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Microstructure and phase transformation of nearly equiatomic Ni-Ti binary shape memory alloy

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ABSTRACT
The phase transformation and microstructure behavior of Ni-Ti shape memory alloy was investigated by scanning electronic microscope, X-ray diffraction and differential scanning calorimetry. The results showed that the microstructure of Ni-Ti binary alloy consists of the $NiTi_2$ phase and the NiTi matrix phase. One-step phase transformation was observed alloy.
Keywords - Shape memory alloy, microstructure, phase transformation,

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I. INTRODUCTION

Ni-Ti shape memory alloys (SMAs) is a very important material because it owns unique shape memory effect and super-elasticity behaviors. Today this kind of material has been used in many different fields, especially in engineering and medical application[1]. Current research interest on SMA are mainly controlling the martensitic transformation temperature and improving the shape memory effect for their applications. The effect of martensitic transformation, super-elasticity and shape memory effect have been studied widely.

Phase transformation behavior is strongly dependent on alloying elements, composition, precipitates and heat treatment.

Moreover, the microstructure and phase transformation temperature of the Ni-Ti binary alloys have also been studied using scanning electron microscopy(SEM), energy dispersive spectrometry (EDS), X-ray diffraction (XRD), and differential scanning calorimetry (DSC). The Ni-Ti binary alloys was found decreaced and increase the phase transformation temperature and change the phase transformation sequence.

II. EXPERIMENTAL

The Ni-Ti alloy were prepared by melting each 10g of raw materials with different nominal compositions (99.9 mass% sponge Ti, 99.7 mass% electrolytic Ni) in a nonconsumable arc-melting furnace using a water-cooled copper crucible. The alloy in denoted Ni-Ti alloy, respectively. Are-melting was repeated five times to ensure the uniformity of composition. The specimens are spark-cut from the ingots and solution –treated at 850^0C for an 1hour in a vacuum quartz tube furnace. Subsequently the specimens were quenched using water. Thereafter, the specimens are mechanically and lightly polished to obtain a plain surface.

The phase transformation temperature of Ni-Ti alloy were determined by DSC using a TA Q2000 calorimeter. The temperature range of heating and cooling was from -30^0C to 155^0C, and the scanning rate of heating and cooling was 10^0 C/min. SEM observations were conducted using a FEI Quanta 650 FEG equipped with EDS analysis systems made by Oxford. An XRD experiment was conducted using a D/MAX-2500PC X-ray diffractometer.

III. RESULTS AND DISCUSSION

3.1. Microstructure of Ni-Ti alloy

Fig.1 depicts the SEM images of Ni-Ti alloy. There are two different morphologies, namely, black phase and matrix can be identified in the SEM image. The black phase is in irregular shape and distributed randomly in the matrix.

To identify the phase structure, EDS analysis was conduced in SEM. The compositions of Ni-Ti alloy are shown in Table.1 The Ti:Ni ratio in the matrix of all Ni-Ti alloy is measured to be near 1. Thus, the matrix can concluded to be NiTi phase. The Ti:Ni ratio in the black phase of Ni-Ti alloy is measured to be near 2:1. By XRD analysis, there is a NiTi2 phase in Ni-Ti. Thus, the black phase can be concluded to be NiTi2.

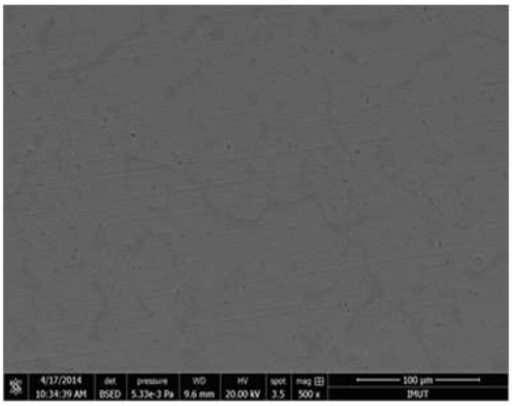

Fig. 1 SEM image Ni-Ti

Table.1 Composition of Ni-Ti alloy

		Ti (at. %)	Ni (at. %)
Ni-Ti	matrix	50.64	49.36
	black phase	66.99	33.01

3.2 XRD analysis of Ni-Ti alloy

Fig.2 depicts the XRD curve of Ni-Ti alloy at room temperature. The diffraction peaks are identified to be from NiTi B19' martensite phase and $NiTi_2$ phase alloy after comparing with JCPDF cards (numbers 65-0145 and 72-0442). The detailed crystal plane indices are marked in Fig.1 for the relative intensities of each XRD curve are quite different because of the differences in martensite phase fraction and $NiTi_2$ phase fraction.

