Electrical resistivity of NiTi with a high transformation temperature

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It is well known that near-equiatomic NiTi alloys show a shape-memory effect due to a thermoelastic martensitic transformation. According to previous X-ray and electron diffraction studies on this transformation, the crystal structure of high-temperature phase of NiTi is considered to be CsCl(B2) type and that of low-temperature phase, which is still not completely elucidated, a monoclinic one [1, 2]. In the high-temperature phase just above M_s (the starting temperature of the martensitic transformation) anomalous phenomena occur upon cooling, such as the increase in electrical resistivity and the appearance of extra diffraction spots at 1/3 positions of the B2 reciprocal lattice, which are known as premartensitic phenomena. The structure of the premartensitic state has been considered to be a rhombohedral distortion of the B2 phase [3]. Although the electrical resistivity increases with the transformation to the intermediate phase of a rhombohedral structure upon cooling, it decreases with the transformation to the low-temperature phase, and a peak in resistivity is formed near M_s. Moreover, the peak in resistivity is enhanced with the repetition of the transformation by thermal cycling [4–6].

Matsumoto and Dohi measured the resistivity on the NiTi alloy with M_s of 288 K, precisely, and showed the increase of the height of peak in resistivity, the shift of M_s to the lower-temperature side and the increase in resistivity in the high- and low-temperature phases with thermal cycling [7]. The same tendency is also observed on NiTi with an M_s of 258 K [8] and NiTi alloys containing an additive such as silicon and aluminium [9, 10].

In the present work the measurement of electrical resistivity on NiTi with higher M_s was carried out precisely, in order to reveal the thermal cycle dependence of the transformation behaviour, and it is emphasized that no premartensitic phenomenon appeared, in contrast to the transformation behaviour of NiTi with lower M_s, which is drastically enhanced with increasing thermal cycles.

The alloy was prepared from 99.99% purity nickel and 99.9% purity titanium by an electron-beam melting method. After several remelts the alloy ingot was annealed at 1273 K in a vacuum of 10^{-4} Pa and the specimen was cut off. After re-annealing, the electrical resistivity was measured by a four-probe potentiometric method. Details of the sample preparation and resistivity measurement were given in [7, 9, 10].

The electrical resistivity versus temperature curve upon cooling is shown in Fig. 1. The resistivity depends linearly on the temperature in the high-temperature phase. Although the resistivity decreases markedly at temperatures lower than the M_s of 353 K, it decreases linearly in the low-temperature phase below the M_f (finish temperature of martensitic transformation) of 318 K. The M_s and M_f were estimated from the changes in resistivity in Fig. 1. In order to reveal the resistivity change, the temperature coefficient is shown in Fig. 2, which was calculated from the resistivity in Fig. 1. The indication of the peak in resistivity is not observed, and the high-temperature phase is directly transformed to the low-temperature phase. With the repetition of the transformation by thermal cycling, the shift of M_s to the lower-temperature side and the increase in resistivity in the high- and low-temperature phases are observed, of which the thermal cycle dependences are in qualitative agreement with those in NiTi alloys with lower M_s [7–9]. However, the peak in resistivity near the M_s is not observed by five thermal cycles. This implies that the premartensitic phenomenon for the NiTi with the higher M_s is not practically enhanced by the thermal cycles. In

