Effect of heat treatment to short-range ordering in medium entropy alloys

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There is growing global acceptance of a concept of high-entropy alloy to improve various kinds of material properties in a lot of fields of material science [1, 2]. Recent studies have pointed out a possibility of tunable stacking fault energies by tailoring local chemical ordering in high entropy alloys. That roughly means the material properties such as strength and ductility could be improved by tuning the atomic-scaled segregation. At the present, clear experimental certifications for the impact of short-range ordering have not yet been established. Under these circumstances, we have carried out neutron diffraction experiments with medium entropy alloys and found a candidate for examining the effect of short-range ordering in high/medium entropy alloys.

We prepared two medium entropy alloys (MnCoNi and CrCoNi) by the arc melting method. To remove the mechanical strain, two samples were annealed in an Ar atmosphere at about 1000°C for 2 hours and then quenched into room temperature. In addition, one sample was annealed at 400°C for 400 hours to grow an atomic-scaled segregation. Neutron diffraction experiments were carried out at room temperature with the HERMES diffractometer installed at the T1-3 beam port in JRR-3, Tokai. Neutron wave length was checked as λ = 1.34219(7) Å by measuring a standard reference material (NIST 660c).

Figure 1 shows the neutron diffraction patterns of MnCoNi (green: annealed, red: ascast) and CrCoNi (blue: annealed, light blue: ascast) as a function of the scattering vector Q. Sharp peaks at around 3 and 3.5 Å^{-1} are the Bragg reflection of (111) and (200) of the face-centered cubic structure. In MnCoNi sample, we can find additional broad signals around 1.7 and 2.4 Å^{-1}, at which the fundamental nuclear Bragg reflections are forbidden for the average fcc structure (Fm-3m). This broad feature is a clear indication for the formation of short-range ordering in alloys. Furthermore, these diffuse signals become clear in the annealed MnCoNi sample, indicating the development of the short-range ordering. A correlation length was roughly evaluated from the width of diffuse signal to be 10 Å and 40 Å for ascast and annealed sample, respectively. The evaluated values are clearly shorter than that of the averaged fcc structure. Observed position of the diffuse signal may indicate that an L10-type (P4/mmm) or an L12-type (Pm-3m) superlattice structure is formed with a short-range correlation length. On the other hand, no evidence of the short-range ordering was observed for the CrCoNi alloy. To characterize the short-range ordering in MnCoNi sample, further examination with a single crystalline sample will be carried out.

[1] As a review, H. Inui, K. Kishida, and Z. Chen: Mater. Trans. 64, (2022); doi: 10.2320matertrans.MT-M2021234, and references therein.

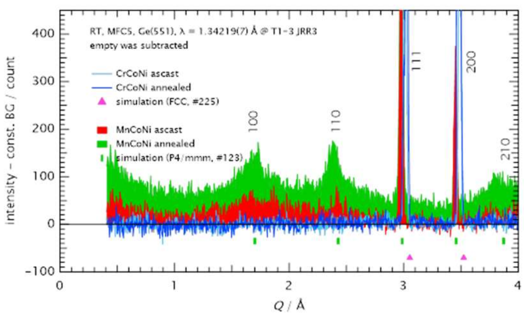

Fig. 1. Neutron diffraction patterns of medium entropy alloys (green: annealed MnCoNi, red: ascast MnCoNi, blue: annealed CrCoNi, light blue ascast CrCoNi). Here the background from the empty cell and air was subtracted.