The lattice parameters of alloy can be also calculated by peaks position in XRD curve and shows in Table.2 It is shown clearly that cell volume V expand for either Ni-Ti binary alloy. The observation can also be confirmed in the following composition analysis.

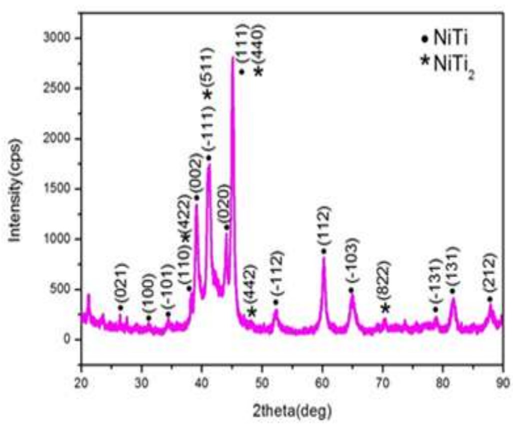

Fig. 2 XRD curve of Ni-Ti

Table.2 Lattice parameters of Ni-Ti alloy

Alloy	Phase	a(nm)	b(nm)	c(nm)	β(°)	V(nm^3)	Source
NiTi	M	0.2898	0.4121	0.4619	97.86	0.05465	This work
NiTi	M	0.2898	0.4108	0.4646	97.78	0.05480	JCPDF card No. 65-0145

3.3 Phase transformation of Ni-Ti alloy

Fig. 3 depicts the DSC curves of the Ni-Ti alloy. Each DSC curve of Ni-Ti shows only one peak during the heating and cooling process, which indicates a one-step B2↔B19' phase transformation. The effect of Ni-Ti concentration on martensitic transformation start temperature M_s. For Ni-Ti alloy, the M_s is measured to be 77.44 °C. It is well known that quenched Ni-Ti binary alloys show one-step B2↔B19' transformation and the transformation temperatures are strongly dependent on Ni concentration. 0.1 at. % increase in Ni concentration can lower the M_s of Ni-Ti binary alloys by more than 10 °C. For example, Liu et al measured the M_s to be about -50 °C for $Ni_{50.7}Ti_{49.3}$ alloy after annealing at 900 °C for 60min[2]. Tabish et al measured the M_s to be -22.12 °C for $Ni_{50}Ti_{50}$ alloy after annealing at 1000 °C for 120min[3]. Wasilewski et al measured the M_s to be 65 °C for $Ni_{49.8}Ti_{50.2}$ alloy[4]. In this work, the composition of the matrix is measured to be $Ni_{49.36}Ti_{50.64}$, which is Ti-rich. So, a high M_s of Ti-Ni binary alloy is reasonable.

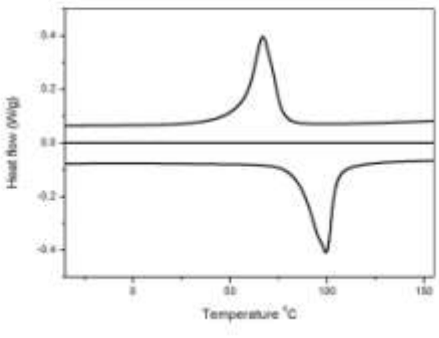

Fig.3 DSC curve of $Ni_{50}Ti_{50}$

IV. CONCLUSION

In summary, the microstructure and phase transformation behavior was investigated by XRD, SEM and DSC. The microstructure of the Ni-Ti alloys consists of NiTi2 alloy and NiTi matrix. The lattice of NiTi matrix is a=0.2898nm, b=0.4121nm, c=0.4619nm. The Ni-Ti alloy has a one-step martensitic transformation.

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