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INDUCED MAGNETIC ANISOTROPY OF COBALT-NICKEL FERRITES

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The crystalline anisotropy and induced magnetic anisotropy constants of cobalt-nickel ferrites were measured by ballistic and oscillation methods. It was found that the constants of induced anisotropy are positive and their values decrease with temperature and increase with the cobalt concentration.

As a result of the previously performed studies of the ferrite $Co_xNi_{1-x}Fe_2O_4$ strong dependences of the constants of crystalline anisotropy on the cobalt ions concentration and on temperature were established [1]. The present work is concerned with the extension of these studies to the phenomenon of the magnetic field induced anisotropy. The results obtained by other authors suggest that, also in this case, strong dependences of the induced anisotropy constants on Co^{2+} ions concentration and on temperature should be expected. For example, for the compounds $Co_xFe_{3-x}O_4$ and $Co_xNi_{0.46-x}Zn_{0.29}Fe_{2.25}O_{4+\gamma}$ the square dependence of the K_1^T constant on x was obtained [2, 3]. On the other hand the studies of $Co_xNi_{1-x}Fe_2O_4$ ferrite by Perthel [4] proved the linear dependence of K_1^T on Co^{2+} ions concentration. Among others, our work aimed at establishing the dependence $K_1^T(x)$ for the wider range of Co^{2+} concentrations $0 < x \leqslant 1$.

The cobalt-nickel ferrite we studied has a reversed spinel structure with an easy magnetization axis parallel to the crystallographical direction [100]. The energy of crystalline anisotropy of these ferrites can be expressed as:

$$E_K = K_1(\alpha_1^2\alpha_2^2+\alpha_2^2\alpha_3^2+\alpha_3^2\alpha_1^2)+K_2\alpha_1^2\alpha_2^2\alpha_3^2,$$

where α_1, α_2, α_3 denote the direction cosines of the magnetization vector determined with respect to the direction of easy magnetization [100] and K_1, K_2 are the constants for crystallographical anisotropy.

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When the sample is heated in an external magnetic field the additional anisotropy is induced and described by the energy:

$$E_T = -K_1^T(\alpha_1^2\beta_1^2+\alpha_2^2\beta_2^2+\alpha_3^2\beta_3^2)$$
$$-K_2^T(\alpha_2\alpha_3\beta_2\beta_3+\alpha_1\alpha_3\beta_1\beta_3+\alpha_1\alpha_2\beta_1\beta_2),$$

where β_1, β_2, β_3 are direction cosines of the inducing field and K_1^T, K_2^T are constants of the induced anisotropy.

In this work, the monocrystalline samples were prepared using the Vernuille method and formed in the shape of spheres having diameters ranging from 2 to 5 mm [1]. Samples having a composition of $Co_xNi_{1-x}Fe_2O_4$ where $x = 0.075$, 0.3, 0.5, 0.7, 0.9 and 1.0 were studied. The sample orientation was determined using the X-ray type method. Our measurements were done using ballistic and oscillation methods. The former method was applied