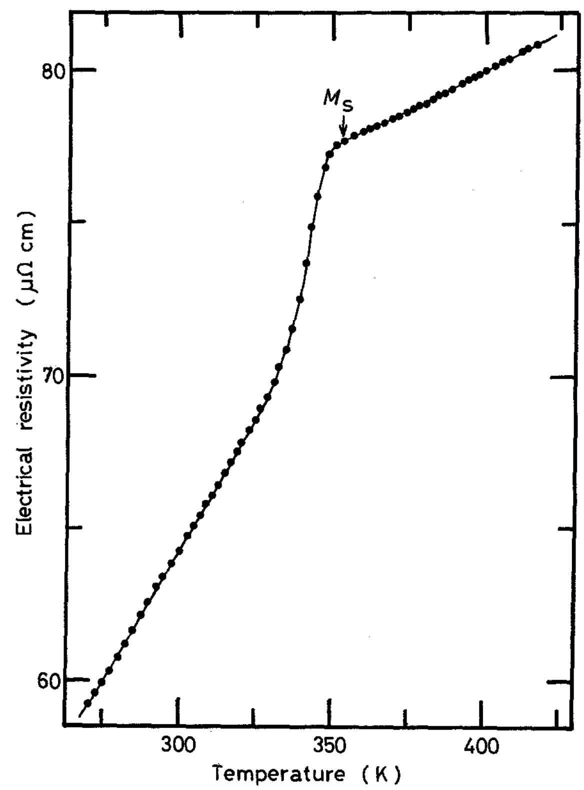

Figure 1 Electrical resistivity as a function of temperature upon cooling for the NiTi alloy with the M_s of 353 K.

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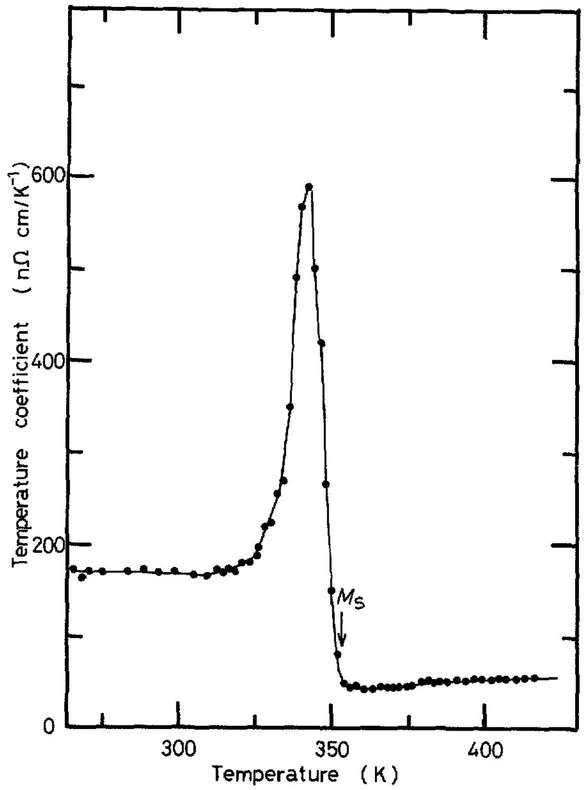

Figure 2 Temperature coefficient as a function of temperature upon cooling for the NiTi alloy with the M_s of 353 K, which was calculated from the resistivity in Fig. 1.

previous papers [7, 11] the thermal cycle dependence of the enhancement of the premartensitic phenomenon was taken to be attributable to defects generated on the transformation. Consequently, the intermediate phase is stabilized with increasing defects due to the repetition of the transformation. In the present measurements the increase in resistivity with increasing thermal cycling, which is observed in the temperature ranges for the high- and low-temperature phases, is considered as the influence of defects because its increase is independent of the temperature in each phase. Moreover, the increase in resistivity (that is, the amount of defects generated with thermal cycling) is comparable with that in NiTi with lower M_s [7, 9]. Therefore, no premartensitic phenomenon is induced by defects, and it is thought that the stability in energy for the low-temperature phase plays an important role in the transformation behaviour near the higher M_s.

In conclusion electrical resistivity was precisely measured for NiTi with the M_s of 353 K during thermal cycling. The results are summarized as follows. The electrical resistivities in the high- and low-temperature phases depend linearly on the temperature. The increase in resistivity with thermal cycling is observed, which is attributable to the defects produced by the repetition of the transformation. No premartensitic phenomenon appears near the M_s, even with the thermal cycles, and the high-temperature phase is directly transformed to the low-temperature phase. The appearance of the intermediate phase with thermal cycling depends on the stability of the low-temperature phase; that is, the martensitic transformation temperature.

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