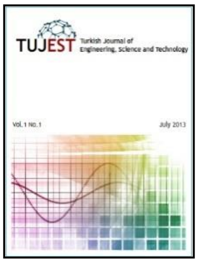
Turkish Journal of Engineering, Science and Technology 02 (2014) 90-96

Turkish Journal of Engineering, Science and Technology

journal homepage: www.tujest.com



Experimental Study of Ti-Ni-Nb Novel Shape Memory Alloys

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Article Info

Article history:
Received March 26, 2014
Accepted June 12, 2014
Available online June, 2014

Keywords:
Shape memory alloy,
Ti-Ni-Nb;X-ray diffraction,
Microstructure,
STA

Abstract

The microstructure, x ray diffractive study and simultaneous thermal analysis of the novel $Ti_{50}Ni_{48}Nb_2$, $Ti_{50}Ni_{46}Nb_4$, $Ti_{50}Ni_{44}Nb_6$, $Ti_{50}Ni_{42}Nb_8$, $Ti_{50}Ni_{40}Nb_{10}$and $Ti_{50}Ni_{38}Nb_{12}$ shape memory alloys were investigated. The dominant phase is titanium nickelide TiNi (B2 phase) intermetallic compound with the ordered bcc CsCl lattice. There is a significant content of the bcc niobium phase. Along with these phases, it contains a strong line of the fcc Ti_2Ni phase. STA results shows that there is no transformation change in this range of temperature. Due to the addition of Nb decreases the transformation temperature, so that these alloys have sub-zero transformation temperature. To find out the transformation temperature of these alloys further investigation is required. The identification of the phases in the Ti–Ni–Nb alloys shows that the dominant phase is TiNi (B2 phase) intermetallic compound, which is seen as coarse gray grains of rounded or dendrite shapes. In the present study Grain boundaries are decorated with white rounded pure niobium inclusions. A softer structural component, namely, the (Ti, Ni, Nb) eutectic, contains isolated dark gray inclusions of nickelide Ti_2Ni alloyed with niobium

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1. Introduction

The particular Ti–Ni based alloys are an important practical shape memory other metals (SMA) with excellent kinetic properties [1]. Although there had also been many controversial problems in past times as described below, many of them have been solved right now. Thus it will be helpful to review them in a unified manner by using an up-to-date basis. Secondly, there are lots of phase transformations in Ti–Ni-based other metals system, which include besides diffusionless/martensitic transformations, from which shape memory and superelastic side effects arise, but also diffusionless transformations [2-5]. Although Ti–Ni-based other metals have many common properties with other shape memory alloys by exhibiting shape memory effect and super-elasticity, two-way shape memory effect etc [6]. Moreover, they exhibit many other traits, which are quite unique in comparison to other shape memory materials. Because of these kind of characteristics, most from the commercial applications have also been done for Ti–Ni other metals among many

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shape memory alloys, such as a new flap in air-conditioner, coffeemaker, brassiere, antenna for mobiles, medical applications such seeing that orthodontic wire, guide cable and stent etc [8].

A ternary alloying element addition to Ti–Ni alloy could optimize the transformation temperatures and mechanical properties [9].It overcomes the Ti-Ni alloy's shortcomings and adjusted the phase transformation temperatures. Compared with traditional binary Ti-Ni alloys, Ti-Ni-Nb alloys possess two advantages as Better machinable properties and Wider transformation hysteresis. Yang Guanjun and ET. All investigated the phase equilibria of TiNiNb ternary at 900 C in 2000 [10].Liming Wang and et al. investigated a two-way Shape Memory Effect in Ti-Ni-Nb alloys by means of bending test and transmission electron microscopy in 2001. [11].T. Sakuma and et al. studied the influences of pre-strain and Nb content on transformation temperature in Ti-Ni-Nb Shape Memory Alloys in 2005.[12].V. Ya. Abramov and et al. studied the effect of zirconium on the structure, characteristics of thermoelastic martensitic transformation and functional properties of Ti-Ni-Nb Shape Memory Alloy in 2006.[13].M.V. Popa and et al. determined the electrochemical behavior of Ti-Ni-Nb Shape Memory Alloy covered with mono and multilayer films in 2013 [14].In the Ti–Ni–Nb ternary alloy, the β-Nb soft phase is believed to be the main reason for the widening of the transformation hysteresis. The plastic deformation of β-Nb particles can relax the stored elastic strain energy of martensite, which results in the increase of reverse transformation temperature upon heating. Among the ternary alloys, Ti–Ni–Nb alloy has attracted considerable attention in recent years as it can exhibit a wide transformation hysteresis. Parts made of Ti–Ni–Nb alloy can be stored and transported at ambient temperature, which is convenient for commercial applications [15].In the present study, the microstructure, x ray diffractive study and simultaneous thermal analysis of the novel $Ti_{50}Ni_{48}Nb_2$, $Ti_{50}Ni_{46}Nb_4$, $Ti_{50}Ni_{44}Nb_6$, $Ti_{50}Ni_{42}Nb_8$, $Ti_{50}Ni_{40}Nb_{10}$and $Ti_{50}Ni_{38}Nb_{12}$ shape memory alloys have been investigated.

