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Short communication

Effect of heating/cooling rate on the transformation temperatures in TiNiCu shape memory alloys

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Abstract

In this note, the effects of heating and cooling rate on the transformation characteristics in TiNiCu shape memory alloy were investigated by differential scanning calorimetry (DSC). The results showed that the martensitic end transformation temperature (M_f) and reverse end transformation temperature (A_f) depend strongly on the scanning rate of the heating–cooling process, M_f decreased and A_f increased with increasing cooling/heating rate. However, the martensitic start transformation temperature (M_s) and reverse start transformation temperature (A_s) are not so sensitive to the scanning rate. The results are in good agreement with simulation results of our previous published model of martensitic transformation [Y. Huo, X.T. Zu, A. Li, Z.G. Wang, L.M. Wang, Acta Mater. 52 (2004) 2683].

Keywords: TiNiCu shape memory alloy; Differential scanning calorimetry (DSC); Phase transformation; Heating and cooling rate

1. Introduction

In previous work [1] we have designed a model of martensitic transformation as a thermal activation process. It considers the transition temperatures are determined by a chemical and a non-chemical term in the Gibbs free energy. Numerical simulations using this model for TiNi shape memory alloys (SMAs) have shown that upon irradiation the austenite finish temperature A_f can be raised slightly at the beginning stage. After that, both A_f and the martensite start temperature M_s will decrease strongly and reach some stable values after extensive irradiations. The simulation results are in good agreement with the experimental results [2–4]. The model also shows that M_s and austenite start temperature A_s are not sensitive to the cooling/heating rate. However, martensite finish temperature M_f and A_f depend strongly on the rate of the heating–cooling process. In this note, the effects of heating and cooling rate on the transformation temperatures in TiNiCu shape memory alloy were investigated using differential scanning calorimetry (DSC) and the results agree with the simulation results of this model.

2. Experiment

The investigations have been carried out on commercial Ti–43 at.% Ni–7 at.% Cu shape memory alloy samples with a thickness of 0.35 mm, which were provided by the Northwest Institute of Non-ferrous Metal of China. Two samples with dimension of 5 mm × 5 mm × 0.35 mm were used in this work. One sample (1#) was annealed at 773 K for 30 min and the other sample (2#) was annealed at 773 K for 3 h in an evacuated silica tube followed by air cooling. The transformation temperatures of the samples have been measured using a Setaram DSC131. Scanning rates of 20, 15, 10, 8, 5, 3 and 1.5 K/min were employed for sample 1# and 20, 15, 10, 8, 6, 4 and 2 K/min for the sample 2#.

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3. Results and discussion

Fig. 1(a) and (b) shows the DSC curves of the samples 1# and 2# measured with different scanning rate, respectively. As apparent in the curve, heating the sample produced endothermic peak, and cooling created an exothermic peak. The starting and the ending points of the transformation temperatures are determined as the intersections of a base line and the tangents to each peak. As can be seen from Fig. 2, M_f and A_f depend strongly on the scanning rate, M_f decreases and A_f increases with the increase of scanning rate. However, M_s and A_s are not so sensitive to the heating/cooling rate.

Fig. 3(a) and (b) show the simulation results using the model [1] for a heating–cooling process with different scanning rate for the samples 1# and 2#, respectively. Fig. 4 shows the transformation temperatures deduced from Fig. 3. It is obvious that M_f decreases and A_f increases with the increase of cooling and heating rate. M_s and A_s are not so sensitive to the heating/cooling rate. These results consist with that observed results in the experiment.

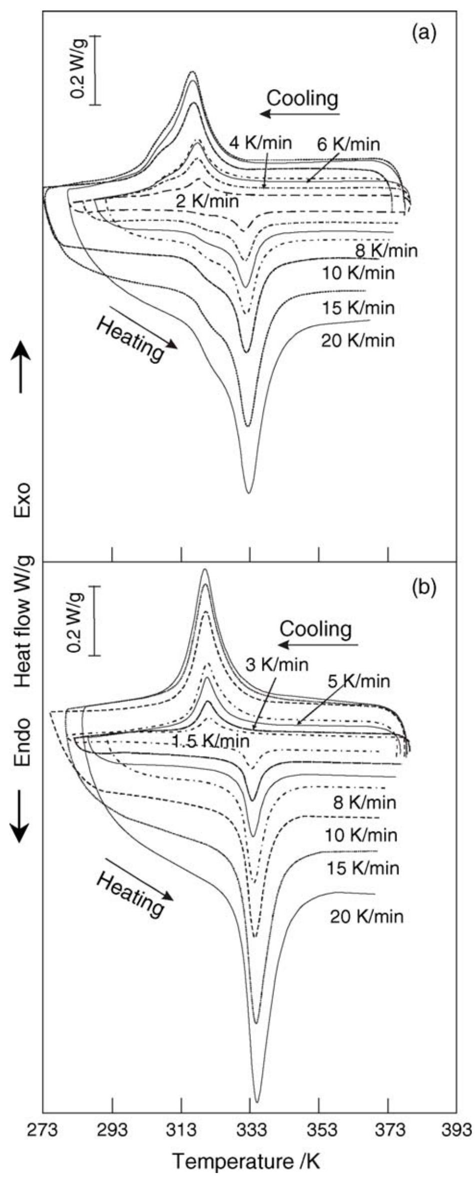

Fig. 1. DSC curves of the sample annealed at 500 °C for (a) 30 min and (b) 3 h and measured with different heating/cooling rate.

