Remanence properties of Co-precipitated cobalt ferrite

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Abstract

Isothermal remanent magnetization (IRM) and DC demagnetization (DCD) curves of a co-precipitated cobalt ferrite sample were obtained. From the IRM and DCD data, the Henkel plot was obtained and analyzed in the Preisach model framework. The Henkel plot data are below the Wohlfarth line that indicates a dominant local disorder (demagnetizing like effect). Forward and reverse switching field distribution curves were obtained from differentiation of the IRM and DCD curves. The peak values of these switching field distributions differ by a factor of about 2.7

Cobalt ferrite has been the subject of investigation in magneto-optical recording media, in which magnetic interactions play an important role in their recording performance.

The description of magnetic interactions and Henkel plots by the Preisach hysteresis model (PM), is a general theory for studying magnetic interactions [1], in the sense that, the assumptions that limit the validity of the Wohlfarth theory, do not play a role in the case of the Preisach framework [2]. On this basis, interactions between non-uniaxial particles with domain structure can be studied, which is the case of the co-precipitated cobalt ferrite, being a spinel cubic ferrite.

The three states, magnetizing (m_r), demagnetizing (M_d) and saturation (M_∞) remanence are associated with three partitions of the Preisach plane [2]. The Henkel plot is obtained by plotting M_d (H) vs. M_r (H). Considering that the Preisach distribution is concentrated along the h_c axis (h_u=0), the upper limit of the Henkel plot region is determined by the relation $M_d=M_\infty-2M_r$ [2], which is the Wohlfarth relation. The search for non-linearity in the behavior ofM_d vs. M_r has been used in the study of interaction e!ects. Interactions for which $M_d>(<)M_\infty-2M_r$, have a magnetizing-like (demagnetizing- like) nature [1]. On the other hand, if the Preisach distribution is focused around a local coercivity $h_c=h_o$, it leads to the lower limit of the Henkel plot region as $M_d = -M_r$ [2]. Both limits lead to the following inequalities: $-M_r < M_d < M_\infty - 2M_r$ [2].

In this work, the Henkel plot for a spinel cubic ferrite was obtained from the IRM and DCD data and analyzed in the Preisach framework, in order to investigate the nature of interactions. IRM and DCD susceptibilities were also calculated in order to obtain information about the switching field distribution involved.

Cobalt ferrite powder was prepared starting from $FeSO_4 \cdot 7H_2O$ and $CoSO_4 \cdot 7H_2O$ in the ratio Fe: Co= 2:1, co-precipitated in acetone medium and sintered at 1100°C for 3 h, as indicated in a previous work [3]. This cobalt ferrite presented a lattice parameter a= 8.376Å, an oxygen parameter of μ = 0.382 Å and an isotropic temperature coefficient B = 1.17Å, according to the Rietveld refinement of the XRD spectrum performed by using the Fullprof program [4]. A cation distribution of $Co^{2+}_{0.43}Fe^{3+}_{0.57}[Co^{2+}_{0.57}Fe^{3+}_{1.43}]O_4$ was found from the Mössbauer spectrum fitting, taken at room temperature, indicating a partial inverse spinel. This sample presented a coercive field H_c of 275.1 Oe, a remanent magnetization M_∞ of 37.5 emu/cm^3 and a saturation magnetization M_{sat} of 162.8 emu/cm^3, according to the major hysteresis loop obtained by vibrating sample magnetometry.

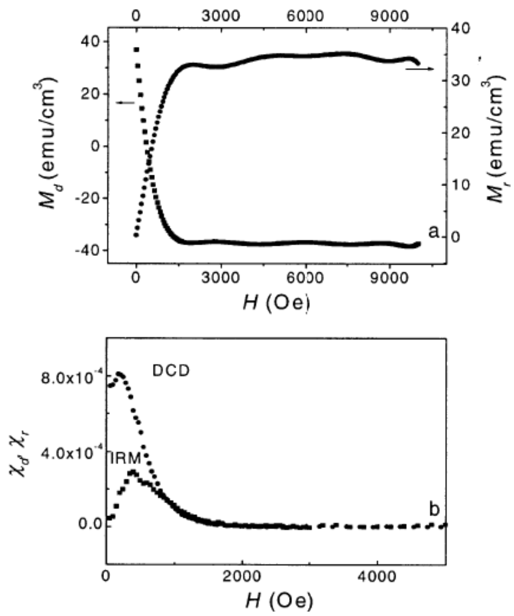

Fig. 1. (a) Remanent magnetization curves IRM and DCD and (b) IRM and DCD magnetic susceptibilities as a function of the applied field.