2. Experimental Work

Six alloys with varying compositions were prepared for this investigation. The constituent elements Ti (99.99%), Ni (99.99%), Nb (99.99%) were used for the preparation of alloys. All constituents were weighed to an accuracy of 0.001g and thoroughly washed with acetone by ultrasonic cleaning to avoid any contamination. The chemical composition of the alloys is given in table 1. Melting was carried out in an Edmund Buhler electric arc furnace provided with water cooled copper hearth and tungsten electrode. The arc furnace was evacuated with vacuum 10-6torr and flushed with high purity argon many times to ensure contamination/oxidation free melts. Each alloy was kept molten for four minutes, allowed to solidify, overturned and re-melted five times to ensure homogeneity. Alloy buttons weighing 10g each were prepared. Weight losses during melting were found to be about 1.0% which lies well within the limits of the equipment.

Table 1. Chemical composition of the samples

Sample Number	Sample designation	Composition	%Ti	%Ni	%Nb
1	S_1	$Ti_{50}Ni_{48}Nb_2$	50	48	2
2	S_2	$Ti_{50}Ni_{46}Nb_4$	50	46	4
3	S_3	$Ti_{50}Ni_{44}Nb_6$	50	44	6
4	S_4	$Ti_{50}Ni_{42}Nb_8$	50	42	8
5	S_5	$Ti_{50}Ni_{40}Nb_{10}$	50	40	10
6	S_6	$Ti_{50}Ni_{38}Nb_{12}$	50	38	12

The homogenization was done in vacuum tube three zones furnace. The samples were homogenized at a temperature of 10000c for 72 hours at a vacuum of -1.0 mbar. After the homogenization the specimens were cut into different sizes according to the requirement of each testing technique.XRD of Ti-Ni-Nb sample was carried out by using Bruker D-8 equipped with monochromatic Cu k-α radiation having wavelength of 1.54060 Å and Ni filter was employed. Diffraction patterns were interpreted using JCPDS cards. The phase transformation temperatures were measured using a Differential Scanning Calorimeter (DSC) (LINSEIS STA PT-1600). In one crucible there was a reference material (alumina) and in other crucible sample of the alloy was taken. Both crucibles were connected to the thermocouples and the components were connected to a computer. Sample of Ti-Ni-Nb weighing 10 mg was cut from the sample. Sample was first heated to 150°C at the rate of 3°C/min. With the help of software, we got DTA curve and identified the phase transformation temperature from it.The samples were gently ground on the silicon carbide grinding papers of grades used are 60,180,320,540,600, 800 and 1200. Polishing was done on 6 and 1 micron size. The etchant used had the following composition 10% Hf, 40% HNO3, and 50% H20. The surface of the specimen was attacked with etchant for 15 seconds. Finally micrographs of each sample were taken at different resolutions, 100x, 200x and 500x respectively.

3. Results and Discussion

Results obtained from characterization (XRD and DSC) and microstructural analysis of the Ti-Ni-Nb alloy has been discussed here and these have been compared with previous results from the literature. It is found from results that the phase compositions of the samples in the initial state and after heat treatment are the same (Figure 1). The X-ray diffraction patterns obtained at room temperature in the Bragg angle range 2θ = 30°–90°show the existence of three phases. The dominant phase is titanium nickelide TiNi (*B*2 phase) intermetallic compound with the ordered bcc CsCl lattice. There is a significant content of the bcc niobium phase. Along with these phases, the X-ray diffraction patterns contain a strong line of the fcc Ti2Ni phase as shown in Figure 1.

