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Effect of Electric Current Heat Treatment on the Shape Memory Characteristics in Ti-Ni Thin Wires

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Ti-Ni shape memory alloy (SMA) is a functional material applied to various fields. This alloy has been applied in the thermal engine, actuator for micro robot, fishing line and dental corrective devices. In general, shape memory treatments were carried out by electric furnace. If using the current heat treatment with a view to improving a shape memory heat treatment, SMA has a much boarder range of application. This study explored the effects of the electric current heat treatment on the shape memory behavior. Ti-Ni thin wires with diameters of 0.3mm were made by melting ingot followed by drawing the wires. The composition of this wire was Ti-50.2at%Ni. These wires were electric current heat treated at 8V 0.7A and 16V 1.7A in the range of 5 minutes, 15 minutes and 30 minutes respectively. The transformation temperatures were measured by a Differential Scanning Calorimeter (DSC) during cooling and heating. Mechanical properties were measured by a tensile machine. From DSC measurement, all specimens were appeared shape memory effect. From stress - strain measurement, the best current heat treatment condition is 8V-30 minutes.

Key words: Ti-Ni, shape memory alloy, current heat treatment

1. INTRODUCTION

Ti-Ni SMA thin wire has been applied in the thermal engine [1-3], actuator for micro robot [4], fishing line and dental corrective devices. In general, shape memory treatments were carried out by electric furnace. On the other hand, SMA wire memorize in the shape of each patient's teeth, the shape memory treatment was done by electric current heating in a dental clinic. However, little is know about the shape memory characteristics of the electric current heat treatment [5]. If using the current heat treatment with a view to improving a shape memory heat treatment, SMA has a much boarder range of application and there are only a few studies done on the shape memory characteristics of the electric current heat treatment. This study explored the effects of the electric current heat treatment on the shape memory behavior. The purpose of this study is to investigate the effect of electric current heat treatment on the shape memory characteristics in Ti-Ni thin wires.

2. EXPERIMENTAL

Ti-Ni thin wires with diameters of 0.3mm were made by melting ingot followed by drawing the wires. The composition of this wire is Ti-50.2at%Ni. Fig. 1 shows the view of electric current heat treatment equipment. The length of this equipment is 600mm and it has two electrode terminals. The power supply was used a TEXIO Corporation, PR18-5A. These wires were electric current heat treated at 8V 0.7A and 16V 1.7A in the range of 5 minutes, 15 minutes and 30 minutes followed by quenching in water. The Transformation behavior during cooling and heating was measured using a DSC, Rigaku Co., Ltd., DSC8230D. The cooling and heating rates were 10°C/minutes. The size of DSC specimen is 0.3mm diameter and 3mm long. Mechanical properties of the thin wires were measured

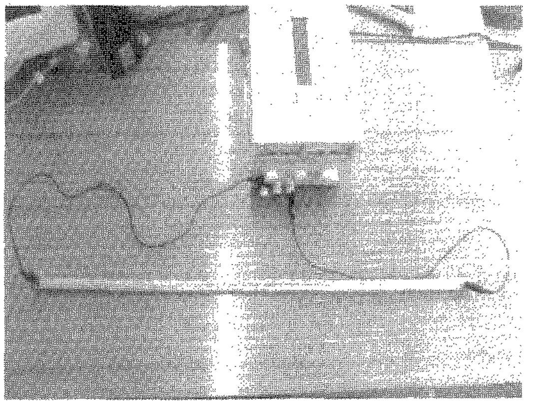

Fig.1 View of the current heat treatment equipment.

