MAGNETOSTRICTION OF THE METAMAGNETIC IRON–RHODIUM ALLOY

R. Z. LEVITIN and B. K. PONOMAREV

Moscow State University

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Magnetostriction of the metamagnetic iron-rhodium alloy was measured at temperatures between 290 and 400°K and at field strengths up to 150 kOe. It was found on transition of the alloy from the antiferromagnetic to the ferromagnetic state under the action of a magnetic field, the magnitude of the magnetostriction may reach 3 to 3.6×10^{-3}.

THE ordered alloys of the system iron-rhodium near the equi-atomic composition, $Fe_{0.5}Rh_{0.5}$, are metamagnetic. They are antiferromagnetic below a certain critical temperature T_c and make a transition to a ferromagnetic state above this temperature.[1-6] The antiferromagnetic-ferromagnetic transition in these alloys is a first-order phase transition and is accompanied by a 0.3% change in the lattice parameter. The crystal structure does not change: both phases have the CsCl-type body-centered cubic lattice.[3, 5] When $T < T_c$ application of a sufficiently strong magnetic field, exceeding a certain critical value H_c, takes the alloy from the antiferromagnetic to the ferromagnetic state; the magnetization thereby increases sharply.[2, 5] The magnitude of H_c is strongly temperature dependent and tends toward zero when $T = T_c$.[5]

Zakharov et al.[5] have shown that the magnetic properties of iron-rhodium alloys can be explained qualitatively on the basis of Kittel's phenomenological theory.[7] According to this theory, the ferromagnetic-antiferromagnetic transition is due to a strong dependence of the exchange interaction on the crystalline lattice parameter. The change in lattice parameter as a consequence of thermal expansion leads to the exchange interaction changing sign at T_c, as a result of which a transition from the ferromagnetic to the antiferromagnetic state occurs.

It is not difficult to see that the transition from the antiferromagnetic to the ferromagnetic state under the action of a field should be accompanied by a very large magnetostriction, equal in the first approximation to the change in the dimensions of the sample during the phase transition from the antiferromagnetic to the ferromagnetic state at the point T_c in the absence of a field. Since at the temperature T_c the change $\Delta l/l \approx 3.3 \times 10^{-3}$, one would expect that below T_c in fields $H > H_c$ the magnetostriction will be of this same order of magnitude.

Up until now no data on the magnetostriction of iron-rhodium alloys in fields greater than the critical field H_c have appeared in the literature. We have measured the magnetostriction of the alloy $Fe_{0.5}Rh_{0.5}$ in the temperature region 290 to 400°K in fields of up to 150 kOe which exceeded the field H_c in this temperature interval.

The measurements were carried out on the same iron-rhodium alloy whose temperature dependence of the magnetization, critical field, lattice parameter, effect of pressure on T_c, etc we studied previously[5] (T_c = 360°K, Curie point Θ = 660°K). The magnetostriction measurements were carried out in pulsed magnetic fields using the apparatus previously described.[8] The method was modified so that the curve of the dependence of magnetostriction on field could be photographed directly from an oscilloscope screen. This permitted the observation of hysteresis phenomena

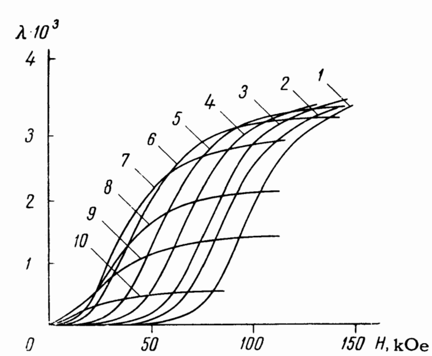

FIG. 1. Field dependence of the magnetostriction of the iron-rhodium alloy at different temperatures (curves taken with increasing field): 1–291, 2–305, 3–314, 4–323, 5–334, 6–340, 7–348, 8–354, 9–367, 10–380°K.

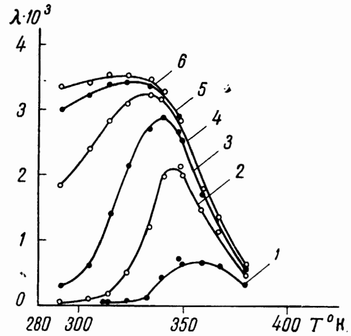

FIG. 2. Temperature dependence of the magnetostriction of the iron-rhodium alloy at different values of the field (curves correspond to the process of increasing field): 1–25, 2–50, 3–75, 4–100, 5–125, 6–140 kOe.

and markedly shortened the measurement process.

Figure 1 shows curves of the dependence of the magnetostriction of the alloy $Fe_{0.5}Rh_{0.5}$ on field at different temperatures, corresponding to the process of increasing the field from zero to its maximum value, and Fig. 2 shows the temperature dependence of the magnetostriction at different values of the field. It is seen that below T_c (~ 360 °K) the magnetostriction increases sharply when H_c is reached (curves 1 to 6, Fig. 1). The magnetostriction at $T < T_c$ in fields $H > H_c$ reaches values of 3 to 3.6×10^{-3}, i.e., close to the magnitude of the thermal expansion anomaly at T_c. The values of H_c determined from the maximum slope of the curves λ(H) coincided, within the limits of experimental error, with the magnitudes of the critical fields found from magnetization curves.[5]

In the ferromagnetic region ($T > T_c$) the magnetostriction decreases sharply (Fig. 2), and the curves λ(H) take on the usual ferromagnetic character (see curves 9 and 10 in Fig. 1).

Thus, the magnetostriction observed in the iron-rhodium alloy below T_c is due principally to the transition from the antiferromagnetic to the ferromagnetic state under the action of a field. Note that the magnetostriction of the iron-rhodium alloy at $T < T_c$ and $H > H_c$ is of the same order of magnitude as the largest magnetostriction observed up until now in polycrystalline samples of rare-earth ferromagnets at nitrogen temperatures.[9] This is evidence that the magnetoelastic interaction in the iron-rhodium alloy is large and, in accordance with the Kittel theory, plays the determining role in the transition of the alloy from the antiferromagnetic to the ferromagnetic state under the action of temperature and magnetic field.

In conclusion we point out that at temperatures

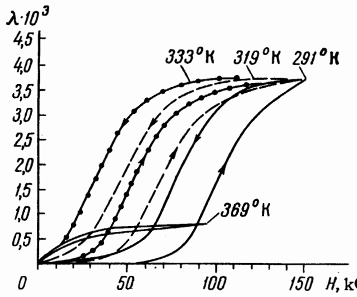

FIG. 3. Hysteresis of the magnetostriction of the iron-rhodium alloy at different temperatures.

less than T_c a marked hysteresis of the magnetostriction is observed in the alloy $Fe_{0.5}Rh_{0.5}$. It is seen in Fig. 3 that the transition from the antiferromagnetic to the ferromagnetic state (with increasing field) occurs at higher fields that the reverse transition from the ferromagnetic to the antiferromagnetic state (with decreasing field). The presence of hysteresis confirms that in the iron-rhodium alloy the transition from the antiferromagnetic to the ferromagnetic state and its reverse is a first-order phase transition.

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