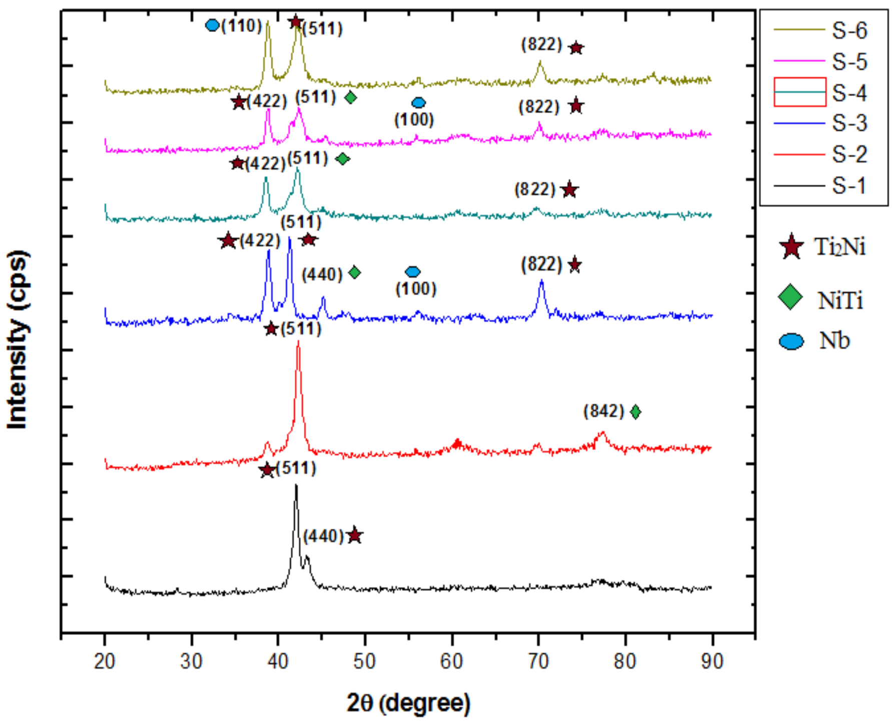

Figure 1. X-ray Diffraction graph of S1, S2, S3, S4, S5 and S6 respectively

The figures 2 (a- f) shows that there is no transformation change in this range of temperature. Due to the addition of Nb decreases the transformation temperature, so that these alloys have sub-zero transformation temperature. The identification of the phases in the Ti–Ni–Nb alloys shows that the dominant phase is TiNi (*B*2 phase) intermetallic compound with a niobium, which is seen as coarse gray grains of rounded or dendrite shapes as shown in Figure 3 (a, b, c, d, e and f). Grain boundaries are decorated with white rounded pure niobium inclusions. A softer structural component, namely, the (Ti, Ni, Nb) eutectic, contains isolated dark gray inclusions of nickelide Ti_2Ni alloyed with niobium (Figure 3 a, b, c, d, e and f).

