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Heat Treatment Conditions to Fabricate Ti-Ni Shape Memory Alloy by Laminate Method

Kazuhiro Kitamura

Department of Mechanical Engineering, Nagano National College of Technology,
716 Tokuma, Nagano, Nagano 381-8550, Japan
Fax: 81-26-295-7053, e-mail: kitamura@me.nagano-nct.ac.jp

The purpose of this study is to investigate the heat treatment conditions to fabricate Ti-Ni shape memory alloy by Ti/Ni multilayers. The Ti/Ni multilayers were fabricated by multi-step cold rolling of laminates of Ti and Ni foils. They were heat treated at temperatures between 973K and 1273K. The shape memory characteristics of the samples made by laminate method were measured by X-ray diffraction and differential scanning calorimeter. The Ti/Ni multilayers were alloyed to Ti-Ni at 973 K or higher temperature for 12 h or 24 h. The shape memory characteristics at the room temperature are best for the sample heat treated at 1173 K for 24 h among all studied samples.
Key words: Ti-Ni, shape memory alloy, multilayer

1. INTRODUCTION

Ti-Ni shape memory alloys (SMAs) have been applied to various fields. It is especially applied to the medical field, and the structure materials such as cellular phone antennas and glasses frames. Applications of the Ti-Ni alloy do not increase a lot because the material cost is high. It is necessary to reduce the processing cost to increase applications further. Crone *et al.* reported that they applied laminate method to produce Ti-50.0at%Ni alloy from [1]. Tomus *et al.* reported that they have applied this method to produce Ti-48.5at%Ni and Ti-50.7at%Ni alloy [2-3]. The aim of the present research is to fabricate Ni rich Ti-Ni alloys by simple cold rolling and heat treatment.

2. MATERIALS AND METHOD

The multilayers were fabricated by the following procedures. Ti (99.5%) and Ni (99.7%) sheets the thickness of 0.1 mm were used for the start materials. These sheets were cut in the width of 10 mm. Ten layers of Ti and Ni sheets were stacked alternately and cold rolled up to 0.05 mm thickness. The cold rolled specimens were cut in the half, and were piled up again. This process was repeated three times. The specimens had 80 layers and the thickness of one layer was 0.025 mm. The mixing composition was Ti-61at%Ni. The multilayer secluded in vacuum were heat treated at 973 K, 1073 K, 1173 K, 1273 K for 12 h and 24 h. After heat treatment, the samples were quenched in water immediately. The fabrication conditions are listed in Table I. The phase constituent of the specimens was determined by X-ray diffraction (XRD) measurement at room temperature. The transformation temperatures of Ti-Ni alloys were measured by differential scanning calorimeter (DSC).

3. RESULTS AND DISCUSSION

The results of the XRD measurement were shown in Fig. 1. The lowest curve of Fig. 1 shows the XRD patter of typical bulk specimen. The diffraction peaks of Ti-Ni alloy (B2) and (B19') is presented in all heat treatment conditions. From XRD measurement, it was found that the Ti/Ni multilayer alloyed to Ti-Ni under all heat treatment conditions. It was found from the results that there are phase transitions at temperatures both higher and lower than the room temperature in all samples. Although Ti and $TiNi_3$ Ni-rich precipitate peaks were presented for all heat treatment samples, Ni peaks vanish completely in the case of 1173K-24h and 1273K-24h specimens. These results show that the Ni change into Ti-Ni and TiNi3 at 1173 K or higher heat treatment temperature.

Table I. Heat treatment conditions of the samples

Sample	Heat treatment temperature (K)	Heat Treatment time (hour)
973K-12h	973	12
1073K-12h	1073	12
1073K-24h	1073	24
1173K-24h	1173	24
1273K-24h	1273	24

The DSC curves indicate the martensitic transformation behavior. The above curve shows a transformation from the parent phase to martensite phase on cooling. The martensitic transformation starts at M_s and finishes at M_f on cooling, while the reverse martensitic transformation starts at A_s and finishes at A_f on heating. Figure 2 shows DSC curves of 1073K-12h. A big peak exists at 335 K and a small peak exists at 320 K in the cooling curve. It suggested that there are two kinds of Ni composition. Figure 3 shows DSC curves of the specimen heat treated at 1073 K for 24 h. Only one

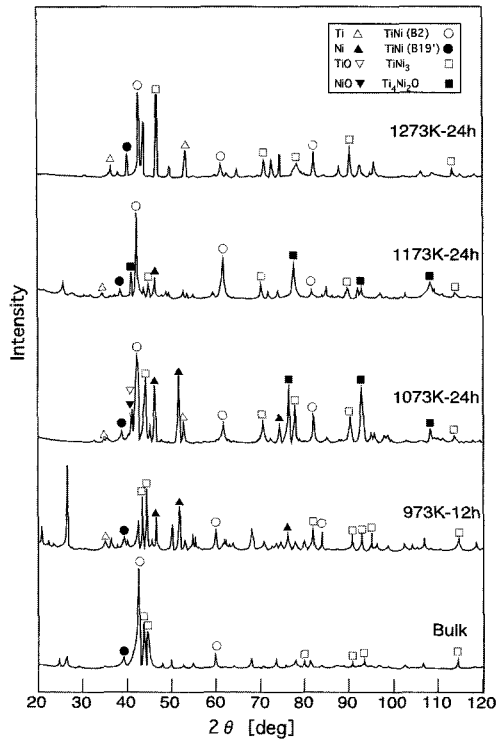

Fig. 1. XRD patterns of several heat treatment specimens.

