INFLUENCE OF MICROSTRUCTURE ON ACOUSTIC EMISSION ALONG HYSTERESIS LOOP OF POLYCRYSTALLINE FERRIMAGNETS

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Abstract. – The acoustic emission AE in stoichiometric YIG samples has been investigated as a function of microstructure; the grain size D_m ranges from 2 to 30 μm, the porosity p from 0.4 to 12 % . AE is always proportional to the hysteresis losses. AE increases with D_m and with $1/p$, but D_m is the dominant parameter.

Introduction

It is known that acoustic emission (AE) can be observed in magnetic materials, due to irreversible changes of the magnetization state [1-4]. The origin of this AE is controversed: Ono and co-workers [2] assume a relation with the release of the internal magnetoelastic energy associated with non-180° domain walls, while we assume a relation with the process of domain wall (DW) creation/annihilation [4]. Ono *et al.* as well as other researchers [5] have investigated metallic alloys with various magnetostriction values and tried in that way to relate AE to magnetostriction. The main objection which can be raised to such studies is that the saturation magnetostriction λ_S, measured on a sample of a given composition, is representative of this composition while this is not true for the saturation AE which is microstructure dependent as it will be shown in the present paper.

Experiment

Measurements have been performed on a series of stoichiometric polycrystalline YIG samples with various grain sizes D_m and porosities p; $p =$ (X-ray density−actual density)/X-ray density (see Tab. I). Toroid shaped samples are magnetized at 100 Hz by using a primary winding. The flux changes are recorded from the voltage induced in a secondary winding. A small drop of gel insures the transmission of the surface acoustic waves from the sample to a resonance piezoelectric tranducer (Brüel & Kjaer N° 8313), which is connected through a high gain amplifier to a digital oscilloscope. A drastic HF filtering of the magnetizing current has been realized in order to eliminate any parasitic AE, due to the combination of a possible HF response of the sample at 200 kHz (resonance frequency of the detection chain) with the very high gain of the chain [6]. For each elementary experiment, three sets of data are simultaneously digitally recorded as a function of time during at least one period: i) magnetizing field, ii) flux changes and iii) amplitude of AE activity. From each elementary experiment corresponding to a maximum magnetizing field H_m the main parameters of the corresponding hysteresis loop are calculated and stored for further analysis. Concerning the AE, we compute the cumulative activity labelled $A(H_m)$. The analysis of the field dependence of AE along a loop will be given in a forthcoming paper.

By adjusting step by step the peak value of the magnetizing field H_m, data are recorded from the demagnetizing state up to about the saturation.

Table I. – *Mean grain size and porosity for all the samples.*

Sample N°	1	2	3	4	5	6	7
D_m (μm)	2.2	3.7	5.0	8.5	12	20	30
p (%)	12.7	2.9	1.4	4.2	0.64	0.52	2.7

Results and discussion

In figure 1 $A(H_m)$ for each sample is compared to the hysteresis losses $W_h(H_m)$ measured on the loop taken at H_m. At first it is clear that, for each sample, $A(H_m)$ is proportional to $W_h(H_m)$. A parasitic effect near the saturation can be seen in the case of large grain samples, i.e. a certain tendency for $A(H_m)$ to slightly decrease near the saturation. At the present

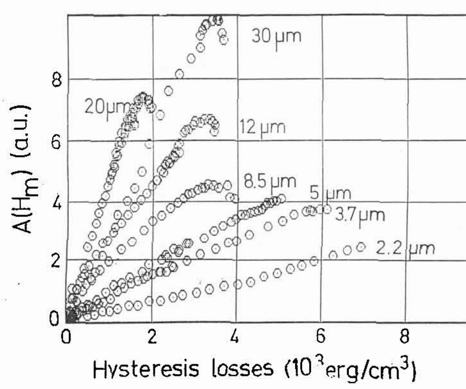

Fig. 1. – For each of the 7 presented samples, total cumulative acoustic emission $A(H_m)$ *versus* hysteresis losses W_h.