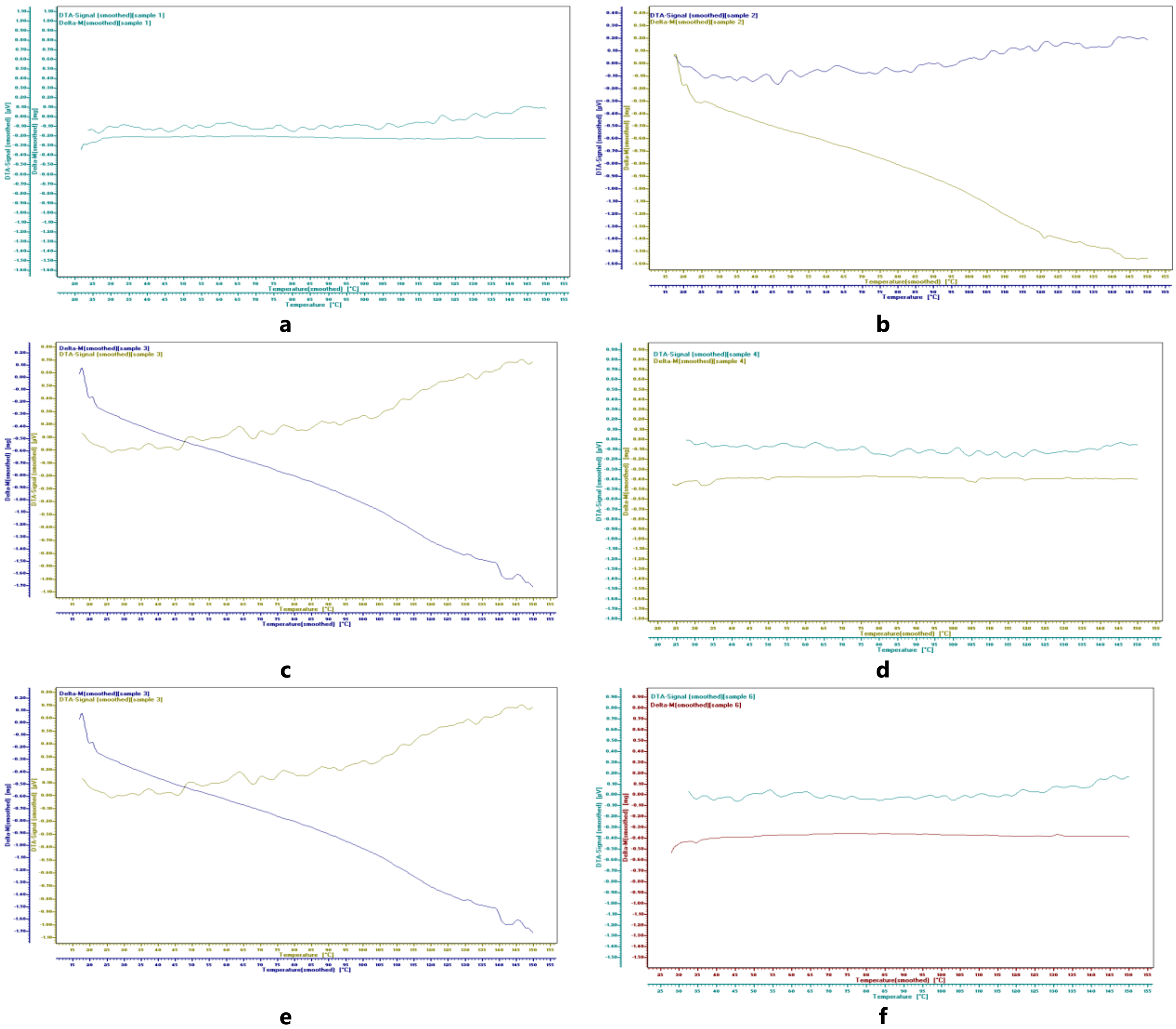

Figure 2. The STA graphs of alloy S1, S2, S3, S4, S5 and S6 having composition Ti50Ni48Nb2

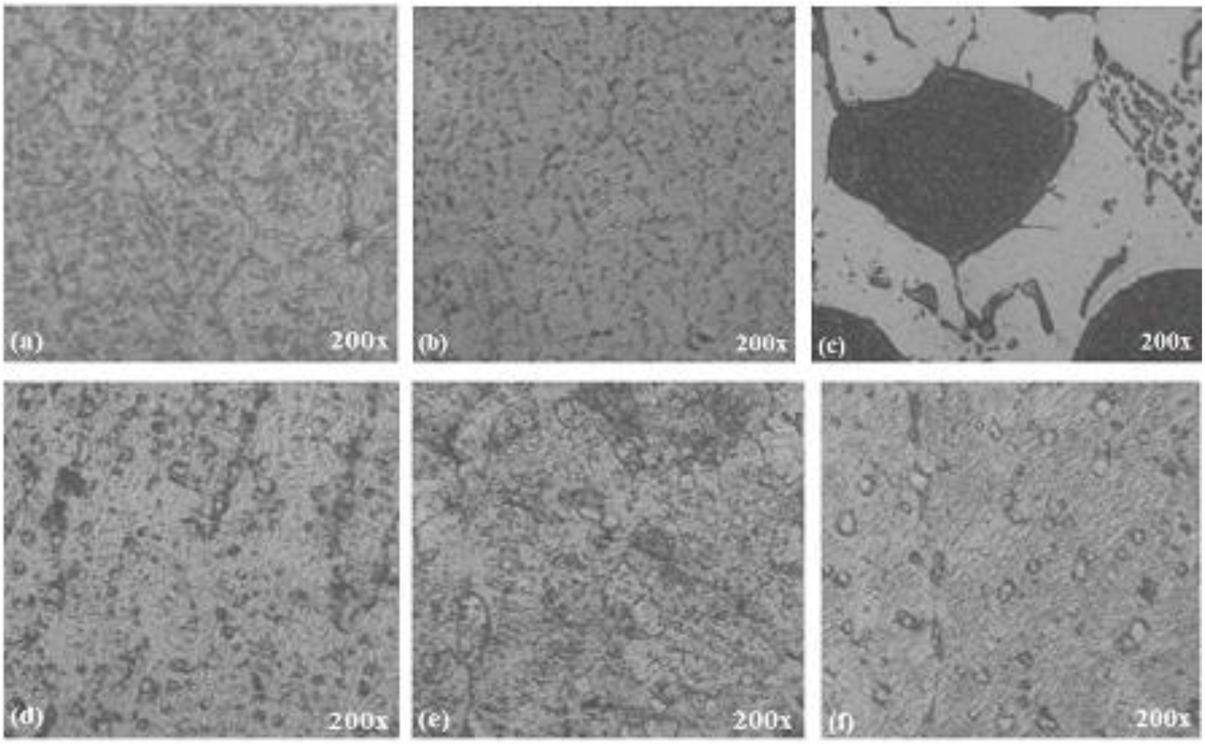

Figure 3. (a, b, c, d, e and f) Micrographs of S1, S2, S3, S4, S5 and S6 respectively at scale 200X

