VISCOSITY AND HYSTERESIS PROPERTIES AT LOW TEMPERATURES OF MANGANESE IRON FERRITES CONTAINING COBALT ADMIXTURES

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The magnetic viscosity, magnetostriction, and hysteresis properties of a polycrystalline ferrite of composition $Mn_{1.75}Co_{0.05}Fe_{1.2}O_4$ were studied in the low temperature region. An extremely high viscosity was found in the temperature region from −100 to −150° C in static fields up to 250 oersteds. The remagnetization time was measured and found to be of the order of tens of minutes to hours. It was demonstrated that in this temperature region Perminvar and rectangular loops are formed in oscillatory fields. The character of the variation in the form of the loop in increasing oscillatory fields is compared with the magnetic viscosity found in static fields.

In the present work, a study has been carried out, in the low-temperature region, of the magnetic viscosity, magnetostriction and hysteresis properties of a polycrystalline sample of manganese-iron ferrite containing a small admixture of cobalt ($Mn_{1.75}Co_{0.05}Fe_{1.2}O_4$).

Magnetization measurements on this ferrite in the low temperature region showed that in weak and moderate magnetic fields (from 4 to 250 oersteds) it possesses a very high magnetic viscosity. The intensity of magnetization of the sample continues to rise after it has been held in a constant field for 17 hours, while when the field is reversed the sample remains magnetized in the former direction of the field for a period which in a number of cases exceeded 1 hour (in one experiment the remagnetization time reached 174 minutes). The existence of such a high magnetic viscosity (for remagnetization of a substance) is nowhere indicated in the literature.

The experiments were carried out at various temperatures and in various magnetic fields. The viscosity is most pronounced over the temperature interval from −100 to −150° C, in fields not exceeding 250 oersteds.

As an example of the data obtained, Fig. 1 presents curves showing the variation of intensity of magnetization with time at −125° C, in a field of 18.8 oersteds. Magnetization and remagnetization curves are given for the sample held in the field for different periods of time. In a given experiment the sample was demagnetized at room temperature; the measurement temperature was then established, the sample was held at this temperature for at least an hour (in order to establish a uniform temperature throughout the whole volume of the sample), and only then was the magnetic field applied. The same experiment was also carried out under other conditions: the sample was

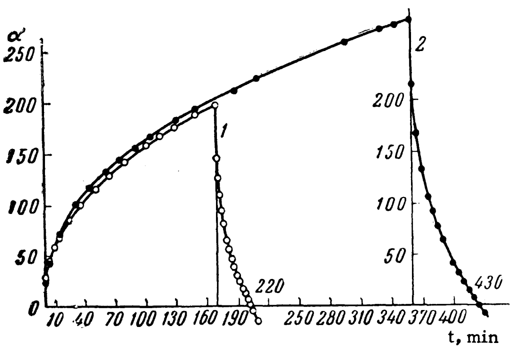

FIG. 1. Magnetization and remagnetization curves for the ferrite $Mn_{1.75}Co_{0.05}Fe_{1.2}O_4$ as a function of time in an 18.8-oe field, at a temperature of −125°C: curve 1 — field direction reversed after 2 hr 50 min; curve 2 — experiment repeated, field direction reversed after 6 hr (α — galvanometer deflection, proportional to intensity of magnetization).

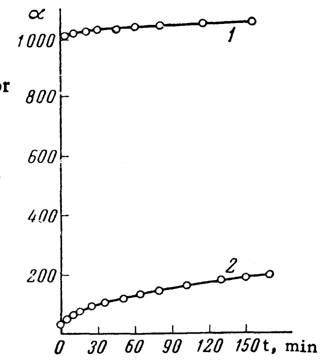

FIG. 2. Magnetization curves for the ferrite $Mn_{1.75}Co_{0.05}Fe_{1.2}O_4$ as a function of time in an 18.8-oe field, at a temperature of −125°C; curve 1 — sample demagnetized at −125°C; curve 2 — sample demagnetized at room temperature.

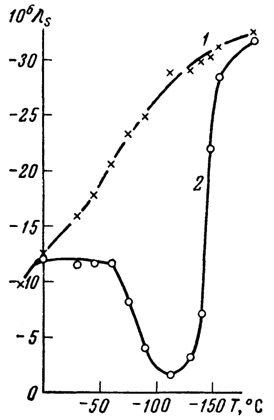

FIG. 3. Temperature dependence of the saturation magnetostriction λ_s for $Mn_{1.75}Co_{0.05}Fe_{1.2}O_4$: curve 1 – sample demagnetized each time at room temperature; curve 2 – sample demagnetized at the temperature of the measurement.

demagnetized, not at room temperature, but at the temperature of the measurement. This change in the conditions of demagnetization exerted a strong effect upon the viscous properties of the sample: the viscosity was markedly reduced, although it did not vanish entirely, while the intensity of magnetization of the sample showed a substantial increase (Fig. 2).

The saturation magnetostriction in the same ferrite was measured in a 2500 oersted field with the aid of cemented-on pick-ups. The influence of the viscosity was manifested in the fact that the value for the magnetostriction proved strongly dependent upon the way in which the sample was demagnetized. In Fig. 3. are presented curves showing the temperature dependence of the magnetostriction for demagnetization of the sample at room temperature (curve 1) and at the temperature of the measurement (curve 2).

In the same temperature region, hysteresis loops were observed for the ferrite sample under study in an alternating field (50 cps) by oscillographic means. It was found that Perminvar and rectangular loops are produced in the same range of weak and moderate fields for which viscosity is evident. If a sample demagnetized at room temperature is placed in an increasing alternating field, then for fields up to a few tens of oersteds an inclined line is seen on the oscilloscope screen — no loop is present. As the field is further increased, the line changes visibly, first into a Perminvar, then a normal, and finally, into a rectangular loop. If the sample is demagnetized at the measurement temperature, the Perminvar and normal loops are not formed at all, and, as the field is increased, the "line" obtained in a weaker-field region changes discontinuously into a rectangular loop having an extremely high rectangularity factor (about 0.97).

The experimental data thus obtained show that the character of the change in form of the hysteresis loop in alternating fields is closely associated with the magnetic viscosity which appears in this material in static fields. Where the remagnetization times are extremely long (of the order of several tens of minutes when the sample is held in the field for approximately 6 hours), the loop in an alternating field has the form of a line. At some specific value of the field (at a temperature of −125° C this field is 43 oersteds) the remagnetization time falls very sharply (becoming less than 1 minute), and in this same field the line is transformed after a short time into a Perminvar loop.

In fields for which the loops become rectangular after a brief time in the field, the viscosity is even less pronounced.

The results obtained may be explained on the assumption that the ferrite which we have investigated undergoes a magnetic "annealing"; i.e., a uniaxial anisotropy arises in each of its domains under the influence of the magnetic field, with the axis of easy magnetization directed along the magnetization vector of the given domain. The development of uniaxial anisotropy in the ferrite under study is evidently the result of an electron diffusion process which is governed by the magnetic field.[1]

It is most natural to assume that an exchange of electrons takes place between the Mn^{2+} ions and manganese ions of higher valency (in manganese-iron ferrites containing excess manganese, in addition to Mn^{2+} ions, manganese ions of higher valency are always present). The role of the cobalt ions in this process is as yet insufficiently clear.

More detailed information on the ferrite described, and on other manganese-iron ferrites containing excess manganese (with and without cobalt), will be published in the future.

In conclusion, we consider it an agreeable duty to express our gratitude to Professor K. P. Belov for his attention to the present work.

[1] A. Kienlin, Zs. Angew. Phys. **10**, 12 (1958).

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