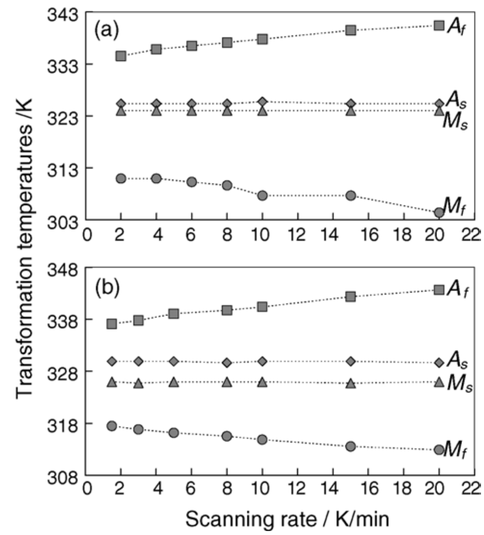

Fig. 2. Phase transformation temperatures as a function of heating/cooling rate for TiNiCu sample annealed 500 °C for (a) 30 min and (b) 3 h.

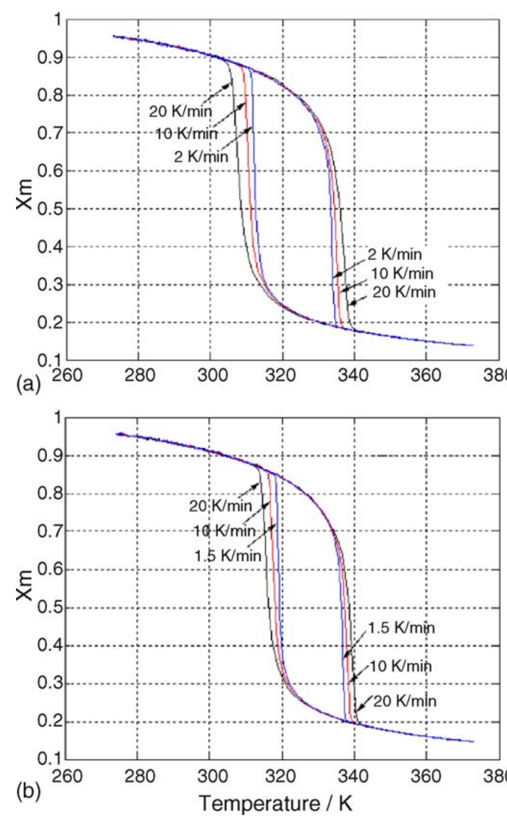

Fig. 3. Phase fraction–temperature relation calculated with the kinetic model for TiNiCu sample annealed 500 °C for (a) 30 min and (b) 3 h with different heating–cooling rate.

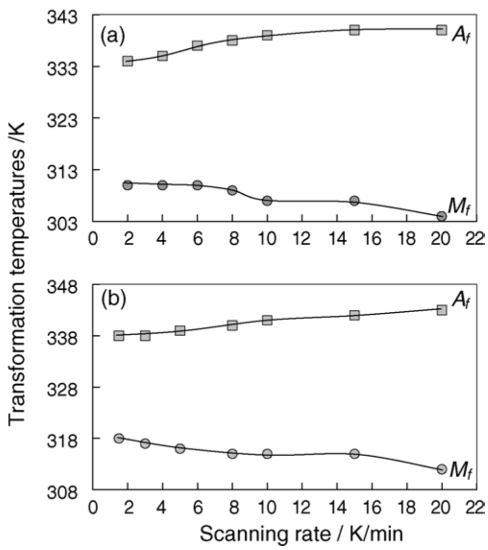

Fig. 4. Phase transformation temperatures as a function of heating/cooling rate for TiNiCu sample annealed 500 °C for (a) 30 min and (b) 3 h calculated with the kinetic model.

4. Conclusions

The heating and cooling rates have an effect on the transformation characteristics in TiNiCu shape memory alloy. M_f and A_f depend strongly on the rate of the heating–cooling process. M_f decreased and A_f increased with increasing cooling/heating rate. However, M_s and A_s are not so sensitive to the cooling/heating rate. The results are in good agreement with simulation results of a martensitic transformation model.

Acknowledgments

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