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Effect of Energetic Ion irradiation on Lattice Structure and Hardness of Double-Phased Zr-Ni Alloy

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1 Introduction

Our previous papers have reported that non-thermal equilibrium lattice structures are induced by energetic ion irradiation in some Ni-based intermetallic compounds. The irradiation-induced lattice structures strongly depend on the target materials. The intrinsic lattice structures of Ni_3V and Ni_3Al are the tetragonal ($D0_{22}$) and the ordered FCC ($L1_2$) structures, respectively. By the energetic ion irradiation, they change to the disordered FCC (A1) structure [1,2]. In the case of Ni_3Nb, and Ni_3Ta, the intrinsic structures (orthorhombic and monoclinic structures, respectively) are amorphized by the irradiation[3,4]. All the Ni-based intermetallic alloys we have investigated so far show the single-phased structures before the irradiation. In the present study, we chose the double-phased Zr-Ni alloy, and the effect of 100 MeV Ni ion irradiation on its lattice structure and hardness was investigated.

2 Experiment

A $Ni_{30}Zr_{70}$ alloy was prepared by using pure Ni and Zr metals. An alloy ingot was made by arc melting in an argon gas atmosphere. The ingot was thermally aged at 1100 K for 12 hours in vacuum of $<3x10^{-4}$ Pa. After the thermal aging, the ingot was cut into some sheets with the dimension of 5x5x0.5 mm^3. The surfaces of alloy sheets were polished by using #2000 emery-paper and #3000 alumina buff. The surface morphology of the alloy sheets was observed using an optical microscope.

The alloy sheets were irradiated at room temperature with 100 MeV Ni ions by using 20 MV tandem accelerator at Nuclear Science Research Institute of Japan Atomic Energy Agency. The ion fluences were 1×10^{13}, 1×10^{14} , 2×10^{14} and 5×10^{14} cm^{-2}.

The lattice structures of the unirradiated and irradiated samples were examined by using an X-ray diffraction method (XRD). The CuKα x-ray was used for the diffraction. To investigate the local structure around Ni atoms, the extended x-ray absorption fine structure (EXAFS) measurements were performed near the Ni K absorption edge at the 27B beamline of the synchrotron radiation facility of High Energy Accelerator Research Organization (KEK-PF). The EXAFS spectra were obtained by using the fluorescence method with a 7-element germanium x-ray detector.

The irradiation-induced hardness change was examined using a Vickers hardness tester with a load of 10 gf and the time interval of indentation was kept at 10 seconds.

3 Results and Discussion

Fig. 1 shows the surface image of the unirradiated Ni-Zr sample obtained by an optical microscope. The figure clearly shows that the Ni-Zr sample consists of two phases. The existence of the two phases in the unirradiated sample was confirmed by the XRD measurement. As can be seen in Fig.2, the XRD peaks for the tetragonal phase ($NiZr_2$) and those for the hexagonal phase (Zr) are observed in the XRD spectra.

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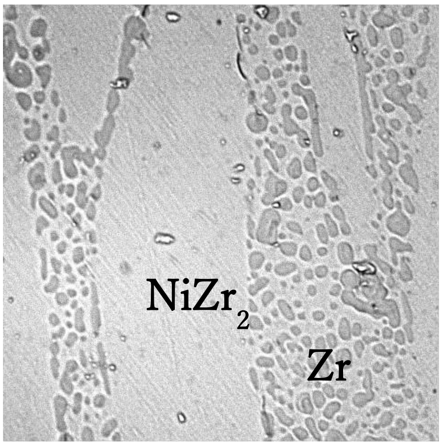

Fig. 1: Surface image of Ni-Zr alloy

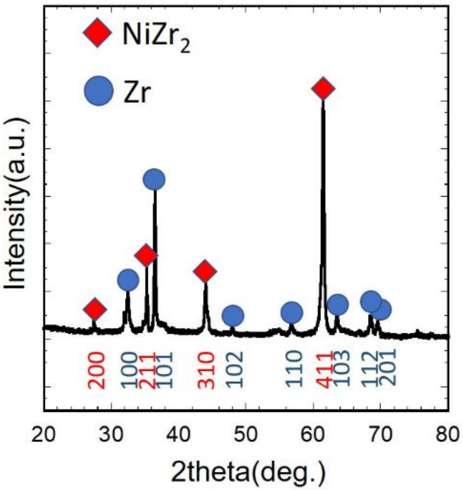

Fig.2: XRD spectra for unirradiated Ni-Zr alloy

Fig. 3 shows the effect of 100 MeV Ni ion irradiation on the XRD spectrum. Even after the ion irradiation, XRD peaks corresponding to the tetragonal and hexagonal lattice structures are clearly observed, which means that the lattice structures keep unchanged by the irradiation. This irradiation effect is quite different from the case of the other Ni-based intermetallic compounds.

