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Influence of the measurement frequency on the magnetic disaccommodation spectra of YIG samples

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Abstract

Magnetic aftereffect phenomena in yttrium iron garnets and their relationship to the dynamics of domain walls are analyzed by means of the magnetic disaccommodation (DA) technique. The samples have been prepared using a standard ceramic technique in CO_2 atmosphere in order to enhance the formation of ferrous ions in the lattice. The results reveal the presence of the well-known process II around 130 K and a process at higher temperatures (187 K). Furthermore, accommodation (or negative DA) processes have been detected at temperatures just below process II. The features of these phenomena are strongly related to the measurement frequency and, hence, they are more noticeable as this frequency is increased. Such behavior is associated with the resonance of the domain wall motion at frequencies around the measurement frequency. The characteristic parameters that define this resonance depends upon time due to the presence of an induced anisotropy relaxation process that occurs after demagnetization.

Keywords: YIG; Magnetic aftereffect; Disaccommodation spectra; Domain wall motion

1. Introduction

It is well known that magnetic aftereffects phenomena are a valuable method for the study of the magnetization mechanisms. Its origin is related to the variation of the domain wall dynamic caused by changes of the induced anisotropy in the material, and thus, they are strongly associated with the presence of ferrous ions and crystal vacancies in the lattice. The technique most frequently used for analyzing them is the magnetic disaccommodation (DA), defined as the time variation of the initial permeability after demagnetizing the material. A new and very different behavior has been checked in the case of yttrium iron garnets (YIG) in relation to other kind of ferrites. In fact, magnetic accommodation processes, which consist in an increase of the initial permeability with time, has been just detected in YIG samples sintered under reducing atmospheres [1,2]. In this work, the critical dependence of these phenomena on the measurement frequency utilized is showed and some reasonable conclusions about its relationship with the wall motion dynamic are pointed out.

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2. Experimental procedure

The polycrystalline samples, with the stoichiometric pure YIG ($Y_3Fe_5O_{12}$) initial composition, have been obtained by a standard ceramic technique [1] in CO_2 atmosphere at different temperatures according to the corresponding phase diagram [3]. Magnetic DA measurements have been carried out with the help of an automatic LCR meter [4] by using a sinusoidal signal with frequencies ranging from 200 Hz to 4 kHz. The results are presented by means of isochronal relaxation curves, so that the relative variation of the permeability at each temperature is represented at different time windows in the following form:

$$DA(\%) = \frac{\mu(t_1, T) - \mu(t_2, T)}{\mu(t_1, T)} \times 100, \qquad (1)$$

where $t_1 = 2$ s and $t_2 = 4, 8, 16, 32, 64$ and 128 s in our plots.

3. Experimental results

Fig. 1 presents the isochronal relaxation spectra measured at different frequencies for the YIG sample sintered in CO_2 at 1420°C. At first sight, it results noticeable the critical dependence of the disaccommodation curves on the measurement frequency, fact never detected previously in similar experiments carried out with other kinds of ferrites. Concretely, we can observe at 200 Hz only a DA process around 125 K, with an activation energy of about 0.35 eV, usually known as process II [2]. Simultaneously, it can be noticed an accommodation process at temperatures just below process II. The features of this process are strongly related to the frequency used in the experiment. So, as this frequency is increased, the negative process seems to overlap the positive, so that the ratio between the amplitudes of both peaks decreases gradually (for example, they become very similar for 2 kHz), and the maxims of both processes shift to greater temperatures. Finally, process II can be hardly detected at 4 kHz and the accommodation peak is now centered around 125 K.

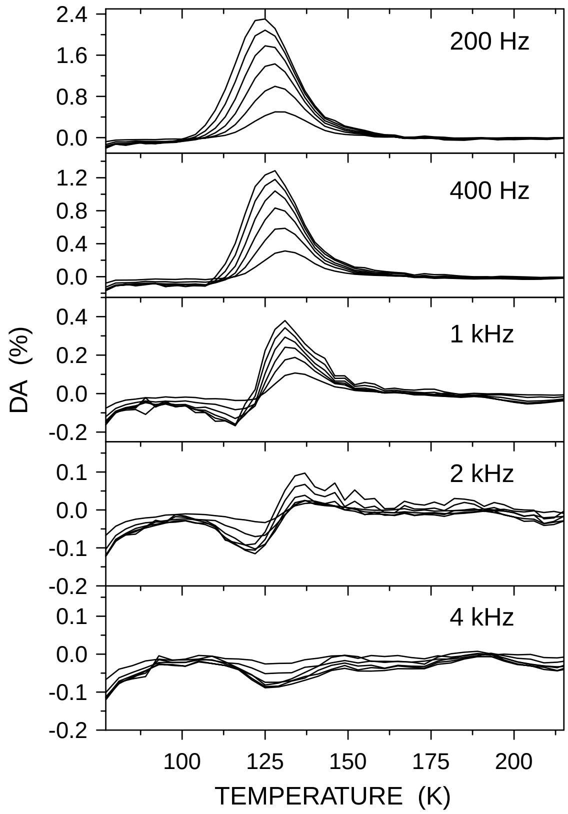

Fig. 1. Isochronal relaxation spectra of the YIG sample sintered in CO_2 at 1420°C at different measurement frequencies.

