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Induction of Magnetic Accommodation Processes in Polycrystalline Yttrium Iron Garnet

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Abstract: Magnetic disaccommodation phenomena are studied in YIG polycrystalline samples. The compounds were prepared by a ceramic technique and sintered at temperatures ranging from 1350°C to 1450°C in air and CO₂ atmospheres. The results are presented as isochronal spectra of the relative time variation of the initial magnetic permeability after specimen demagnetization. For samples sintered in air atmosphere, it can be observed a clear positive relaxation peak around 125 K. When the sintering temperature is increased, the amplitude of this peak decreases slightly and a new process appears at higher temperatures (around 180 K). On the contrary, a drastic change is produced when samples are resintered in CO₂ atmosphere. In this case, relaxation spectra exhibit negative peaks (accommodation processes) around 115 K. Also, the relaxation features of these processes seem to be influenced by sintering temperature. Some reasonable speculations about the mechanism responsible for this behaviour are pointed out.

1. INTRODUCTION

In the last years our group has reported several works dealing with magnetic disaccommodation (MDA) measurements in polycrystalline YIG depending on sintering atmosphere [1] and temperature [2]. We have also observed that magnetic accommodation (MA) processes appear in stoichiometric YIG samples sintered in atmospheres with low oxidation pressures ($P(O_2) < 10^{-2}$) [1]. In this paper we show how it is possible to induce accommodation processes in YIG samples sintered in air by a resintering in CO₂ atmosphere. Comparison between MDA and MA spectra in these series of samples before and after the resintering in CO₂ provides very interesting information for the understanding of magnetic accommodation processes.

2. EXPERIMENTAL PROCEDURE

For our purpose, a series of YIG polycrystalline samples has been prepared from stoichiometrically mixed high-purity Fe₂O₃ and Y₂O₃ powders. The mixtures were ball milled for several hours in an agate mortar, pressed in a cylindrical die and sintered for 8 hours in air at temperatures ranging from 1350°C to 1450°C according to the phase diagrams of the Y-Fe-O system [3]. Finally, vacancy annealing was avoided by rapid quenching in an air stream. Each sample was resintered at the same temperatures but now in CO₂ atmosphere. X-ray powder diffraction patterns of these samples showed that single phase YIG was obtained at each sintering temperature.

Magnetic aftereffect measurements have been carried out with a computer aided system based on an automatic LCR bridge [4]. During the measuring process, the time variation of the reversible magnetic permeability after sample demagnetization is recorded at different rate windows with scanning temperature. The measuring signal is a weak 1 kHz ac field, whereas specimen demagnetization is achieved by means of a linearly decreasing 100 Hz signal, with amplitude higher than coercitive field.

3. EXPERIMENTAL RESULTS

Figure 1 displays the isochronal spectra for YIG samples sintered in air at different temperatures, whereas the spectra for the same samples after resintering in CO₂ are shown in figure 2. A first inspection of both spectra reveals that a profound change takes place in the magnetic relaxation processes of our samples after resintering. For the samples fired in air we can observe the presence of a relaxation process around 125 K which amplitude decreases with rising sintering temperature. When this temperature is higher than 1415°C a new process appears at 180 K. These two phenomena exhibit the characteristics of thermally activated processes with activation energies close to 0.34 eV and 0.4 eV, respectively. When the samples are

resintered in CO_2 , the spectra change drastically which means that the relaxation features of these materials depend strongly on the sintering conditions and especially on the partial oxygen pressure. It can be seen in figure 2 how now a magnetic accommodation process is observed at 115 K. At the same time a positive peak appears at temperatures immediately higher, around 130 K. Finally, it is noteworthy that a new process takes place at 180 K when the sample is prepared at 1450°C as it happens in air atmosphere. Furthermore, we can note that in this last case a new negative peak seems to appear below the lowest temperature accessible by our experimental device (80 K).

Figure 1: Isochronal relaxation spectra for YIG samples sintered in air at different temperatures ($t_1=2$ s and $t_2=4, 8, 16, 32, 64$ and 128 s, curves from bottom to top).

Figure 2: Isochronal relaxation spectra for YIG samples sintered in CO_2 at different temperatures ($t_1=2$ s and $t_2=4, 8, 16, 32, 64$ and 128 s, curves from bottom to top).

4. DISCUSSION

Keeping in mind the sintering conditions [4] it might be expected an oxygen deficiency in the crystal which promotes the existence of Fe^{2+} ions in octahedral positions. Thus, the process at 125 K in figure 1 is attributed to an electronic orientational process by means of point defects and the variation of its amplitude to the competition between the presence of ferrous ions and point defects when the sintering temperature is increased [2]. The thermally activated process at 180 K, which appears when the sintering temperature is above 1415°C , could be explained by the electron transfer between Fe^{2+} and Fe^{3+} ions in octahedral sites, which creates a local order responsible for induced anisotropy and a domain-wall relaxation [1]. When the samples are resintered under low partial oxygen pressures, accommodation processes, that is, an increase in the initial permeability of the sample, are induced as we can see in figure 2. These phenomena could be related with the appearance of some amounts of defects or diffusants inside the material [5]. These diffusants are responsible for a diffusion magnetic aftereffect which can be observed when the inverse of its relaxation time is smaller than the measurement frequency but both have the same order of magnitude. This is our case for low temperatures and 1 kHz measuring frequency [5]. Therefore, the induction of magnetic accommodation processes could be due to an increase of diffusants or defects inside the material and of the associated diffusion relaxation when the samples are sintered under low partial oxygen pressures. Further researches are required to verify this hypothesis.

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