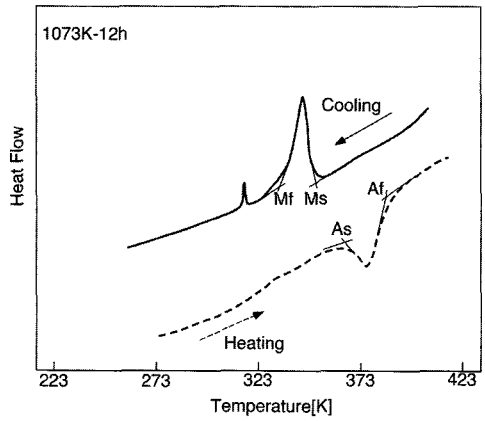

Fig. 2. DSC profile of 1073K-12h specimen.

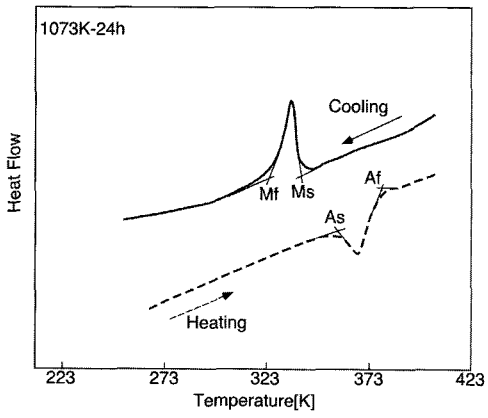

Fig. 3. DSC profile of 1073K-24h specimen.

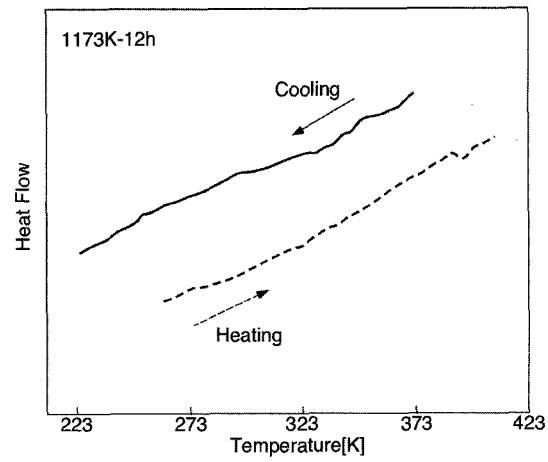

Fig. 4. DSC profile of 1173K-12h specimen.

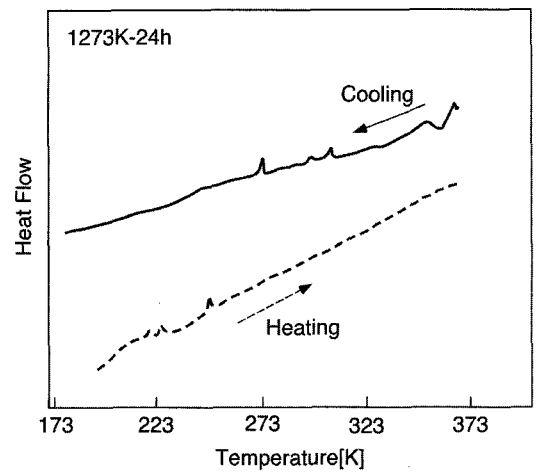

Fig. 5. DSC profile of 1273K-24h specimen.

martensitic transformation peak was appeared. This results show the specimen was made by single composition of Ti-Ni alloy. Figures 4 and 5 show the DSC curves of 1173K-12h and 1273K-24h specimens, respectively. The small DSC peak corresponding to multi step martensitic transformation was appeared. The result of this multi step transformation shows difference of Ni composition in the specimen. No appearance of the large transformation peak indicates the very low martensitic transformation temperature due to high Ni composition.

4. CONCLUSIONS

Ti-Ni SMAs were fabricated by laminate method using a single rolling machine. From DSC measurement, the Ti/Ni multilayer was alloyed to Ti-Ni under all heat treatment conditions. From DSC measurement, the sample heat treated at 1073 K for 24 h showed only one martensitic transformation peak. This results reveal that the specimen was made by single composition of Ti-Ni alloy. For 1173K-24h and 1273K-24h specimen, the small DSC peak corresponding to multi step martensitic transformation was appeared. This multi step transformation reveals difference of Ni composition in

the specimen. The best heat treatment condition for shape memory effects was 1073 K and 24 h.

5. ACKNOWLEDGMENT

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