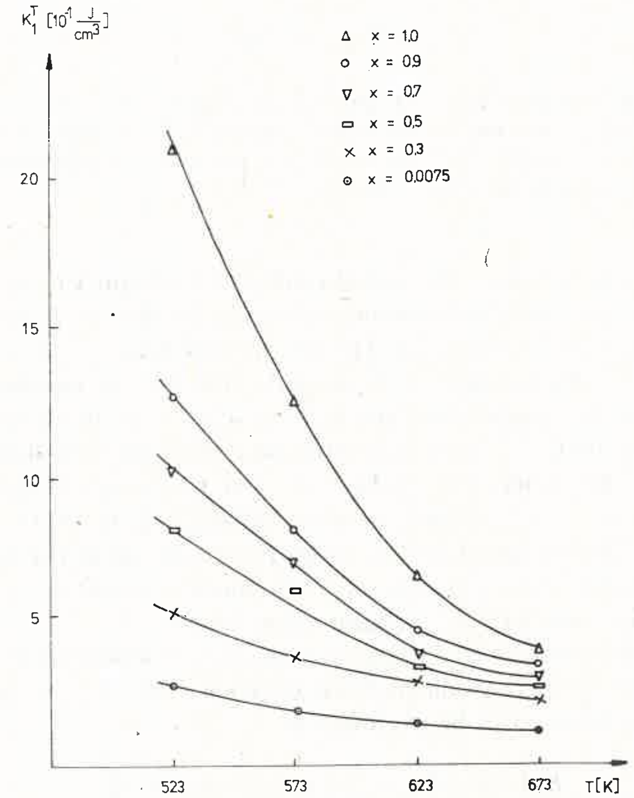

Fig. 1. Induced anisotropy vs. temperature and cobalt concentration

to determine the magnetization curves for different crystallographical directions and at different temperatures. The magnetic field of the strength up to 1 T was applied. The results allowed us to calculate the constants for crystalline anisotropy K_1, in terms of the free magnetization energy in the crystallographical directions [100] and [110]. At room temperature the results are consistent with those of Elbinger's [2]. Also the temperature dependence of K_1 agrees with these obtained earlier by Szydłowski [1].

Applying the oscillatory method, the sample was suspended in such a way that it could oscillate around the crystallographical direction [110]. The sample studied was placed in the field of 0.6 T which, according to the ballistic measurements, provided the state of magnetic saturation at the temperatures considered. The constant of induced anisotropy was calculated from:

$$K_1^T = B(T_0^2 - T_H^2)(T_0 T_H)^{-2} - K_1,$$

where T_H denotes the vibration period of the sample in a magnetic field, T_0 is the vibration period of the sample in the absence of a magnetic field and B is a constant. In order to induce anisotropy, the samples studied were maintained in a magnetic field at temperatures

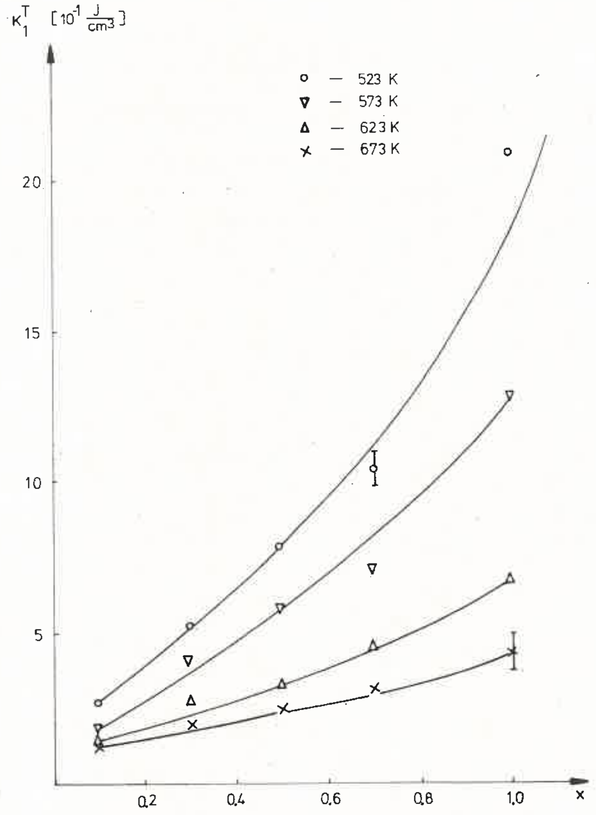

Fig. 2. Induced anisotropy vs. cobalt concentration, at constant temperature

of 523, 573, 623 and 693 K for 6, 3, 0.5 and 0.5 h. Heating the samples longer does not cause a measureable increase in the induced anisotropy.

Relative measurements of the K_1^T constant were performed. In calculating the B constant, as a standart value K_1 values were taken which were determined for each sample at room temperature using the ballistic method. The measurement of K_1^T were done at the same temperature at which the anisotropy was induced. The K_1^T constant was calculated as the difference between the value of the effective constant of anisotropy after heating in a magnetic field and the value of the crystalline anisotropy constant found at the same temperature before heating. The measurements of K_1 were performed by both methods, however at high temperatures only the oscillatory method was employed as the ballistic method yielded the results of greater uncertainty due to a slight difference in the course of the magnetization curves for the directions [110] and [100].

These results suggest that the constant of induced anisotropy, K_1^T, is positive and decreases with increasing temperature and increases with cobalt concentration. For small values of x the Perthel conclusion about the linear dependence of K_1^T on x was confirmed, but for high values of x and especially at low temperatures some defections in this linear dependence were observed.

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