§2. XAFS Study of Ni^{3+} Irradiation Effects on NIFS-V Alloy and Metals

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XAFS analysis performed in an attempt to detect a localized structure of the alloying element in V-4Cr-4Ti and the irradiation effect of Ni^{3+} ions on the constituent atoms in V alloys and Ti, Zr, Cu metals. It was found to be possible to study nanostructures of alloying element in the cluster state such as Ti substitution to V host lattice. An irradiation effect was obviously observed in Zr foil, namely the coordination number of Zr atom changed from 12 to 8 by Ni^{3+} ion irradiation.

Regarding efforts to realize fusion reactors, one of the key issues is elucidation of the behavior of hydrogen and its isotope in the reactor components and their joined interfaces, which are exposed to the heavy irradiation of ions and neutrons. In the first step, we tried to clarify the nanostructure of the lattice defects introduced by ion irradiation through X-ray absorption fine structure (XAFS). This in-laboratory XAFS apparatus is of a type first constructed in 1997 in the Tanaka Solid Junction Project of JST and is for investigating the nanostructure of light elements. XAFS reveals electronic structures and symmetry of the specified atoms and atomistic structures around them using intensity vibration near the X-ray absorption edge (XANES) and in the higher energy region (EXAFS) which are inherent to the constituent atom. In this study, we checked whether the localized atomic structure introduced by the heavy ion irradiation is detectable by XAFS or not.
Irradiated specimens were sheet-like V-4%Cr- 4%Ti and film made of its constituent element. A vanadium alloy, NIFS-HEAT-1, was supplied from the National Institute for Fusion Science (NIFS) for the large-sized fusion reactor components. The V alloy was rolled to 34 μm in thickness and then annealed with Zr foil wrapping, whereas metal films were Ti, Zr and Cu having 10 μm in thickness. All specimens were irradiated by 4MeV Ni^{3+} ions in vacuum up to 1.55 dpa at the High Fluence Irradiation Facility of the University of Tokyo. Average depth of Ni^{3+} ions in vanadium was calculated to be 1.35 μm by TRIM92. The XAFS apparatus was made by Rigaku Corporation and equipped with a high-powered X-ray source, 18kV-1000mA, which provides absorption signals with high S/N ratio as a transmitted or fluorescent beam. Energy-shift, distance of the nearest neighbor atoms and coordination number were obtained from Fourier transformed XANES and EXAFS signals.

The effects of Ni^{3+} ion irradiation were analyzed by XAFS and the results are as follows:
(1) The irradiation effects on V, Ti and Cr in V-4%Cr-4%Ti and their state---transmitted signal from V atoms in vanadium alloy was hardly detected in this specimen because of the large absorbance. There were no knock-on effects on Ti and Cr alloying element. A XAFS signal of Ti atoms in the vanadium alloy shows the decrease of Ti-Ti interatomic distance, as shown in figure, which suggests the clustering state having bcc structure.
(2) Ni^{3+} ion irradiation up to 1.5 dpa induced no remarkable change of the localized structures of Ti or Cr atoms in the vanadium alloy.
(3) The irradiation to Zr foil induced the decrease of coordination number from 12 to 8.
(4) Ni ions implanted seem to exist as a compound state with light elements.
Subjects for future work are, firstly, further XAFS study of irradiation defects in a thinner specimen; secondly, HRTEM study of the defects; and thirdly, quantitative analysis of the effects on the hydrogen behavior.

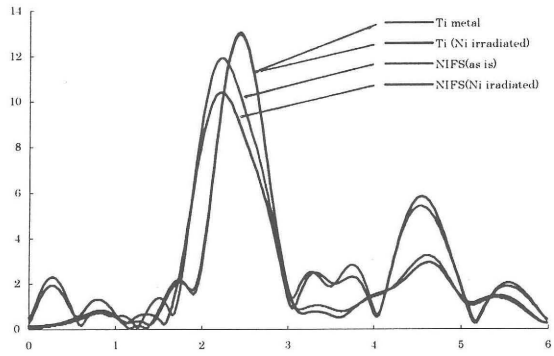

Figure Radial distribution diagram of the Ti atoms in V-4%Cr-4%Ti and pure Ti. Ti atoms in vanadium alloy form bcc cluster state different from hcp structure in pure titanium. There is no nanostructure change by the irradiation.