The IRM remanence curve started from an AC-demagnetized state, with the remanent magnetization being measured as a function of increasing positive applied fields. First, a certain field H was applied and then it was removed, the magnetization when the system reached zero applied field was M_r (H). This procedure was done until positive saturation was obtained (10 kOe). The DCD remanence curve started from the saturated state, with the remanent magnetization being measured as a function of decreasing applied fields. As before, a certain field - H was applied and then removed; the magnetization when the system reached zero applied field was M_d(H). This procedure was done until negative saturation was obtained (-10 kOe).

The IRM and DCD remanence curves are shown in Fig. 1a, which represent the variation of M_r and M_d with the applied field. The first differential of these curves gives a direct measure of irreversible changes in the magnetization states, or in other words of the switching field distributions in the sample. Thus, the IRM and DCD susceptibilities shown in Fig. 1b were obtained from differentiating the remanence curves, respectively. Differentiating the Wohlfarth relation, one obtains the remanence susceptibilities proportion as X_d/X_r for non-interacting systems. In our case, the amplitudes of the X_d and X_r peaks differ by a factor of 2.7 and neither the widths nor the positions of the peaks coincide, as can be seen from Fig. 1b. This indicates that the system presents interaction e!ects, which can be better studied by the construction of the Henkel plot.

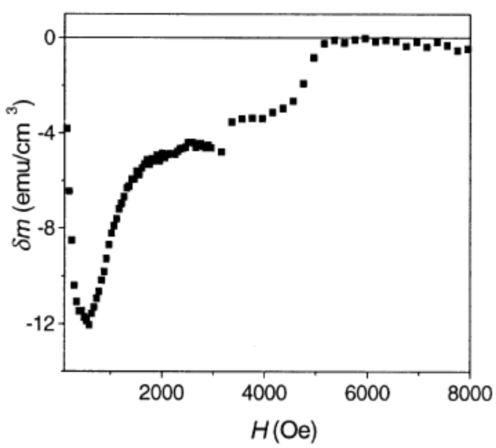

Fig. 2. Variation of the δm curve with the applied field.

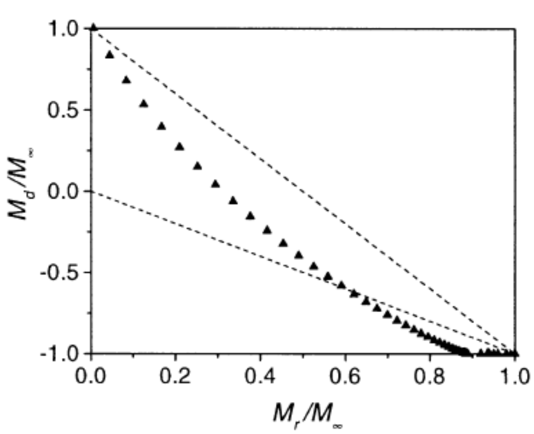

Fig. 3. Henkel plot showing the upper and lower limits in dashed lines.

Fig. 2 shows the δm plot as a function of the applied field. This plot would be a horizontal line through the origin if there were no interactions [5]. The curve shows negative δm, which results from interactions making it diffcult to magnetize the sample from the AC-demagnetized state [6]; this means that the interactions present a demagnetizing-like nature.

The Henkel plot (M_d vs. M_r) obtained from the IRM and DCD remanence data is shown in Fig. 3. In this figure the upper and lower limits for the Henkel plot range are also represented. It indicates an interaction of demagnetizing-like nature ($h_u \neq 0$), in the entire Henkel plot range, because the condition that $M_d/M_\infty) < 1 - 2\, M_r / M_\infty$ Is always satisfied. The upper limit contains just a point of the Henkel plot at H≈750 Oe; this means that the saturation hysteresis loop and the virgin magnetization curve are coincident only for that field [1]. Deviations from the Henkel plot range can be expected for different values of the moving Preisach parameter K_m that depends on the internal field of the sample, as reported before [3].

In conclusion, a dominant local disorder with a demagnetizing nature is the main interaction between particles in the system.

References

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