Entropy change during bcc/fcc martensitic transformation in Fe-Mn-Al-Ni shape memory alloy

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1. Introduction

Recently a new iron-based shape memory alloy system, namely Fe-Mn-Al-Ni alloy [1], has been reported. In this alloy system, superelasticity can be obtained by using martensitic transformation between ferromagnetic α (BCC) parent and antiferromagnetic martensite γ (FCC) phases. Compared to the commercially available SMAs like Ni-Ti, it has lower costs and better workability, which makes it an attractive alternative for practical usage. One of the most important and interesting features of this alloy is its extremely small temperature dependence of critical stress for stress-induced martensitic transformation. According to Omori's reports [1], the entropy change $\triangle S = S^M - S^P$ was determined as -0.43 J mol^{-1} K^{-1} using the Clausius-Clapeyron relation based on the data of tensile tests at various temperatures. However, no direct measurements of △S have ever been made. Hence, in this study, we measure the specific heat directly, from which the △S is calculated.

2. Experiments

$Fe_{43.5}Mn_{34}Al_{15}Ni_{7.5}$ (at.%) ingots were prepared by induction melting under an argon atmosphere. Sheet specimens with a thickness of 2 mm were obtained by hot-rolling at 1473 K and solution treatments were conducted at 1473 K for 30 min, followed by water quenching. In order to obtain the martensite and parent phases of the same composition, the parent phase sample was obtained by aging at 473 K for 3 hours and the martensite phase was obtained by strong cold rolling. Specific heat measurements in the low temperature range (2 K~200 K) were conducted by heat capacity option of PPMS (physical properties measurement system, Quantum Design Ltd.,) using relaxation method. Measurements in the high temperature range (200 K~473 K) were conducted by DSC (Differential Scanning Calorimetry, 204 F1, Netzsch) using heat flow method. Thermomagnetization measurements were conducted using SQUID (superconducting quantum interference device, Quantum Design Ltd.,) in the temperature range from 6 K to 300 K and VSM (vibrating sample magnetometer, Toei Industry Co., Ltd) in the temperature range from 77 K to 473 K.

3. Results and discussion

The calculated entropies S of parent and martensite phases in the temperature range from 2 K to 473 K are shown in Figure 1. It is found that the values of both phases at each temperature are very close. The entropy change during martensitic transformation is shown in Figure 2. △S is negative in the whole temperature range except almost zero at near zero Kelvin. The △S increases with increasing temperature from about 200 K up to near T_N (Neel temperature) and then decreases near to T_C (Curie temperature). It is found that the entropy change during martensitic transformation in this alloy is affected by magnetic transitions.

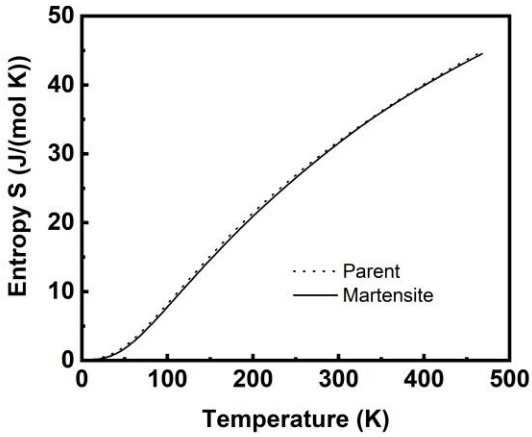

Figure 1. Experimental values of the entropy of parent and martensite phases in a temperature range from 2 K to 473 K.

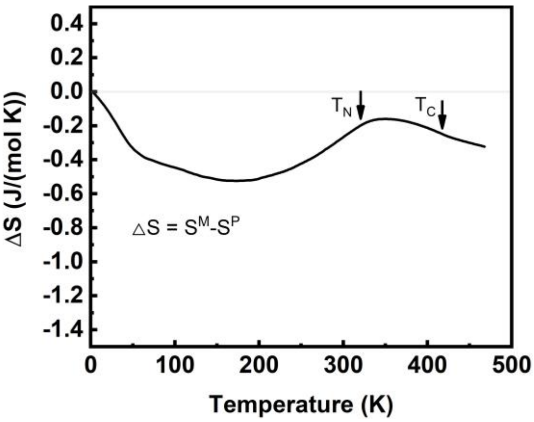

Figure 2. Experimental values of entropy change △S from 2 K to 473 K.

4. Reference

[1] T. Omori, K. Ando, M. Okano, X. Xu, Y. Tanaka, I. Ohnuma, R. Kainuma, K. Ishida, *Science* 333 (2011) 68-71.