The influence of Nb content on phase transition and microstructure of $TiNiFe_2$ shape memory alloy

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Abstract. TiNi matrix alloy is one of widely used shape memory alloys. We studied the influence of Nb content on the microstructure of TiNiFe2 shape memory alloy. The result of experiments shows the conclusions that the matrix of Ti50-xNi48Fe2Nbx is NiTi with B2 structure and and the phase transformation point decreased and phase transformation hysteresis increased with Nb content increasing.

Introduction

TiNi matrix alloy is one of the earlier shape memory alloys, which was found 50 years ago. As one kind of intelligent material, TiNi matrix alloy with excellent shape memory and super-elasticity, mechanical property and corrosion resistance, is widely used in instruments and meters, automation, manufacturing, aeronautical and space technologies, biomedicine and architecture and so on.[1-3]

The phase transformation temperature of martensite is decreasing significantly by adding Fe element to substitute Ni in TiNi matrix alloy. By adding 3at.% Fe element, Ms point will decrease to below -100℃ and R phase transformation will separate from B19' martensite. Therefore, the low temperature for phase transformation is the most highlighted feature of TiNiFe shape memory alloy [4, 5]. Not only the temperature for phase transformation of TiNi shape memory decreases by adding Fe element, but also TiNiFe alloy has the same shape memory and mechanical property as TiNi. The martensite transformation temperature of TiNiFe shape memory alloy is low. So the soften phenomena due to stress-induced martesite phase transformation is avoided, and TiNiFe is stable in low temperature. TiNiFe shape memory alloy is the preferred material in aeronautical and aerospace pipe connection [6, 7].

$TiNiNbFe_2$ was made to improve the mechanical property. The research on the influence of Nb content on the microstructure of $TiNiFe_2$ shape memory alloy was finished by making $TiNiNbFe_2$ alloys with different Ni content and investigating its microstructure.

Experiment

$Ti_{50-x}Ni_{48}Fe_2Nb_x$ was smelt in water cooling copper crucible of vacuum non self-consumption electric arc furnace. X was selected as 0.5, 1, 1.5 and 2, and numbering was 1#, 2#, 3# and 4#. Every casting ingot was smelt four times to guarantee the homogeneousness of alloy composition. The casting ingot was in vacuum homogenization annealing treatment for 24 hours at 1130K. Some of the casting ingot was rolled to plate with 1mm thickness at 1130K, and the shape memory effect of these casting ingots was tested. The specimens for XRD, SEM and tensile test were made by wire cutting. The phase composition was tested by XRD instrument whose type was Japan D/max2200pc. Apollo 300 SEM was used to observe the microstructure of alloy. The R-T curve was gotten by electric resistance phase transformation instrument. The temperature range was 100K～300K, and the temperature decreasing velocity was 2K/min. The MTS880 mechanical testing machine was used to test the shape memory. The gauge length of the specimen was 30mm.

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The experimental result and analysis

