Effect of High Energy Ion-irradiation on Defect Structure in Pure Ni

Tsuneo MATSUI[1)], Hideki YUYA [2)], Hirotake SHIGEMATSU[1)], Yoichi KONDO[1)], Yukihiro KAWAMURA[3)] and Naoshi IKEDA[4)]

1) Nagoya University, 2) Chubu Electric Company, 3) Yamaguchi University, 4) SPring-8/JASRI

1. Introduction

In metals, it had been considered for a long time that atomic displacement and radiation annealing (defect annihilation during irradiation) could be caused only by elastic interaction (direct collision of ions with target atoms). However, it was found that the energy transferred from electron-excitation to lattice atoms caused the radiation annealing. The resulting defect structure was expected to be influenced by this defect annihilation, however, a detailed information about the defect clustering was not available.

The purpose of our study is to clarify the effect of the radiation annealing on the resulting defect structure in pure Ni at the end of stage II (around 300 K).

2. Experiment

The irradiation with 85 MeV iodine ions (I^{7+}) was performed at 40 K. Diffuse X-ray scattering (DXS) experiments were performed at room temperature at the Crystal Structure Analysis beamline BL02B1 with a wavelength of 1.51 Å.

3. Results and Discussion

Figure 1 shows the intensity of DXS close to the (111) Bragg reflection in the [111] direction measured for Ni irradiated with iodine ions at room temperature.

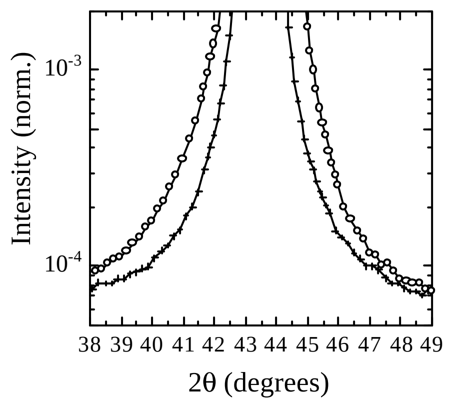

Fig. 1. Intensity of X-ray scattering from Ni close to the (111) reflection in the [111]direction.
o : after irradiation
+ : before irradiation

The intensity is the normalized value compared to that of the incident X-ray beam. Figure 2 shows the q-dependence of diffuse scattering intensities. The q^{-4} dependencies are seen, indicating the presence of both interstitial- and vacancy-loops.

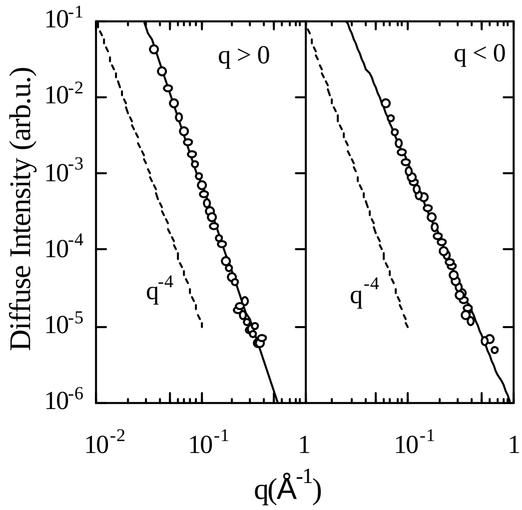

Fig. 2. The q-dependence of diffuse scattering.

More detailed information on the defect structures (*i.e.* number density and size distribution of loops) can be obtained by fitting the theoretically calculated q-dependence of diffuse scattering intensity to the experimental data. For this purpose, the q-dependencies of scattering amplitudes from vacancy and interstitial dislocation loops were calculated as a function of loop radius. The q-dependencies of scattering amplitudes along <111> reciprocal lattice vector calculated theoretically are shown in Fig. 3 for both a single vacancy loop and a single interstitial loop with a loop radius R = 10 and 30 Å in Ni as a typical example [1]. The size distribution of the dislocation loops can be obtained by assuming of the coexistence of several dislocation loops with different radii (5 - 60 Å) and fitting the calculated q-dependence to the experimental data. The results of the fitting, that are given by the dashed line, are also shown in Fig. 4 in comparison with the experimental data points. The number density of interstitials in interstitial loops in Ni irradiated with 85 MeV iodine ions was 0.74×10^{18}cm^{-3} for a irradiation dose of 1.9×10^{13}ions/cm^2 (5.2×10^{-4} dpa). Comparing the number of displaced atoms estimated by Trim code, the total number of interstitial atoms in Ni was about 1.6 % of the calculated number of displaced atoms. Resistivity recovery curve obtained by Iwase [2] following 100 MeV iodine irradiation to similar doses indicate that 50 % of the defects remain at 300 K. Therefore, we could estimate that about 97 % of the initially created interstitials were lost during 85 MeV I-ion irradiation by radiation annealing. The recombination probability within the mother cascade for high energy ion-irradiation was larger than that for neutron-irradiation (50 %) [3], indicating the presence of the enhanced radiation annealing.

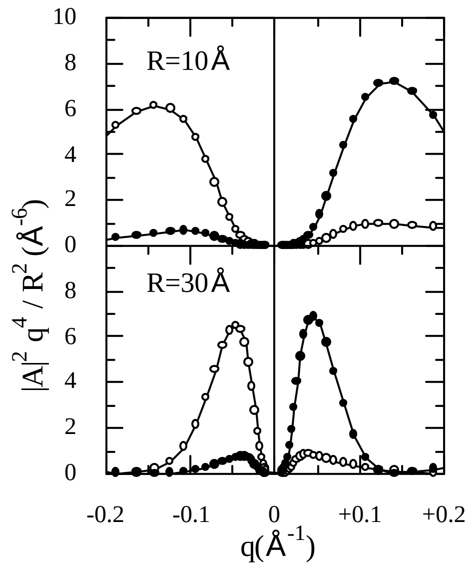

Fig. 3. Scattering amplitude $|A|^2$calculated and scaled by q^4/R^2 for vacancy (open circle) and an interstitial loop (closed circle) with loop radius R=10 and 30 Å in Ni.

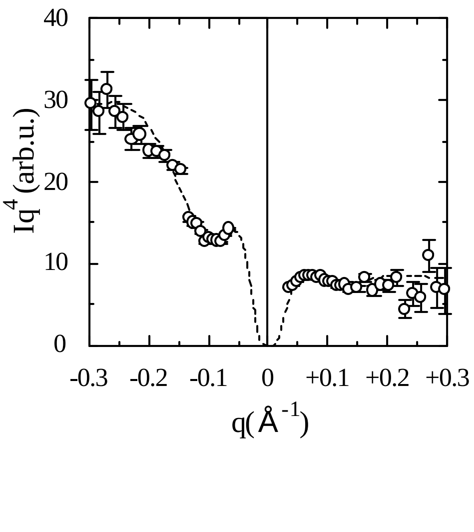

Fig. 4. Diffuse scattering intensity I scaled by q^4 obtained experimentally from Ni.
---- : fitting line for evaluating the size distribution.

References

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