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DEPENDENCE OF NORMAL AND REVERSED GYROREMANENT MAGNETIZATION ON AC FIELD STRENGTH IN PARTICULATE MEDIA

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In this paper we present experimental results of the dependence of gyroremanent magnetization (GRM) on AC field strength for both “normal” and “reversed” GRM. The experiments were performed on samples of whole tape containing γFe_2O_3 particles, as well as samples containing dilutely dispersed γFe_2O_3 particles set in resin, to highlight any differences due to particle interactions. The dispersed particles also had differing degrees of anisotropy, so that any potential differences due to intrinsic anisotropy could also be determined. The results were also compared with recent data on dilutely dispersed CrO_2 particles.

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1. Introduction

Gyroremanent magnetization is produced when a sample containing an anisotropic distribution of single-domain (SD) magnetic particles is placed in a strong AC magnetic field [1], in the absence of any other fields. The effect has been qualitatively explained in terms of an effective biasing field arising from the intrinsic angular momentum of the moments of single-domain particles, which undergo irreversible flips in the strong AC [1]. The GRM is oriented perpendicular to both the maximum anisotropy (easy) axis and the AC field axis, and is related to the magnitude of the sample’s anisotropy. Early measurements showed that the GRM was oriented towards +z direction for AC field applications along positive orientations of θ in the xy plane (Figure 1) in line with theory [1]. By convention the angle θ is positive between x and y and negative between x and –y. Recently, however, a sample containing dispersed CrO_2 particles studied by Madsen [2] and some tape samples containing γFe_2O_3 particles studied by Salaoru et al [3] have exhibited a GRM in the reverse direction, along –z direction for AC field applications along positive orientations of θ. This type of GRM was called “reversed” GRM, and we have presented some micromagnetic simulations that might help to explain this effect in γ-Fe_2O_3 magnetic tape samples [3].

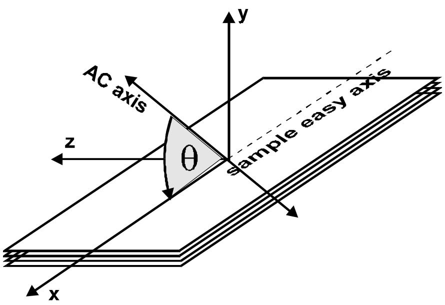

Fig. 1. Sample containing strips magnetic tape used for studying the angular dependence of GRM.

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The original experiments on the angular dependence of GRM were made by measuring the remanence acquired by the sample for different orientations of the angle (θ) between the maximum anisotropy axis and the AC axis [1]. These experiments on samples containing strips of γFe_2O_3 magnetic tape suggested that the angular dependence was close to the theoretically predicted sin 2θ variation, except that the maximum GRM was not at 45 degree as expected, but was skewed towards a slightly higher angle for both positive and negative values of θ for the one field strength (50 mT) that was measured [1]. This skewing effect was thought to be due to interactions between the particles in the tape. Some support for this idea came from later experiments on dilute dispersed (weakly interacting) samples of γFe_2O_3 particles set in resin [4] and on rock samples [5], which gave results much closer to a sin 2 θ curve. It is worth mentioning that another form of gyroremanence, called rotational remanent magnetization (RRM), occurs when a sample is rotated in an AC field [6,7]. The ratio of RRM to anhysteretic remanent magnetization (ARM) is a good indicator of ferrimagnetic particle size or domain state [6].

In this paper we present an experimental study of the angular dependence of GRM, with the sample stationary, as a function of the AC field strength. A key objective of this work was to determine the influence of the AC field strength on the position and magnitude of the maximum GRM. Further objectives were to determine whether there were any differences between samples exhibiting “normal” and “reversed” GRM, between samples of whole magnetic tape and dilutely dispersed particles from tape, and between samples with different intrinsic anisotropy. All the measurements were performed using an 180 Hz AC field with peak strengths between 30 mT and 80 mT.

2. Samples and experimental setup

The study was undertaken on two types of sample: (1) γFe_2O_3 magnetic tapes and (2) dilute anisotropic dispersions of γFe_2O_3 particles set in resin. Sample ST1 was used by Stephenson [1] and consisted of 100 short strips of magnetic tape which exhibited “normal” GRM. Sample A50 was used by Salaoru et al [3] and consisted of 50 short strips of magnetic tape which exhibited “reversed” GRM. Samples TDK30 and TDK70 were used by Stephenson and Potter [4] and were prepared by dilutely dispersing γFe_2O_3 particles in a resin and applying a 30 mT and 70 mT DC magnetic field respectively during setting of the resin to induce different degrees of anisotropy in the two samples. We used a Molspin demagnetizer for both the demagnetization of the samples, and for applying the single axis AC to produce the GRM. Prior to each GRM acquisition the samples were demagnetized by tumbling (that is, randomized rotation about more than one axis) to remove any prior remanence. The GRM was measured with a high sensitivity fluxgate magnetometer as in previous studies [1-5].