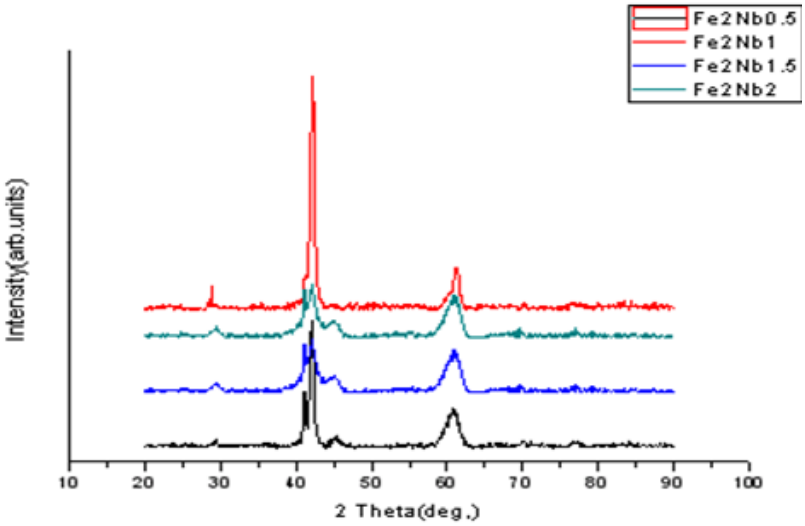


Figure.1 XRD of as- cast TiNiFeNb alloy

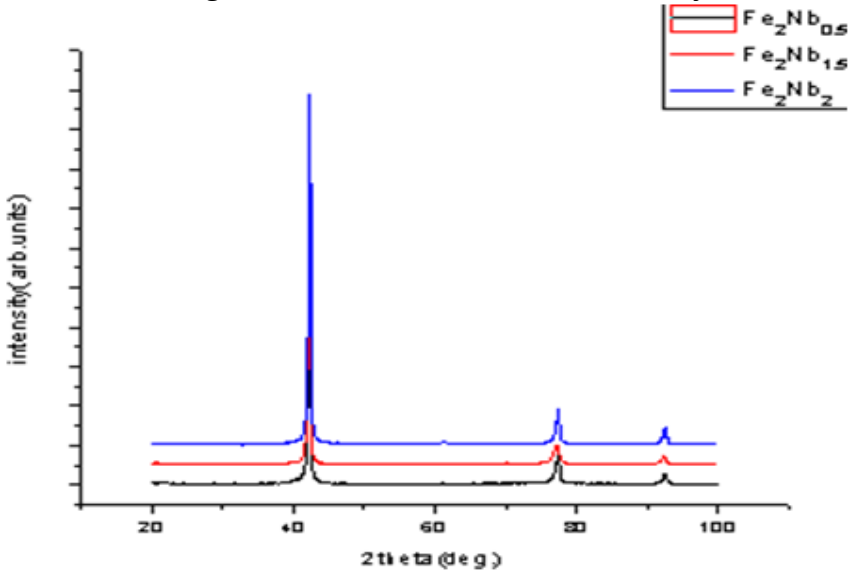
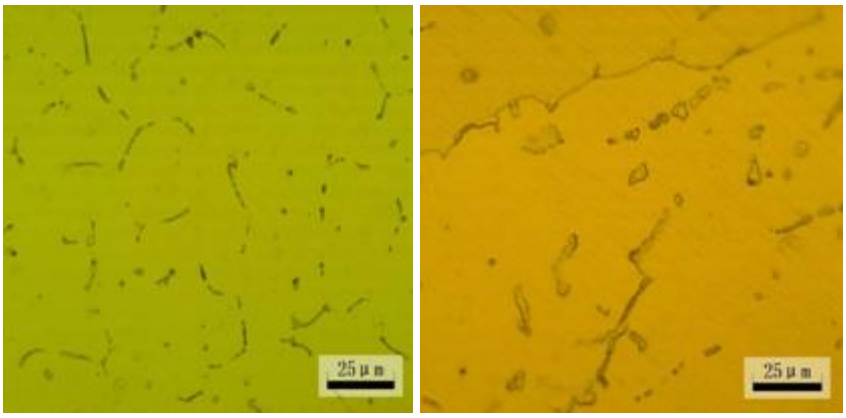


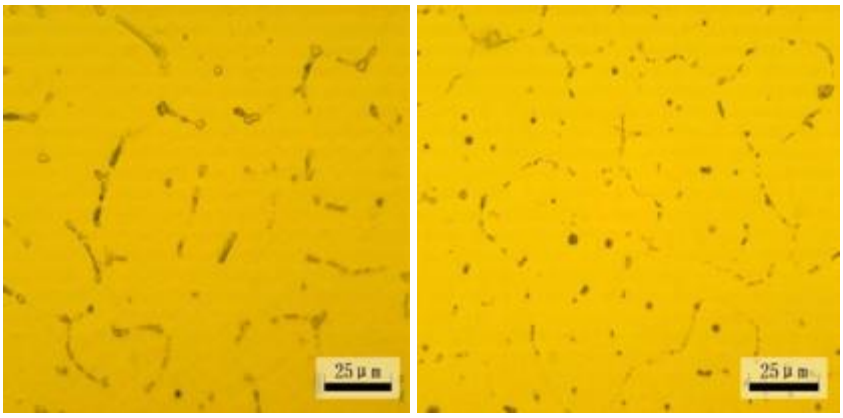
Figure.2 XRD of rolled TiNiFeNb alloy

After comparing the results of as-cast XRD and rolled state XRD (figure.1,2), the results showed that the highest peak intensity was about 240 before rolling while it was 5500 after rolling. So the peak intensity was far lower before rolling than after rolling. Among the three diffraction peaks of TiNi, the peak intensity at 42 °was about 5500 while the other two peak intensity was lower than 1000. So the peak intensity at 42 °was much higher. There was some TiNi phase peaks besides some suspected small Ti_2Ni peaks before rolling. However, there were only three obvious high intensity TiNi peaks in XRD graph after rolling.

The preferred orientation was generated during rolling. So the diffraction peak intensity was high at 42 °. The preferred orientation appeared at (110) face. In addition, there are some small peaks of suspected Ti_2Ni phase before rolling while they disappeared after rolling. The first possibility was that the small peaks did not appear. Because their diffraction intensity was relatively rather small compared with other three main peaks, they can not be observed in graph. The second possibility was that the small peaks really disappeared during rolling.



(a) Nb0.5 (b) Nb1



(b) Nb1.5 (d) Nb2

Figure.3 metallograph of as-cast TiNiFeNb alloy

Figure. 3 shows that the microstructure was homogeneous and the grain boundary appeared. With the increasing Nb element, more points with Nb precipitated phase were found in metallograph.

