Order-disorder reaction in Ni_2Cr alloy

SungSoo Kim
Nuclear Materials Technology Dept.
Korea Atomic Energy Research Institute,
P. O. Box 105, Yusung-Ku, Taejon 305-353, Korea

1. Introduction

Recently, it has been reported that there is an order disorder reaction in Alloy 600 through DSC (differential scanning calorimetric) analysis. A short range order (SRO) phase forms in Alloy 600 during an aging under a critical temperature for ordering reaction [1, 2]. The type of SRO phase is a $Ni_2(CrFe)$, which is based on Ni_2Cr of orthorhombic crystal structure.

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

Therefore, it is important to understand the effects of ordering on physical properties in Ni_2Cr. In this study, in order to understand the effects of an ordering reaction on Ni_2Cr alloy, a neutron diffraction studies were carried out from room temperature to 700 °C. The ordering effect on the lattice spacing was discussed.

2. Experimental

Ni_2Cr alloy was vacuum induction 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.

Some 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 were examined by the neutron diffraction from RT to 700 °C under a vacuum. The wavelength of the neutron beam was 1.837225 $\pm$0.000034 A. The axial direction of the rod was aligned vertically and it was rotated during a measurement.

High temperature measurements were carried at 300, 450, 500, 550, 600, 700 °C during a heating and during a cooling. The neutron diffraction experiments from RT to 600 °C during heating were measurements for the ordered state, whereas those from 700°C to RT during cooling were that for the disordered state. Because the starting material is fully ordered state and a disordering reaction in Ni_2Cr alloy occurs at above 600 °C.

3. Results and Discussions

Fig. 1 shows the neutron diffraction results in Ni_2Cr. The super lattice peaks are observed in the aged specimen. This means that long range order (LRO) forms in the aged specimen at 474 °C for 80,000 hours. This is consistent with the electron microscopy observation, since it has been confirmed that the super lattice peaks are shown in the aged specimen at 474 °C for 880 hour in the transmission electron microscopy (TEM).

This has been confirmed by the DSC analysis. The magnitudes of the integrated energy for the exothermic and the endothermic reaction in the WQ and aged Ni_2Cr alloy 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 10 times greater than that of Alloy 600. This means that LRO in Ni_2Cr 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.

The super lattice peaks only appeared during a heating, whereas there was no such peaks during a FC process. Each step of the 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 neutron diffraction measurement process during cooling.

Fig. 2 shows that the super lattice peaks from the ordered Ni_2Cr disappears at above 700 °C. Although it is reported that the critical temperature for Ni_2Cr is

영원한 우리땅, 독도
Dokdo forever
belongs to Korea

590 °C, those peaks does not disappear. This seems to be due to the non equilibrium state of examination condition. The shifts of the peaks are due to the thermal expansion of a $(020)_{orthorhombic}$ peak of Ni_2Cr

Fig. 3 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 the orthorhombic one. The full width half maximum (FWHM) for (311) for the ordered specimens is roughly 2 times broader than that of the disordered one. The shape of the peak is not symmetry. This seems to be due the superposition of the (311) and the super lattice peak of LRO. This behavior is very similar in the other planes except (111). However, the FWHM of the (111) diffraction is not sensitive.

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 existence of the super lattice peak, and expands during the disordering process. This behavior is consistent with the previous results [5].

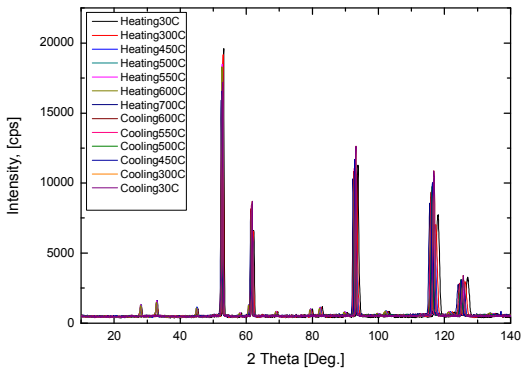

Fig. 1. Summary of neutron diffraction results in ordered Ni_2Cr alloy.

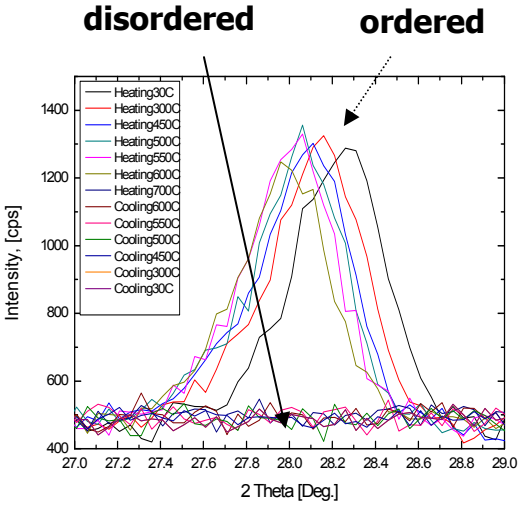

Fig. 2. Comparisons of super lattice peaks of ordered Ni_2Cr alloy.

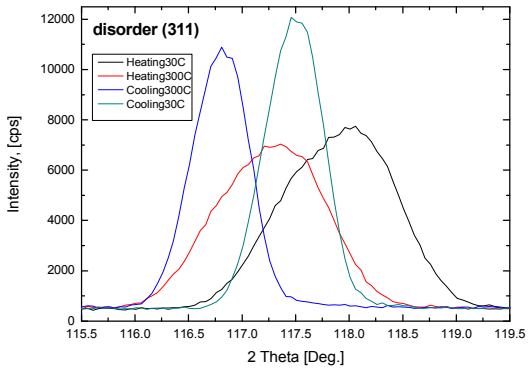

Fig. 3. Comparisons of (311) peaks of Ni_2Cr alloy at RT and 300°C in the ordered and the disordered state.

4. Summary

Ni_2Cr alloy forms LRO phase with an orthorhombic crystal structure during an aging at 474 °C for 880 hour. The super lattice peaks from the ordered Ni_2Cr phase were maintained at 600 °C and the LRO phase was decomposed in the measurement at 700°C. The LRO phase is not formed during measurement of cooling. Ordering process in Ni_2Cr causes a line broadening in all plane, however, the magnitude of the broadening varies from plane to planes. Certain portion of the line broadening seems to be due the appearance and the superposition of the super lattice peak of the LRO phase. The lattice contraction occurs during an ordering process, whereas the lattice expansion occurs during a disordering process.

Acknowledgements

This work has been carried out in the Nuclear Materials Technology Development project as a part of the Nuclear R&D program funded by the Ministry of Education and Science and Technology in Korea.

REFERENCES

[1] S. Kim, I. L. Kuk, and J. S. Kim, Materials Science and Engineering A279, 142, 2000.
[2]. S. Kim, J. Kim, and H. Kim, Journal of Korean Metal and Materials, 44, 473, 2006.
[3] A. Marucco, Key Eng. Mat., Vol.48, p. 77, 1990.
[4] A. Marucco, B. Nath, J. Mat. Sci. Vol.23, p. 2107, 1988.
[5] L. Karmazin, Materials Science and Engineering 54, 247, 1982.

영원한 우리땅, 독도
Dokdo forever belongs to Korea