time it is not clear whether this observation has some physical origin or comes from experimental errors. The other evidence which appears in figure 1 is the opposite dependence on the grain size of the maximum of both $A(H_m)$ and $W_h(H_m)$. $W_h(H_m)$ roughly decreases when D_m increases (in agreement with early results [7]) while $A(H_m)$ on the contrary increases with D_m. This is more clearly shown in figure 2a, where the maximum A_m of the cumulative AE is plotted as a function of D_m. Finally, figure 2b shows the variation of A_m as a function of the reciprocal of the porosity p. Although a general tendency for A_m to increase with $1/p$ could be seen, one must remark that sample N° 7 gives a value 2.5 times greater than sample N° 2, both of them having the same porosity (2.8 ± 0.1 %). In the same way samples N^{os} 2, 3 and 4 give roughly the same A_m while their porosity ranges from 4.2 % to 1.4 %.

As mentioned above there are two different main interpretations of the origin of the field dependence of AE in magnetic materials: i) release of the magnetoelastic energy associated to non-180° DW [2]; ii) DW creation/annihilation process [4].

We have not been able yet to check directly our hypothesis by using simultaneously visualization and piezodetection, but we know that such an experiment has been performed on ferroelectric materials [8]. Nevertheless we have earlier quantitatively attributed the hysteresis losses to the DW creation/annihilation process [7]. Then the proportionality between $A(H_m)$ and $W_h(H_m)$, which is systematically observed in all the studied samples, establishes a link between AE and the DW creation/annihilation process. Our representation of the magnetization processes [7] assumes that the total surface of DW included in a sample decreases when D_m increases, which results in hysteresis losses inversely proportional to D_m (as generally observed in good quality materials). Then, if the origin of AE is the DW creation/annihilation process, one might observe that AE is inversely proportional to D_m, that is

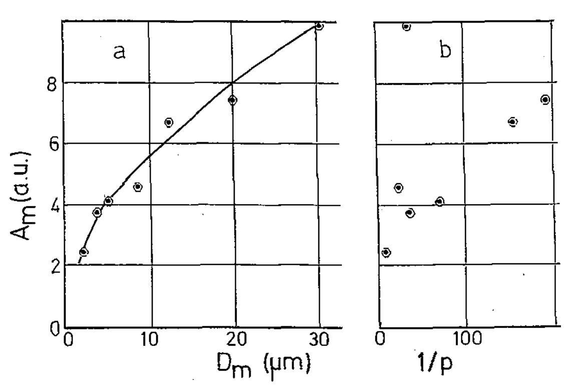

Fig. 2. – Maximum of the cumulative acoustic emission A_m, a) *vs.* grain size D_m, b) *vs.* the reciprocal of the porosity $1/p$.

completely at the opposite of our results (as well as those of Jiles and co-workers [3] on steels). If we take Ono's hypothesis, one might admit that the larger D_m, the higher the number of closure domains, which is not established at all. In addition Ono's idea cannot explain the relation between AE and W_h.

So we come back again to our hypothesis and try to explain the surprising grain size dependence of AE. Several hypothesis can be introduced which are not exclusive. The first one might be that the spectral repartition of the AE bursts depends on D_m. As our detection system works at resonance at a fixed frequency (200 kHz) a part of the effective AE is only detected, which could be artificially D_m dependent. Another possibility is the self-absorption and dispersion of the sample itself. On the one hand the grain boundaries are regions of dispersion and adsorption of the ultrasonic waves and can contribute to a change in the spectral repartition of the AE bursts and/or their absorption. As the density of the grain boundaries decrease when D_m increases, one could justify the increase of A_m with D_m. On the other hand it has been shown earlier on a YIG single crystal by Le Craw and Comstock [9] that ultrasonic waves are dramatically absorbed when the sample begins to be non saturated. In other words the presence of DW in the material is a crucial source of ultrasonic absorption. Since we postulate that the larger D_m, the smaller is the total DW surface in the sample, we can explain the increase of A_m with D_m by a smaller self-absorption by the domain walls in large grain samples.

In order to test these hypothesis, we are planning to: i) measure single crystals (YIG first); ii) use other piezoelectric tranducers with different center frequency or bandwidth.

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