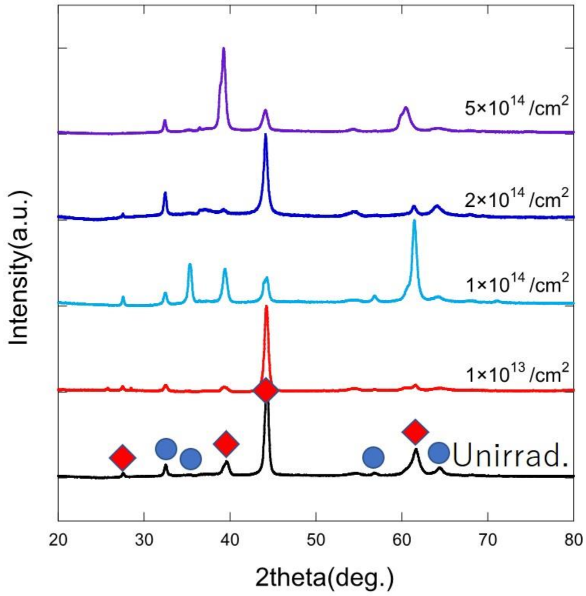

Fig.3: XRD spectra for unirradiated and irradiated Ni-Zr alloy. Fluences of 100 MeV Ni ions are shown in the figure.

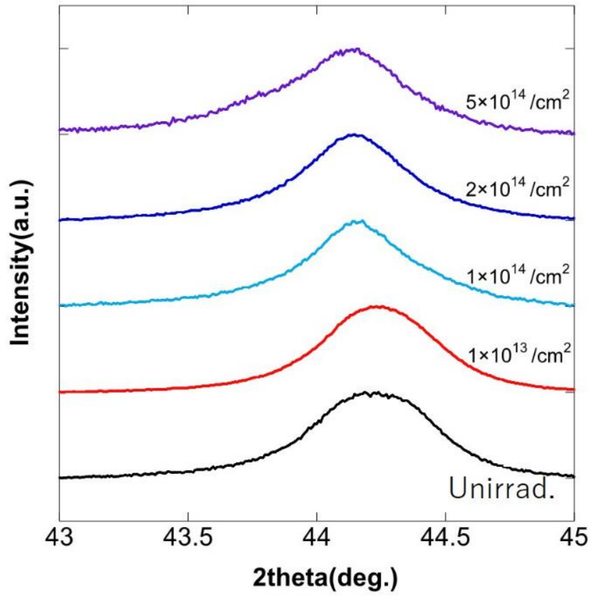

Fig.4: Magnified XRD spectra of unirradiated and irradiated Ni-Zr alloy around 44.2 degree.

Fig. 4 shows the magnified XRD spectra around 44.2 degree. With increasing the ion fluence, the XRD peak shifts to lower angles. This experimental result indicates that the lattice is expanded by the ion irradiation.

The effect of 100 MeV Ni ion irradiation on the lattice structure is also observed in the EXAFS spectrum. Fig. 5 shows that the intensity of EXAFS-FT spectrum decreases by the irradiation. This result means that the atomic arrangements near Ni atoms are disordered by the irradiation.

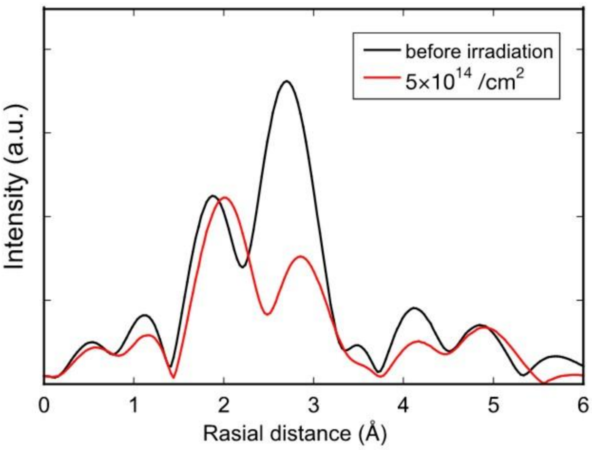

Fig. 5: EXAFS-FT spectra for unirradiated and irradiated Ni-Zr alloy.

Fig. 6 shows the micro Vickers hardness of Ni-Zr alloy as a function of 100 MeV Ni ion fluence. Although the tetragonal and hexagonal structures remain unchanged by the irradiation, the hardness increases with increasing the ion fluence. The investigation for the mechanism of the ion irradiation-induced hardness change is now in progress.

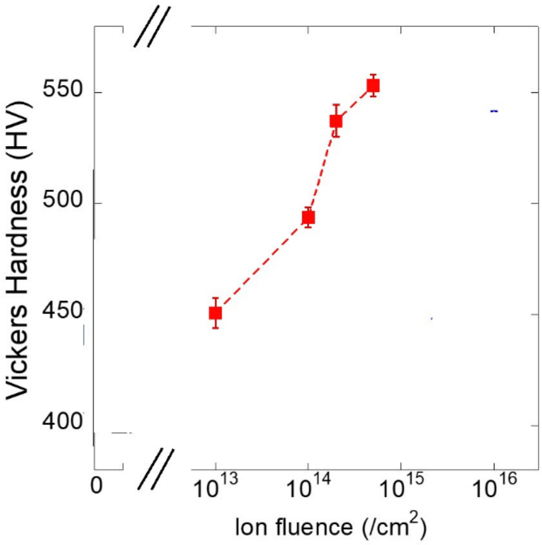

Fig. 6: hardness of Ni-Zr alloy as a function of 100 MeV Ni ion fluence.

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