3. Results

The experimental results for sample ST1 are presented in Figure 2. It is clear that the higher the applied field strength, the further the modulus of the maximum GRM migrates towards higher angles, for both positive and negative values of θ. The maximum is also larger for stronger fields. We obtained very similar results to the one field (50 mT) examined by Stephenson [1]. The results for sample A50 (Figure 3) also show a similar migration of the modulus of the maximum GRM with field strength for these predominantly “reversed” GRM results. Note that the GRM is actually “normal” for a field of 30 mT, is predominantly “reversed” (but partly “normal”) for intermediate fields and is completely “reversed” for the highest field of 80 mT.

The dependence of GRM amplitude on AC field strength, normalised to the GRM amplitude at 80 mT and ignoring the sign of the GRM, is shown in Figure 4. In addition to the two tape samples we have also plotted our results for the dispersed γ-Fe_2O_3 samples (TDK30 and TDK70), as well as previous results from Madsen [2] for dispersed γ-Fe_2O_3 particles (which gave a “normal” GRM response) and dispersed CrO_2 particles (which gave a “reversed” GRM response). For the TDK samples the experiments were performed at only two values of AC field strength (40 mT and

80 mT); smaller field strengths produced very weak values of GRM that could not be accurately measured. For all five samples containing γFe_2O_3 particles the amplitude of the GRM had a very similar trend, when one ignores the sign of the GRM. The whole tape samples gave slightly higher normalised GRM amplitudes at low applied field strengths than the samples containing dispersed particles. The trends for all samples were close to being linear for weak AC fields. The GRM amplitude of the sample containing CrO_2 particles saturates at much higher applied AC field strengths than the GRM amplitude for the samples containing γFe_2O_3 particles.

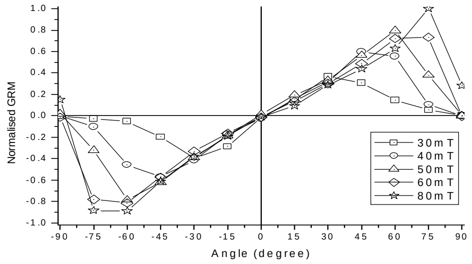

Fig. 2. Angular dependence of GRM (normalised to the maximum GRM at 80 mT) for sample ST1 exhibiting “normal” GRM.

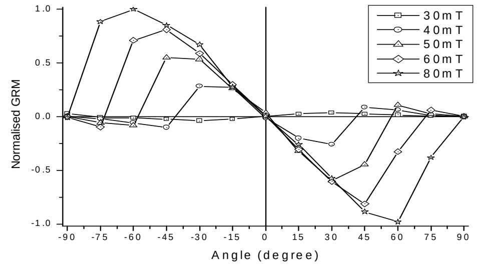

Fig. 3. Angular dependence of GRM (normalised to the maximum GRM at 80 mT) for sample A50 exhibiting “reversed” GRM.

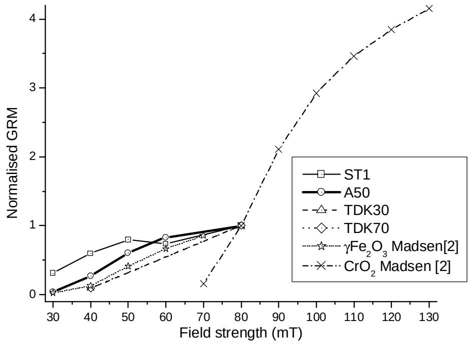

Fig. 4. Dependence of GRM amplitude (normalised to the GRM amplitude at 80 mT and irrespective of the sign of the GRM) on AC field strength.

Figure 5 shows the dependence of the position (as a function of θ in the xy plane) of the maximum positive GRM value as a function of AC field strength. Clear differences are seen between samples that exhibited “normal” GRM (ST1, TDK30, TDK70 and Madsen’s γFe_2O_3 particles) and those that exhibited “reversed” GRM (A50 and Madsen’s CrO_2 particles). For sample A50, the figure highlights the change in position of the maximum GRM from positive angles (+30°) in a weak field of 30 mT corresponding to a “normal” GRM, to negative angles (up to -60°) at higher applied field strengths corresponding to a “reversed” GRM.

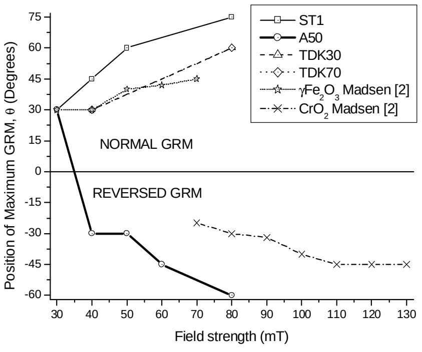

Fig. 5. Dependence of the position (as a function of θ in the xy plane) of the maximum positive GRM value as a function of AC field strength.

4. Conclusions

This study demonstrates that the AC field strength has a significant effect on the GRM, regardless of whether the GRM is "normal" or "reversed". For all the samples containing γFe_2O_3 particles, the amplitude of the GRM (if one ignores the sign of the GRM) as a function of AC field strength showed very similar trends, irrespective of (a) whether the GRM is "normal" or "reversed", (b) intrinsic anisotropy, and (c) whether the sample was whole tape or dilutely dispersed particles, although there were slight differences between these two types of sample. The dependence of the position of the maximum positive GRM was very different for samples exhibiting "normal" GRM and those exhibiting "reversed" GRM. Sample A50 had a "normal" GRM at small AC field strengths that became "reversed" at higher field strengths.

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