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Effects of long term aging at 474℃ on ordering in Ni_2Cr alloy

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1. Introduction

Recently, it has been reported that there is an order disorder reaction a through DSC (differential scanning calorimetric) study in alloy 600, where a short range order (SRO) forms during an aging under a critical temperature for ordering reaction [1, 2].

Marucco has established the existence of an order disorder transformation in Ni–Cr base alloys from the study of Ni_2Cr, Ni_3Cr, and Ni–Cr–Fe alloys [3]. The presence of Fe has a strong delaying effect on the ordering kinetics, even in small quantities and other alloying elements can also influence the transformation.

It is reported that most commercial Ni–Cr based alloys have an ordering reaction based on Ni_2Cr at below 550°C [4]. Therefore, an ordering study on Ni_2Cr alloy has been carried out by some investigators [5].

In this study, in order to understand the effects of an ordering reaction on Ni_2Cr alloy, neutron diffraction studies were carried out from room temperature (RT) to 700 °C. The ordering effect on the lattice spacing was discussed.

2. Experimental

Ni_2Cr alloy was vacuum arc melted by using Ni and Cr metal with a commercial purity. The ingot was homogenized at 1250°C for 2 hours and rolled at 900°C into a 5 mm thick plate. A chemical composition of the prepared Ni_2Cr alloy is 65.4 at% Ni – 34.6 at % Cr.

A water quenching (WQ) and furnace cooling (FC) from 1095°C to fully resolve the carbide to carbon in a solution, and aged at 474°C for 880 hours specimens were prepared, then DSC measurements were carried out on theses specimens.

Because it is expected that an ordering progresses with an aging under Tc for an ordering, Ni_2Cr alloy rods with 5 mm diameter were aged at 474°C for 80,000 hours in order to understand the effects of a long term aging.

These rods were examined by a neutron diffraction from RT to 700 °C under a vacuum. The wavelength of the neutron beam was 1.837225 ±0.000034 A. The axial direction of the rod was aligned vertically and it was rotated with respect to the center line of the rod during a measurement.

This temperature variation covers an ordered state below 600 °C and a disordered state during a cooling, since a disordering reaction in Ni_2Cr alloy occurs at above 600 °C.

High temperature measurements were carried at 300, 450, 500, 550, 600, 700 °C during a heating and a cooling. Diffraction results before 500 °C show the aged state, and those after the 600 °C measurement show the disordered state.

3. Results and Discussions

Fig. 1 shows the DSC results for the WQ, the FC, and the aged Ni_2Cr alloy specimens. An exothermic reaction appeared in the WQ specimen. This is due to the non equilibrium cooling during WQ process. This exothermic reaction is not shown in the FC specimen. Atomic bonds in the FC specimen are relatively stable, when it is compared to the WQ process. It is clearly shown that LRO forms in the aged specimen at 474 °C for 880 hours. Super lattice peaks are shown in the aged specimen at 474 °C for 880 in the transmission electron microscopy (TEM).

The magnitudes of the integrated energy for the exothermic and the endothermic reaction in the WQ and aged Ni_2Cr alloy in Fig. 1 are 6 J/g and 65 J/g, respectively. The magnitude of the exothermic reaction in the Ni_2Cr alloy is very similar to an alloy 600 [2]. However, that of the endothermic reaction in Ni_2Cr alloy is roughly 10 times greater than that of alloy 600. This means LRO needs more energy to be disordered state.

It is thought that an aging treatment at 474 °C for 80,000 hours makes Ni_2Cr alloy fully ordered, and forms LRO. Therefore, this specimen maintains the ordered state until its temperature reaches Tc. Thus, the diffraction results during a heating and a cooling can be thought simply as the ordered and the disordered states.

Although all the diffraction results are not shown in this paper due to a lack of space, the super lattice peaks appeared during a heating, whereas there was no such peaks during a FC process. Each step of a neutron diffraction measurement takes two hours except for the temperature controlling time. Therefore, the disordered specimen stayed at least for 8 hours at 300~550°C during for the neutron diffraction measurements. This means that LRO is not formed by the FC process only.

Fig. 2 shows a comparison of the (311) peaks at RT and 300°C for the ordered and the disordered states. The index of the diffraction planes was based on the disordered state, since the crystal structure of the ordered state of Ni_2Cr is a orthorhombic one. The full width half maximums' (FWHM) for (311) for the ordered specimens are roughly 2 times broader than that of the disordered one. This behavior is very similar in the other planes except (111). The FWHM of the (111) diffraction is not sensitive. This seems to be due to a close packed plane.

The other difference between the ordered and the disordered state is a contraction or an expansion of the lattice. The lattice contracts during the ordering process in addition to the super lattice, and expands during the disordering process. This behavior is consistent with the previous results [5].

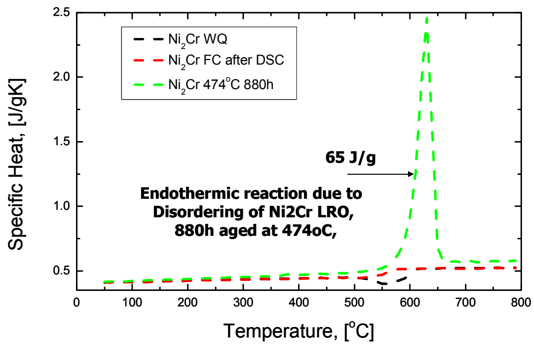

Fig. 1. Summary of DSC results for the WQ, FC, Aged specimen in Ni_2Cr alloy.

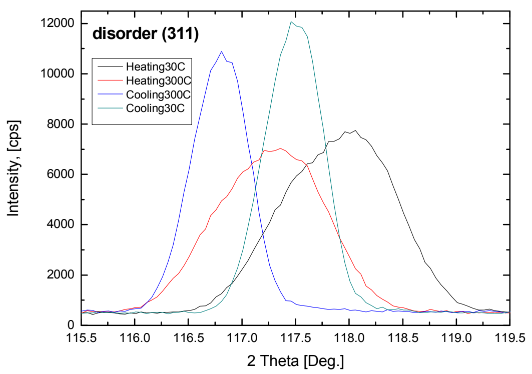

Fig. 2. Comparisons of (311) peaks of Ni_2Cr alloy at RT and 300°C in the ordered and the disordered state.

4. Summary

Ni_2Cr alloy forms LRO with an orthorhombic crystal structure during an aging at 474 °C. Ordering process in Ni_2Cr induces a line broadening in most lattice planes, however, the magnitude of the broadening varies from plane to planes. Furthermore, the lattice contraction occurs during an ordering process. In contrast, lattice expansion occurs during a disordering process above Tc, e.g. 700 °C.

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