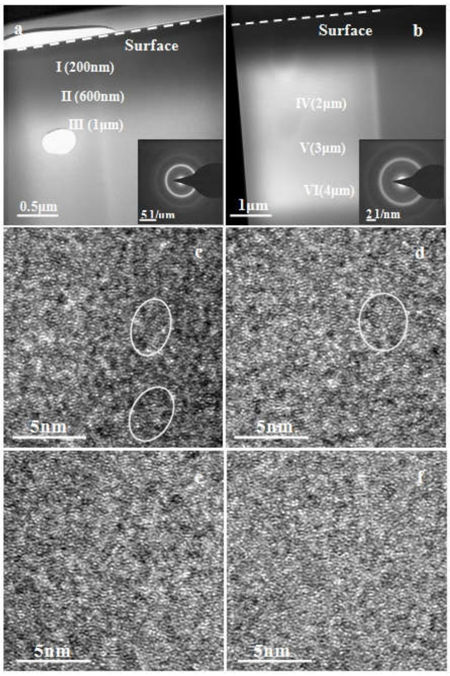

Fig.2. The cross-sectional TEM image of $Fe_{80}Si_7B_{13}$ metallic glass after being irradiated for 300 times. (a),(b) cross-sectional TEM morphology, the inset is the SAED; (c),(d): The white ellipse marks the crystalline ordered structure corresponding to the region I, II (e),(f): The disordered structure in region V,VI.

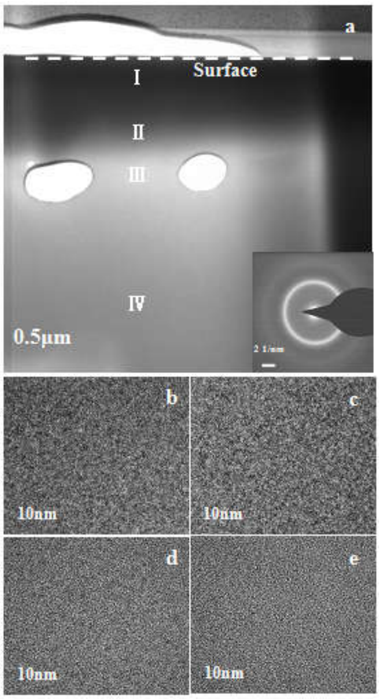

Fig.3. TEM image of Ni-based metallic glass after being irradiated for 300 times (a) cross-section TEM; (b),(c),(d),(e) HRTEM and diffraction pattern

4. Conclusion

Metallic glasses are considered to have good resistance to irradiation because of their long range disordered structure and the existence of abundant free volume. Due to the unique characteristics of high-intensity pulsed ion beam (HIPIB) such as high ion current, short pulse, high kinetic ion energy, HIPIB irradiation technology could be used to study the thermal irradiation damage of metallic glass. After the irradiation with the impulses number of 300 and the energy density of 0.32J/cm^2, a large number of round holes and a few "bumps" appeared on the surfaces of the metallic glasses and no radiation damage such as cracks occurred. Under the HIPIB irradiation, the metallic glasses remained amorphous, while the arrangement of atomic structure in the sub-surfaces of Fe-based metallic glasses became more disordered: irradiation induced strong migration and aggregation of atoms inside the metallic glass, making the atomic arrangement uneven. After the irradiation, the surface reflectance of the metallic glass decreased slightly. The number of impulses had greater impact on metallic glass than energy density. Both the metallic glasses have good heat radiation resistance and structural thermal stability.

5. Acknowledgements

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6. References

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