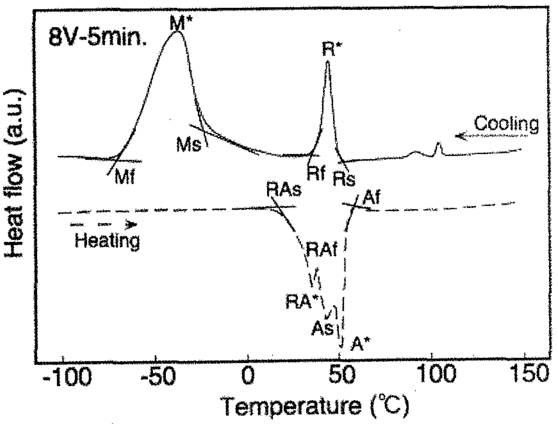

Fig. 2 DSC curves of 8V-5 minutes.

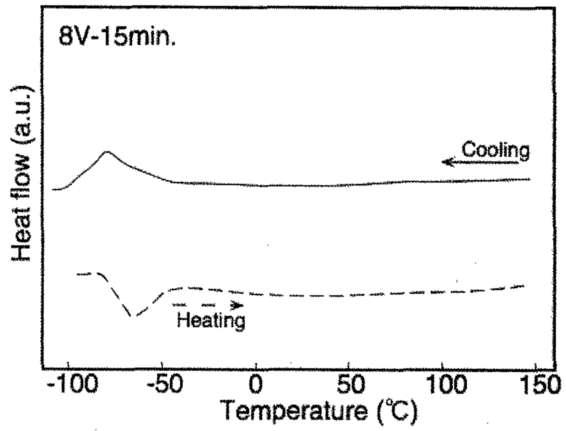

Fig. 3 DSC curves of 8V- 15 minutes.

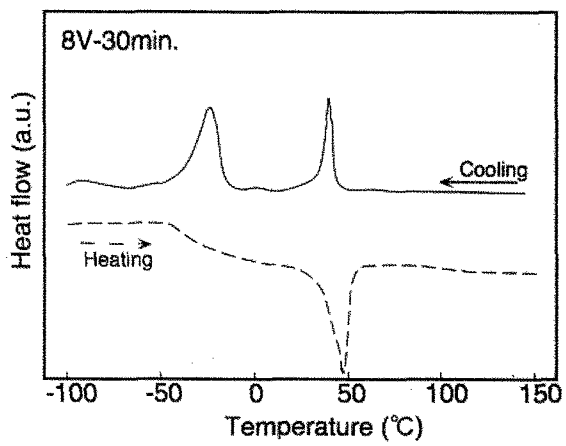

Fig. 4 DSC curves of 8V- 30 minutes.

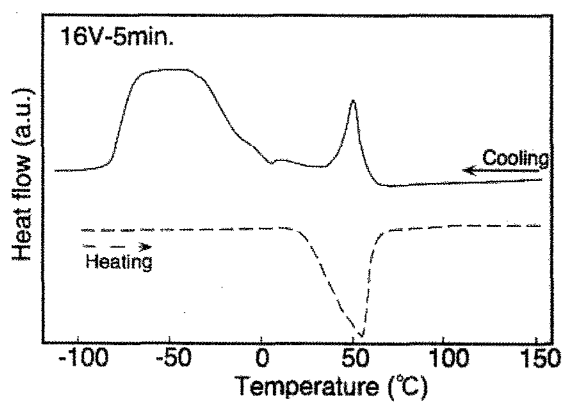

Fig. 5 DSC curves of 16V- 5 minutes.

using a tensile machine, INSTRON Corporation MODEL 1122 at room temperature. The length of tensile specimen is 10mm.

3 RESULTS AND DISCUSSION

The transformation temperatures and crystallization of the specimens are measured from DSC measurement and the result of the mechanical test is predictable from the shape of the DSC peaks. Therefore the DSC measurement and the mechanical test are necessary to evaluate the shape memory characteristics.

The shape memory characteristics are different depending on the heat treatment temperature and heat treatment time. The following results are expected from this experiment. The current heat treatment of 8V specimens the same effect as heat treatment with the furnace of 400°C and it is expected that the current heat treatment of 16V specimens the same effect as heat treatment with the furnace of 600°C.

