Magnetic order in Ni_3Mn alloys*

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Recent measurements reveal significant changes in the magnetic moment and superparamagnetic Curie point during the initial stages of atomic order in Ni_3Mn alloys. The rate of increase of the induced moment at 8 kG and 300 °K with annealing time at 400 °C exhibits a discontinuity at about 1.5 h. The superparamagnetic Curie temperature is also found to increase from 145 °K for the disordered alloy to 250 °K after an extremely brief (20 min) anneal. These results show that significant atomic rearrangement is actually taking place rather quickly during the initial stages of ordering, contrary to the previously accepted model of homogeneous long-range-order development which saturates only after extremely long annealing times (1000 h or more), proposed by Marcinkowski and Brown. The discontinuity at 1.5 h is tentatively associated with the short-range-order saturation observed for anneals at higher temperatures, also at about 2 h, and the peak in the field-induced uniaxial anisotropy after 2 h of annealing.

Nickel-manganese alloys near the Ni_3Mn composition show large changes in magnetic properties with the degree of atomic order. Apart from one early examination of the magnetic-moment dependence on atomic ordering,[1] most investigations have concentrated on the rather complicated but technologically important field-induced anisotropy behavior.[2–4] Because of the intricate nature of the anisotropy as a function of ordering, a new study of the basic magnetic properties (moment, critical temperatures, etc.) has been undertaken with the ultimate aim of understanding *both* the magnetic ordering and the anisotropy. The present results provide several clues to the initial atomic-ordering processes for annealing of the disordered alloy at relatively low temperature (400 °C) and reveal a possible connection between these processes and the field-induced uniaxial anisotropy in Ni_3Mn alloys.

The basic results concerning the anisotropy behavior[4] are shown in Figs. 1 and 2. Figure 1 shows the temperature dependence of the field-induced unidirectional and uniaxial anisotropy components for a disordered sample (DO)[5] and for the same sample after a 2-h anneal at 400 °C to induce partial ordering (PO). The data were obtained (Ref. 4) from torque data after initially cooling from room temperature to 4.2 °K in a field of 10 kOe, using a measurement field of 10 kOe. As initially reported by Kouvel,[2] the disordered alloy exhibits a large unidirectional anisotropy at 4 °K, denoted by an anisotropy constant K_d, which decreases rapidly and disappears somewhere below 70 °K (solid triangles in Fig. 1). The partially ordered alloy shows a field-induced anisotropy of a predominantly uniaxial character (K_u in Fig. 1, open circles) which decreases with increasing temperature much more slowly. The presence of large K_d for the disordered alloy and its rapid decrease with temperature or with atomic ordering is qualitatively explained by the exchange anisotropy concept.[2] The appearance of a uniaxial character with weak partial ordering is not explained by this or any other existing model.

Figure 2 shows the dependence of K_u and K_d, measured at 77 °K, on the annealing time at 400 °C after field cooling down to 77 °K.[4] During the initial stages of annealing both are small. 77 °K is too high for any significant exchange anisotropy related K_d, and the

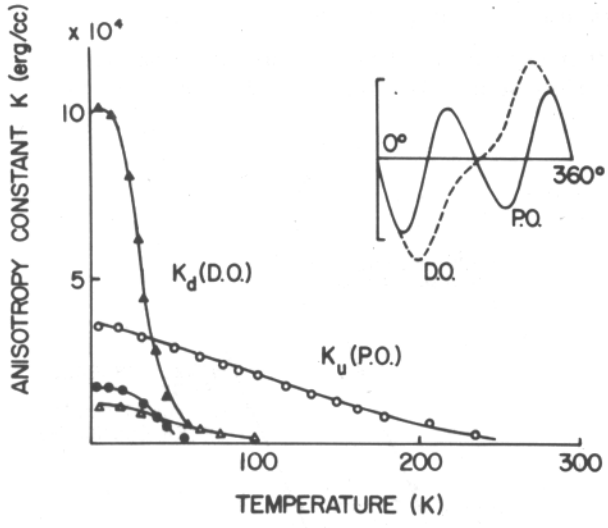

FIG. 1. Effect of partial ordering on the induced anisotropy in 27% Mn alloy. The circles denote the uniaxial anisotropy K_u; the triangles denote the unidirectional anisotropy K_d. The inset shows torque curves for the DO and PO samples at 4.2 °K. The solid symbols are for the DO alloy; the open symbols are for the PO alloy.

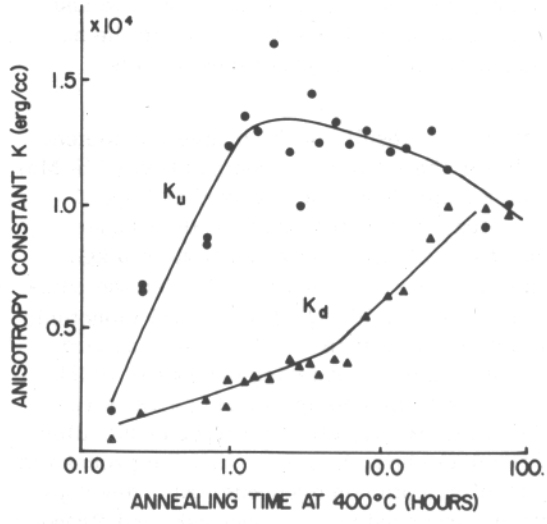

FIG. 2. Dependence of K_u and K_d on annealing time at 400 °C, as measured at 77 °K after field cooling down to 77 °K from room temperature in 10 kG.

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