The results obtained for the YIG sample sintered in CO_2 at 1450°C are showed in Fig. 2. The behavior is very similar to the previous sample except for the presence of a new DA process centered at 187 K, with an activation energy around 0.5 eV. On the contrary to process II, the features of this new peak do not depend on the measurement frequency. It just can be detected a reduction of its amplitude at the highest frequencies due to the worsening of the signal–noise relation in the measurement equipment.

4. Discussion

Previous works have demonstrated that YIG samples have an oxygen deficient structure when they are sintered at high temperatures under reducing atmospheres as CO_2 [3]. The resulting

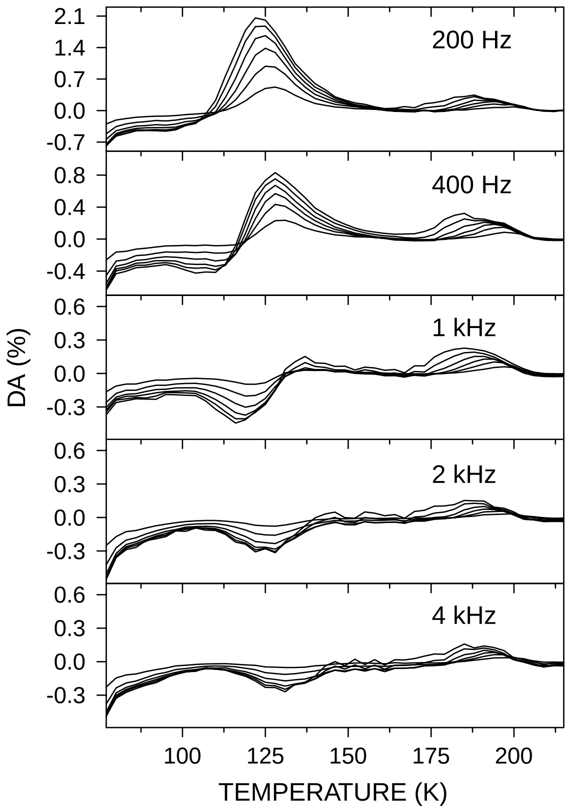

Fig. 2. Isochronal relaxation spectra of the YIG sample sintered in CO_2 at 1450°C at different measurement frequencies.

oxygen vacancies behave as positive charge centers in the lattice, and thus, they may be compensated by the formation of some Fe^{2+} ions in order to establish global neutrality. The electron hopping between Fe^{3+} and Fe^{2+} in the octahedral positions of the garnet structure creates a local order responsible for induced anisotropy and stabilization wall effects, thus giving rise to process II. In addition, the migration of oxygen vacancies through the lattice has been proposed as a source of magnetic aftereffect in YIG. The activation energies suggested [2,5] are very similar to the value found in our case for the process at 187 K, and thus, we must associate this process to the migration of oxygen vacancies, enhanced by the increasing sintering temperature.

Additionally, there has not been found, until now, a hypothesis that justified the mechanisms responsible for the magnetic accommodation processes. However, the dependence on the measuring frequency, here showed, is in accordance with the theoretical ideas previously proposed by our group [6]. According to this theory, with high measurement frequencies, the rearrangement of the defects is too slow to follow the domain wall motion. As this rearrangement takes place, the wall damping diminishes. Finally, when it has finished, the defects will stay at their equilibrium positions, giving rise to an additional elastic stress. Therefore, taking into account a second-order wall dynamics, this stress will be increased at each time instant due to the relaxation term and the wall resonance frequency will be increased, as a consequence, in the same way. Thus, depending on the measuring frequency, the wall amplitude (and so the initial permeability) may decrease, increase, or both with time. This is the phenomenon analyzed near process II, which can be hardly noted at high frequencies because now this time-dependent resonance process is observed. On the contrary, the DA process detected at higher temperatures does not depend on the frequency in our measurement range because no accommodation processes is detected in its proximities. A detailed study about this matter will be carried out in a forthcoming paper.

Acknowledgements

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