Fig. 2 shows the DSC curves during cooling and heating for 8V-5 minutes specimens. The solid curve shows a two-stage transformation from B2(parent) phase to R(rhombohedral)-phase to M(martensite)-phase upon cooling, while the dashed line a two-stage transformation from M to R to B2 upon heating. The martensitic transformation starts at Ms and finishes at Mf upon cooling, while the reverse martensitic transformation starts at As and finishes at Af upon heating. The R-phase transformation starts at Rs and finishes at Rf upon cooling, while the reverse R-phase transformation starts at RAs and finishes at RAf upon heating. The peak temperatures R*, M*, RA*, A* of these transformations were 43°C, -37°C, 35°C and 50°C, respectively. Due to not crystallizing internal structure, the martensite DSC peak is broad and the shape memory effect is not fully in this heat treatment.

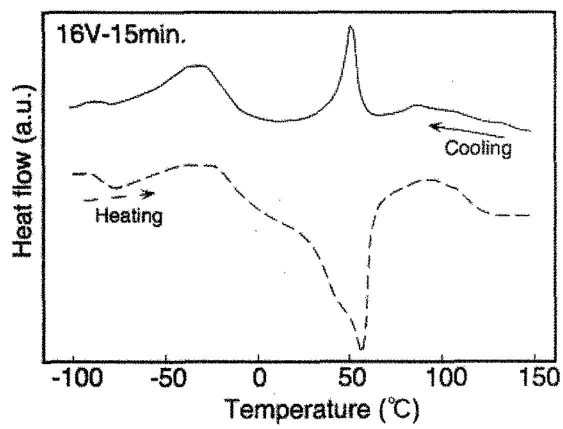

Fig. 6 DSC curves of 16V- 15 minutes.

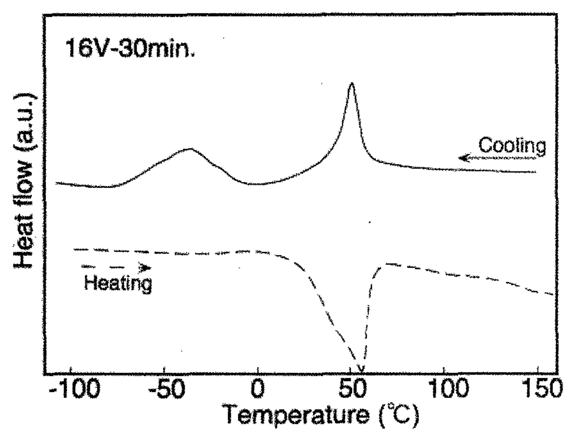

Fig. 7 DSC curves of 16V- 30 minutes.

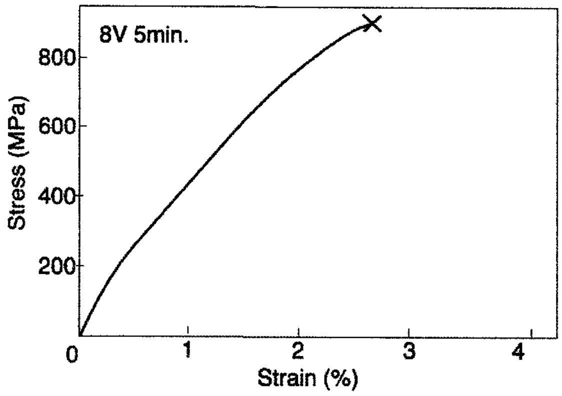

Fig. 8 Stress-strain curve of 8V-5 minutes thin wire.

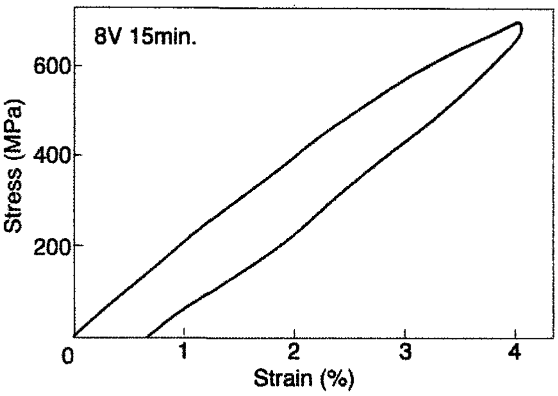

Fig. 9 Stress-strain curve of 8V-15 minutes thin wire.

