BL-27B/2020G109

EXAFS Study of Thermal Aging and Energetic Ion Irradiation Effects on CuTi alloy

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1 Introduction

It is well known that the thermal aging of supersaturated alloys at elevated temperatures induces the precipitation of solute atoms, resulting in the increase in hardness. Energetic particle (ions or electrons) irradiation also increases the hardness of supersaturated alloys through the process of "irradiation enhanced precipitation". In our previous papers, we have reported that in Al-2 wt.%Cu and Al-4wt.%Cu binary alloys, energetic ion irradiations produce small Cu clusters, and they contribute to the hardness increase [1,2]. The existence of Cu small clusters in the irradiated samples was confirmed by the EXAFS measurement near Cu-K absorption edge [1].

In the present report, we show the result of hardness and EXAFS measurements for CuTi alloy samples irradiated with energetic heavy ions and for those thermally aged at elevated temperature.

2 Experiment

Cu-4.2 at.%Ti alloy samples 250 μm thick were prepared for the present study. To obtain supersaturated samples, CuTi samples were heat-treated at 1223 K for 15 min. and then quenched into iced water. The samples were irradiated with 10 MeV iodine ions at room temperature by using a tandem accelerator at Takasaki Advanced Radiation Research Institute of National Institutes for Quantum Science and Technology (QST-Takasaki). For comparison, some supersaturated samples were thermally aged at 723 K in air for 12 hrs - 480 hrs.

The Vickers hardness for unirradiated, irradiated and thermally-aged samples was measured with an applied load of 98 mN and a holding time of 10 s.

The EXAFS spectra for the samples were measured near Ti-K absorption edge (4966 eV) at the 27B beamline of the synchrotron radiation facility of High Energy Accelerator Research Organization (KEK-PF). The EXAFS spectra were measured using a fluorescence method with a 7-element germanium x-ray detector at room temperature.

3 Results and Discussion

Fig.1 shows the relative change in Vickers hardness for 10 MeV iodine ion irradiated CuTi alloy samples as a function of ion fluence. The hardness of CuTi alloy once rapidly increases by the irradiation with relatively low fluences, and then it remains almost constant even with increasing the ion fluence.

Fig.2 shows the hardness change for thermally aged CuTi sample [3]. With increasing the aging time, the hardness increases, and reaches the maximum value at the aging time of 12 hrs. For the further long aging, the hardness decreases with increasing the aging time. This behavior is called " over aging".

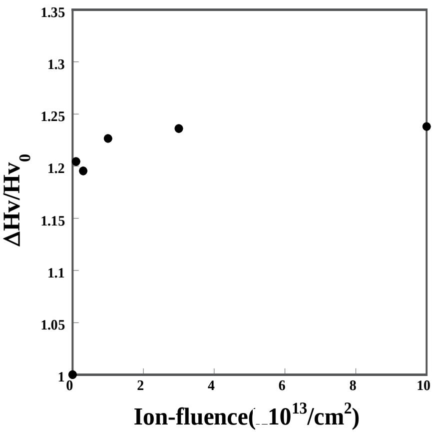

Fig. 1: Relative change in Vickers hardness for CuTi alloy as a function of 10 MeV iodine ion fluence.

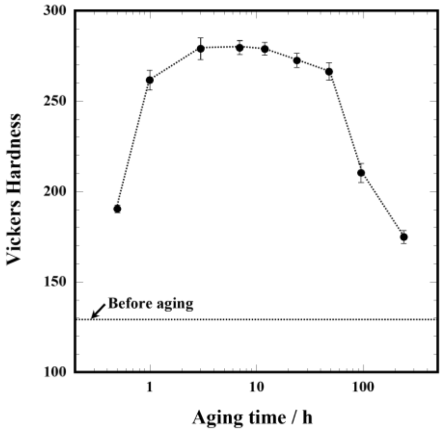

Fig. 2: Vickers hardness of CuTi alloy as a function of aging time. Aging temperature is 723 K.

Fig. 3 shows the Fourier transformed EXAFS spectra for unirradiated sample, the sample irradiated with 10 MeV iodine ions to the fluence of 1x10^{14}/cm^2, and the samples thermally aged for 12 hrs and 480 hrs. Large peaks around 2.5 Å correspond to the nearest neighbor (Cu) atoms of each Ti atom.

As well known, at the early stage of thermal aging, the spinodal decomposition causes the fluctuation of solute atom concentration, and metastable β'-Cu_4Ti precipitates with the tetragonal phase appear. In the over-aged CuTi, stable β-Cu_4Ti (orthorhombic) precipitates are produced. The changes in EXAFS spectra for thermally aged samples indicate the rearrangement of Cu and Ti atoms around each Ti atom by the Cu_4Ti precipitatation. On the other hand, the EXAFS spectrum is rarely affected by the iodine ion irradiation. The result implies that even by the ion irradiation at room temperature, the atomic arrangement around each Ti atom is not largely changed. The atom probe tomography has never found any precipitates in CuTi samples irradiated with energetic ions [4].

Therefore, in the CuTi alloy, energetic ion irradiation does not induce the irradiation enhanced precipitation. The irradiation enhanced precipitation is triggered by the thermal diffusion of radiation-produced lattice defects. Unlike in the case of aluminum alloys, in which lattice defects can easily diffuse even at room temperature, the thermal diffusion of lattice defects in CuTi does rarely cause radiation enhanced precipitation at room temperature. The hardness increase shown in Fig.1 is, therefore, due to the lattice defects in Cu matrix and not due to the radiation enhanced precipitation.

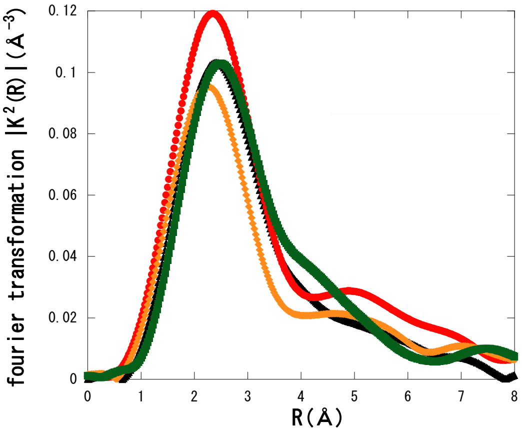

Fig. 3: FT-EXAFS spectra tor unirradiated sample (black triangles)and that irradiated with 10 MeV iodine ion irradiation at room temperature (green squares). For comparison, the spectrum for CuTi samples aged at 723 K for 12 hrs (red circles) and that for 480 hrs (orange diamonds) are also shown.

Acknowledgement

The authors thank Prof. S Semboshi for CuTi sample preparation and fruitful discussion. They also thank the staff of the accelerator group at QST-Takasaki.

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