Diffusivity of Nickel in Fe under 3MeV Fe Irradiation at 673K Studied by Atom Probe Tomography

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For the development of Mn-Ni-Si clustering model in reactor pressure vessels (RPVs), nickel films on iron based alloy were irradiated by 2.8 MeV Fe ions at various temperatures and the depth distribution of Ni atoms was measured using atom probe tomography (APT). The diffusion coefficient of Ni into Fe at 673K under 10^{-4} dpa/s of Fe irradiation was estimated to be 8.1×10^{-15} cm^2/s, which is larger than the estimation from thermal diffusion.

Keywords: Diffusivity, RPV, Irradiation, APT

1. Introduction

It is known that, in highly-irradiated RPVs, the embrittlement effect can be caused by nm-scale precipitates of solute Ni, Mn and Si generally called MNS clusters. Hence, the development behavior of MNS clusters is essential for the irradiation embrittlement prediction model. The migrations of Mn, Ni and Si atoms under irradiation are essential to the formation mechanism of Mn-Ni-Si clusters. In order to develop the clustering model, diffusion information of Ni are essential. However, the data of diffusion coefficients of Ni into Fe at the temperature close to reactor operation temperature (near 573K) is insufficient. In addition, the information of the effect of irradiation in Ni diffusion is insufficient. Since APT technique has enabled the quantitative evaluation of concentration distribution even for short-range diffusion of a few hundred nanometers [1], here a measurement method which consists of ion-irradiation enhancing and APT technique to measure the diffusion coefficients of Ni at low temperature was adopted.

2. Experimental

0.5um Ni film on iron based alloys are prepared using electroplating technique. Then 2.8MeV Fe^{2+} ion irradiation was performed to the center around $8\times6mm^2$ area of Ni film with pure iron substrate at 473, 573 and 673 K, respectively. The dose and the dose rate of irradiation simulated by Stopping and Range of Ions in Matter (SRIM) is 0.3 dpa and 10^{-4} dpa/s, respectively.

The measurement of concentration distribution of irradiated specimens were performed using ultraviolet (UV) laser-assisted local-electrode atom probe and the data reconstruction was performed by the analysis software of APT (IVAS 3.8.0), as illustrated in Fig.1. The reconstructed results of concentration distribution of Ni were fitted by error function deduced from Fick's second law.

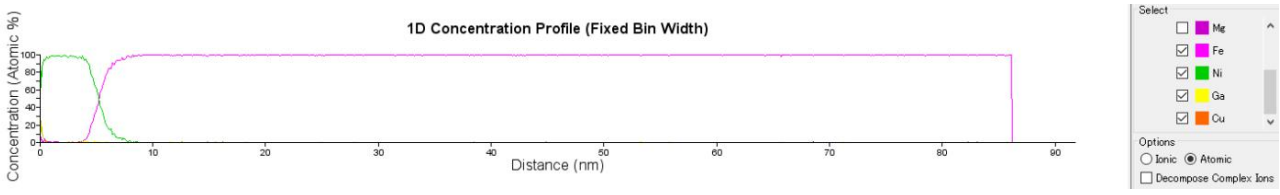

Fig. 1 Concentration distribution of Ni diffusion into Fe by IVAS 3.8.0

3. Results and discussion

In this study, the diffusion coefficient of Ni into Fe at 673K under irradiation is 8.1×10^{-15} cm^2/s. Comparing to the extrapolation of data acquired at high temperature [2], the effect of irradiation in the enhancing of diffusion is significant.

References

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