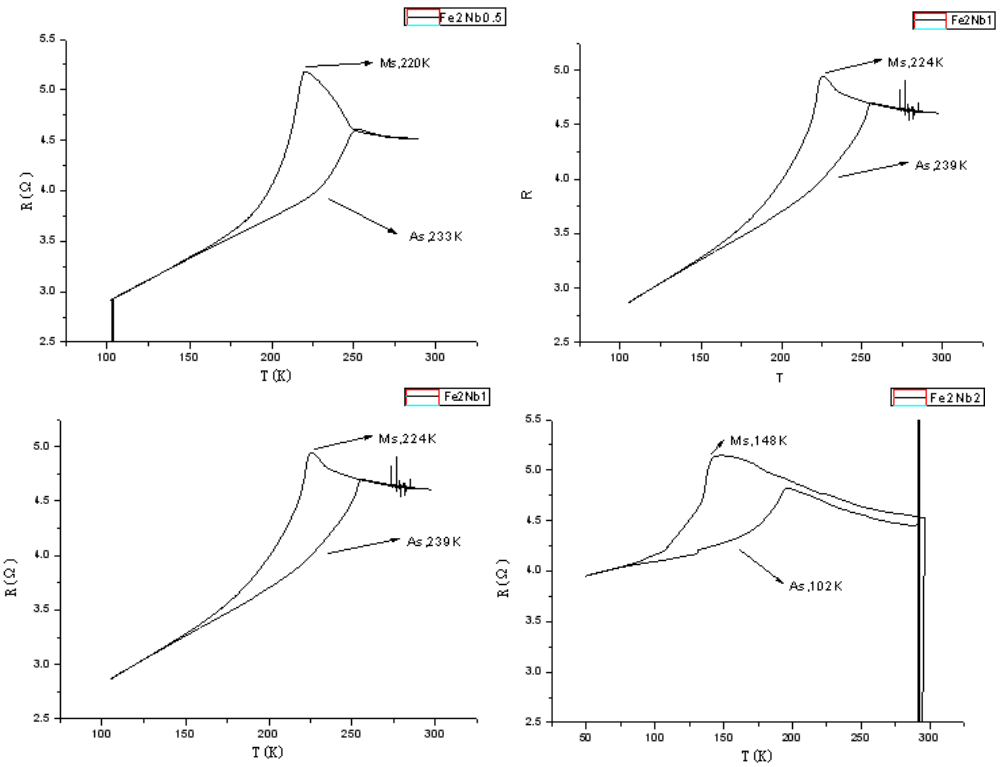


Figure.4 R-T curve of as-cast TiNiFeNb alloy

The R-T curve of as-cast TiNiFeNb alloy shows :

1.Both |Ms-As| and transformation hysteresis became larger with Nb composition increasing.

2. Except the 2# specimen, Ms, Mf ,As and Af of other specimens decreased.

Figure.5 shows the comparison of the results about phase transformation point by electric resistance between rolling state and as- cast state.

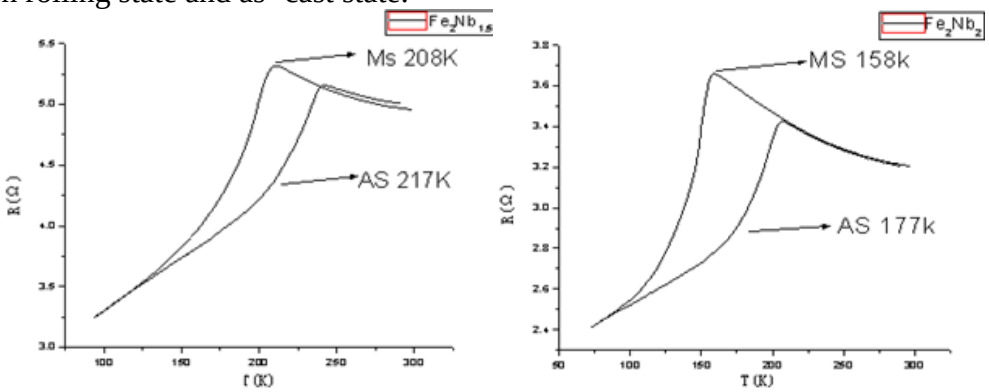


Figure.5 the R-T curve of rolled TiNiFeNb alloy

The Ms point of number 3 alloy increased by 52K after rolling. The Ms point of number 4 alloy increased by 10K after rolling. So it was obvious that the Ms point of number 3 alloy had a much higher increment than number 4 alloy. It was the same to As, Mf and Af. The phase transformation point of number 3 alloy increased more obviously than number 4 alloy.

The alloy phase transformation point after rolling should be lower than as-cast state. However, the phase transformation point of the rolled specimen without heat treatment can not be detected by electric resistance. To get the data by taking electric resistance method, the rolled alloys were kept at 850℃ for 30 minutes, then they were cooled in air. The results showed that the phase transformation point of alloy with rolling and heat treatment is higher than as cast alloy when the Nb content was the same. Because heat treatment played a more important role in improving the phase transformation point than rolling which decreased the phase transformation point.

Conclusions

1. The matrix of $Ti_{50-x}Ni_{48}Fe_2Nb_x$ is NiTi with B2 structure.
2. There was no other variation except the increasing precipitated phase with Nb. There was only one phase in metallograph.
3. The phase transformation point decreased and phase transformation hysteresis increased with Nb content increasing. The alloy phase transformation point increased and phase transformation hysteresis decreased after keeping ate 850℃ for 30 minutes.

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