Changes in local structure and hardness of Ni-Ti alloy induced by heavy ion irradiation

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Abstract
B2-type Ni-Ti alloys were irradiated with 200 MeV Au and Xe ions to investigate the changes in crystal structure and microstructure, and the associated changes in hardness. The results showed that the Au ion irradiation induced an amorphous phase, whereas the Xe ion irradiation maintained the crystalline structure and produced only lattice defects, despite the same irradiation energy. In addition, a difference in hardness in response to these structural changes was observed, confirming the dependence of the hardness on the ion species. This is thought to be due to the difference in the nuclear stopping power.

1. Introduction
Amorphous materials have different properties from crystalline materials, such as strength, electrical conduction, and magnetism, but the method of creating amorphous materials is generally done by rapid cooling, which has the drawback that amorphization is difficult to control. Heavy ion irradiation is known to cause local disturbances to lattice ordering in materials and is being studied as a new method of material modification. Our previous work showed amorphization by swift heavy ions irradiation for some kind of alloys. It has been reported that Ni-Ti alloy with a hexagonal structure do not become amorphous and that amorphization in other alloy systems is ionic species dependent [1-3]. From these points of view, in this study, to investigate the difference in crystal structure in the same alloy and its dependence on ion species as a factor in irradiation-induced amorphization, the structural changes induced by irradiation of B2-type Ni-Ti alloy with ion species with significantly different nuclear stopping power were investigated.

2. Experiment
Ni-Ti alloy with a composition ratio of 1:1 was prepared by arc melting method in an argon atmosphere. This sample was cut into the size 5 mm × 5 mm × 0.5 mm plate, then polished the surface and annealed at 900 °C for 30 minutes in vacuum. They were irradiated with 200 MeV Xe and Au ions up to the flluence of 5×10^{14} cm^{-2} using a tandem accelerator at JAEA-Tokai. X-ray diffraction, extended X-ray absorption fine structure (EXAFS) at the Ni and Ti-Kα absorption edges, positron annihilation coincidence Doppler broadening (CDB), and micro-Vickers hardness measurements were performed for samples before and after each ion irradiation.

3. Results and discussion
Figures 1 and 2 show the XRD results of Ni-Ti alloys with Au and Xe ion irradiation, respectively. In case of Au ion irradiation, a halo pattern indicating amorphization appeared by the irradiation, while amorphization did not observed in case of Xe ion irradiation. EXAFS results showed that Ni-Ti bonding decreased significantly with increasing irradiation dose for

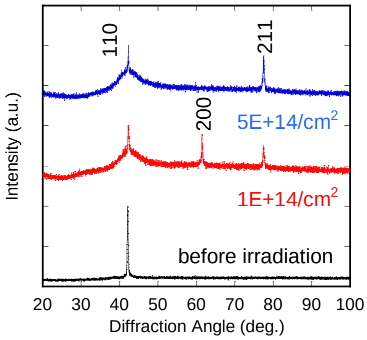

Fig.1 XRD spectra before and after irradiation of 200MeV-Au

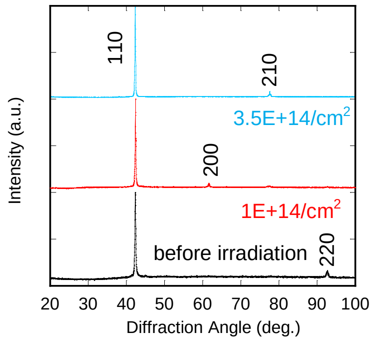

Fig.2 XRD spectra before and after irradiation of 200MeV-Xe

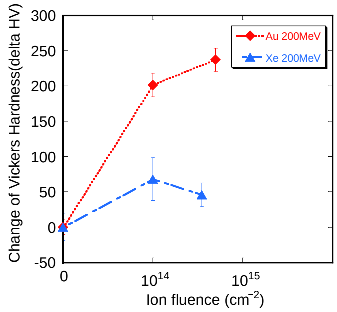

Fig.3 Micro Vickers hardness change of Ni-Ti alloy irradiated with 200 MeV Au and Xe ion.

Au ion irradiation, whereas it decreased only slightly for Xe ion irradiation. On the other hand, CDB measurements showed an introducing vacancy type defects by the irradiation for both ion irradiations. These results indicate that local damage is introduced regardless of the ion species, but that there is a difference in the disorder of the ordered structure depending on the ion species. This difference is thought to be due to the fact that Au ions have a nuclear stopping power Sn about 1.5 times higher than Xe ions. In other words, Xe ion irradiation retains the crystal state with a low defect density due to damage, whereas Au ion irradiation may have frozen the disordered state because of damage with high dense lattice defects that cannot be recovered. Figure 3 shows the change in micro-Vickers hardness after Au and Xe ion irradiations. Although hardness increased in both irradiation cases, the amorphized Au ion irradiation resulted in a larger increase in hardness than the Xe ion irradiation. The increase in hardness due to Xe ion irradiation can be attributed to defects such as dislocations caused by irradiation [4,5].

4. Conclusions

Ion species dependence was confirmed for amorphization of B2-type Ni-Ti alloys by heavy ion irradiation. Furthermore, it was found that irradiation induced amorphization depends sensitively not only on the crystal structure of the target but also on the irradiation conditions. Especially, it was found that amorphization was greatly enhanced by 200 MeV Au ion irradiation, which has a high nucleation stopping power. We also found that amorphization has a significant effect on hardness change.

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