4. Conclusion

It is found from results that the phase compositions of the samples in the initial state and after heat treatment are the same. The dominant phase is titanium nickelide TiNi (*B*2 phase) intermetallic compound with the ordered bcc CsCl lattice. There is a significant content of the bcc niobium phase. Along with these phases, it contains a strong line of the fcc Ti_2Ni phase. STA results shows that there is no transformation change in this range of temperature. Due to the addition of Nb decreases the transformation temperature, so that these alloys have sub-zero transformation temperature. To find out the transformation temperature of these alloys further investigation is required.The identification of the phases in the Ti–Ni–Nb alloys shows that the dominant phase is TiNi (*B*2 phase) intermetallic compound, which is seen as coarse gray grains of rounded or dendrite shapes. Grain boundaries are decorated with white rounded pure niobium inclusions. A softer structural component, namely, the (Ti, Ni, Nb) eutectic, contains isolated dark gray inclusions of nickelide Ti_2Ni alloyed with niobium.

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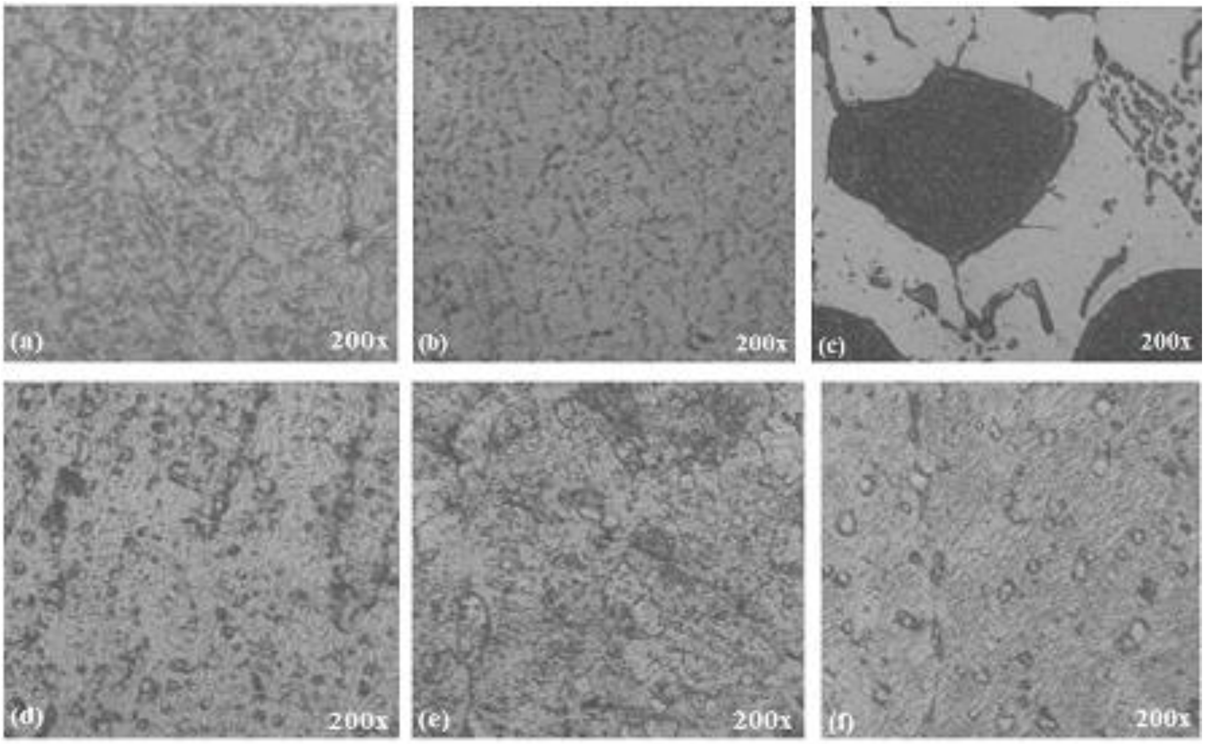

Figure 3. (a, b, c, d, e and f) Micrographs of S1, S2, S3, S4, S5 and S6 respectively at scale 200X