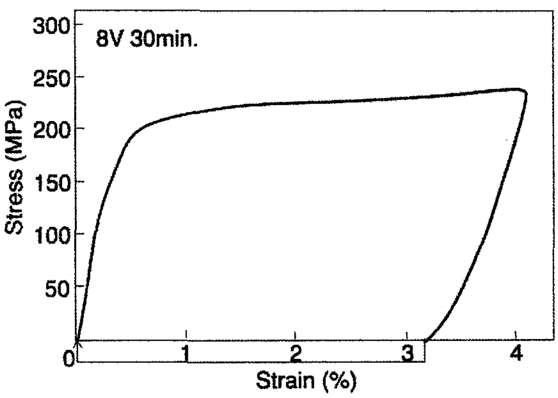

Fig. 10 Stress-strain curve of 8V-30 minutes thin wire.

In consequence, this heat treatment condition is an unsuitable.

Fig. 3 shows the DSC curves for 8V-15min specimens. In the specimen, a single-stage transformation from B2 to M-phase appeared on cooling, while one-stage reverse transformation from M-phase to B2 appeared on heating. R-phase transformation was not appeared in this sample. The same DSC broad peak of martensitic transformation appears to this specimen. Compared with 8V-5 minutes sample, the martensitic transformation temperature is low in 8V-15 minutes samples.

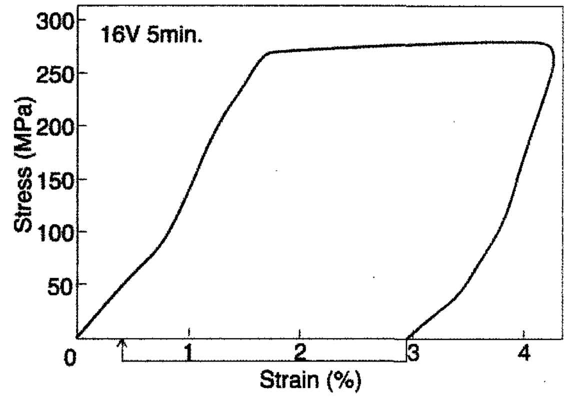

Fig. 11 Stress-strain curve of 16V-5 minutes thin wire.

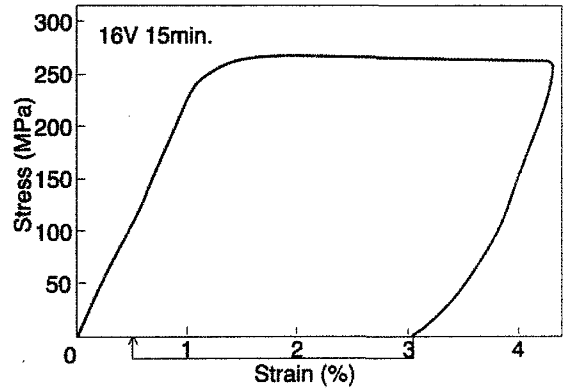

Fig. 12 Stress-strain curve of 16V-15 minutes thin wire.

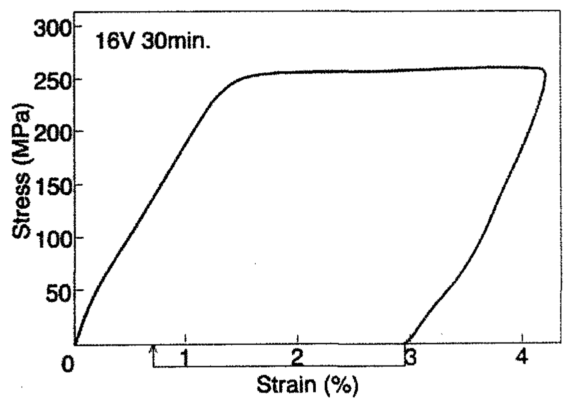

Fig. 13 Stress-strain curve of 16V-30 minutes thin wire.

Fig. 4 shows the DSC curves for 8V-30 minutes specimens. This specimen has two-stage transformation shows on cooling and two-stage reverse transformation showed on heating. The DSC curves stabilized rather than 8V-15 minutes sample. This DSC curves are quite similar heat treatment at 673K-60 minutes in electric furnace. This specimen has good shape memory behavior.

Fig. 5 shows the DSC curves for 16V-5 minutes specimen. This specimen has two-stage transformation shows on cooling and two-stage reverse transformation showed on heating. Compared with 8V-5 minutes samples, the martensitic transformation peak is broad in

16V-5 minutes samples.

Fig. 6 shows the DSC curves for 16V-15 minutes specimen. This specimen has two-stage transformation shows on cooling and two-stage reverse transformation showed on heating. The DSC curve stabilized rather than 16V-5 minutes samples.

Fig.7 shows the DSC curves for 16V- 30min specimen. This specimen has two-stage transformation shows on cooling and two-stage reverse transformation showed on heating. The DSC curves stabilized rather than 16V-15 minutes sample. This specimen has good shape memory behavior. Therefore, in order to stable shape memory characteristic need to be electro heat treated for 16V-30minutes.

Fig. 8 shows the stress-strain curve obtained from tensile test for 8V-5 minutes at room temperature. It was inadequate to obtain an good shape memory characteristics in this heat treatment condition. The shape memory behavior did not appear and the specimen was broken until 3% strain.

Fig. 9 shows the stress-strain curve obtained from tensile test for 8V-15 minutes at room temperature. The sample was not broken in the strain range up to 4% strain but the shape memory effect did not appear in this heat treatment condition.

Fig. 10 shows the stress-strain curve obtained from tensile test for 8V-30 minutes at room temperature. The plastic strain was not observed and the stress-strain curve shows an ideal shape memory behavior. The best condition for 8V current heat treatment specimen is 30 minutes [6].

Fig. 11 shows the stress-strain curve obtained from tensile test for 16V-5 minutes at room temperature. From this stress-strain curve, an unstable deformation behavior was showed in the elastic area, because of the internal structure was not stabilized. This sample showed the deformation behavior similar to the solution heat treatment specimen [6]. The plastic strain was 0.4%.

Fig. 12 shows the stress-strain curve obtained from tensile test for 16V-15 minutes at room temperature. The deformation behavior was similar to the solution heat treatment specimen [6]. Plastic strain was 0.5%.

Fig. 13 shows the stress-strain curve obtained from tensile test for 16V-30 minutes at room temperature. This sample showed the shape memory behavior similar to the solution heat treatment material as well as 16V-15 minutes.

The 8V heat treatment samples showed the same shape memory characteristic at 400°C heat treatment material and the shape memory characteristics have improved as time increases up to 30 minutes. The slipping deformation does not occur because the processing structure remains in this voltage. The other hand, the 16V heat treatment samples showed the same shape memory characteristic at 600°C heat treatment material. In this voltage, the slipping deformation occurs because the crystal grain grows by the recrystallization. The shape memory characteristics have improved as time increases up to 15 minute. The shape memory effect worsens by current heating for more 15 minutes because of the increase of the coarsening. The best current heating condition is 8V-30 minutes.

4. CONCLUSIONS

This study was investigated shape memory characteristics by using the current heat treatment method. From DSC measurement, all specimens were appeared exothermo and endothermo peaks.

From tensile tests, the good shape memory characteristics appear for 8V-30 minutes, 16V-15 minutes and 16V-30 minutes. The plastic strain was observed with all 16V samples. The best current heat treatment condition is 8V-30 minutes.

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