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THE ROTATIONAL CONTRIBUTION TO THE INITIAL MAGNETIC PERMEABILITY IN Ni-Zn FERRITES

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ABSTRACT

A study on the magnetization mechanisms in polycrystalline Ni-Zn ferrites is presented. In addition to the magnetic wall contribution, it is shown that a rotational permeability term has to be considered for the total initial magnetic permeability.

RESUMEN

Presentamos un estudio de los mecanismos de magnetización en ferritas Ni-Zn policristalinas. Además de la contribución debida a la pared magnética, es necesario considerar un término debido a la permeabilidad rotacional con objeto de obtener la permeabilidad magnética inicial total.
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INTRODUCTION

Magnetization mechanisms in ferro- and ferrimagnetic materials have received considerable attention. At relatively low frequencies ($f < 5$ MHz) the magnetic domain structure proposed by P. Weiss(1) can be used as a basis in order to consider the possible magnetization processes. Two main mechanisms can be proposed: the domain wall movements to increase the volume of the domains which orientation is the nearest to the applied field, and the collective rotation of the magnetization vectors within the magnetic domains.

For the case of polycrystalline samples, the problem is more complex due to the granular structure (grain boundaries, porosity, etc.) interactions with the domains and the domain walls.

A. Globus showed(2) that the main contribution to the initial magnetic permeability (the permeability in the reversible magnetization range) in polycrystalline ferrites is the wall contribution. Globus also proposed a simple model(3) in which the initial permeability is a linear function of the mean grain diameter, provided that the porosity is low and has an intergranular character.

The linear relationship between the initial permeability and the mean grain diameter has been verified by other authors(4),(5) on different ferrites. However, the initial permeability value for $D_m \sim 0$ does not vanishes out, suggesting the possibility of a constant contribution other than the wall movement.

In this paper we present a study on the origin of this contribution to the initial magnetic permeability for polycrystalline Ni-Zn ferrites.

EXPERIMENTAL TECHNIQUES

Ni-Zn ferrites were chosen because the cations in this system (Ni^{2+}, Zn^{2+}, Fe^{3+}) are stable on their valency-state and their distribution on the two types of crystalline sites (tetrahedral and octahedral) is well known(6). The prepared compositions correspond to $x = 0.33$, 0.53 and 0.70 in the formula:

$$Zn_x\ Ni_{1-x}\ Fe_2\ O_4 \quad .$$

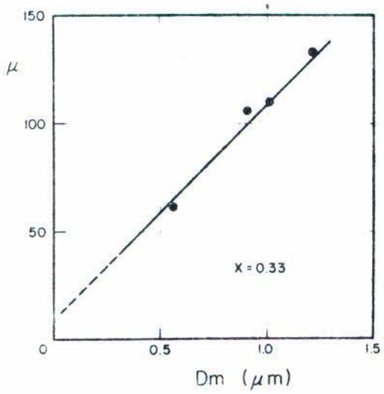
The samples were prepared from high purity oxides by the normal ceramic method[7]. A relatively low sintering temperature was used (1180°C) in order to avoid[8] intragranular porosity.

The room temperature permeability was obtained from the bridge-measured inductance at 1 kHz on toroidal samples. A special apparatus[9] was used for the measurement of the initial permeability as a function of the temperature, up to the Curie point. This property can be used[9] to evaluate the chemical homogeneity of the sample and is an effective method to controll the quality of the samples.

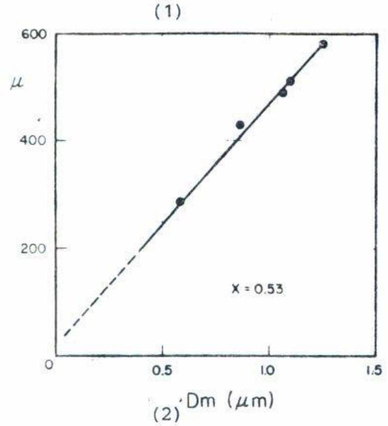
The determination of the mean grain diameter was made by polishing and thermally attacking one face of the sample. The thermal attack was performed in an oxidant atmosphere (O_2 100% at 1 atm) at a lower temperature (1160°C) than the sintering process, to avoid a supplementary grain growth. Several photographs were taken on different areas of each sample by means of an optical microscope.

EXPERIMENTAL RESULTS AND DISCUSSION

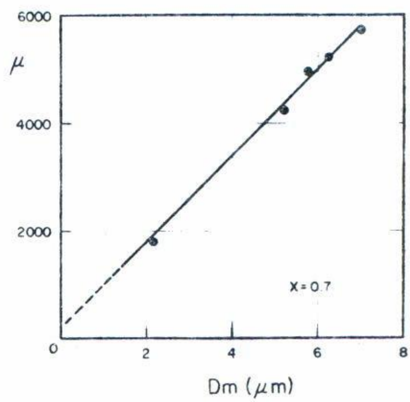
We first plotted the initial magnetic permeability as a function of the mean grain diameter for the three compositions, Figs. 1, 2 and 3. A straight line is obtained with a clearly different slope for each composition. A common feature appears in these figures; the extrapolation of the permeability at $D_m = 0$ is not null; it has a well defined value. This value, as obtained by a simple least square method is plotted on Fig. 4, as a function of the composition. We have also plotted the value for $x = 0$ [6]. The rotational magnetic permeability, as measured from ferromagnetic resonance experiments by Gieraltowski[10] is plotted as the straight line on the same Fig. 4. Although a certain dispersion appears, a reasonable agreement is seen for the whole range of composition. The dispersion is easily explained by taking into account the important differences between the slope of the linear relationship for, for example, the extreme compositions. The slope for x = 0 is ≃ 25 while in the case of x = 0.70 we have ≃ 800.



(1)



(2)



(3)

Fig. 1 The initial magnetic permeability for x = 0.33. A linear relationship is obtained. The extrapolated value to $D_m = 0$ is not zero.

Fig. 2 The initial magnetic permeability as a function of the mean grain diameter for x = 0.53.

Fig. 3 The linear dependence of the initial permeability for x = 0.70. This is a high-permeability composition.

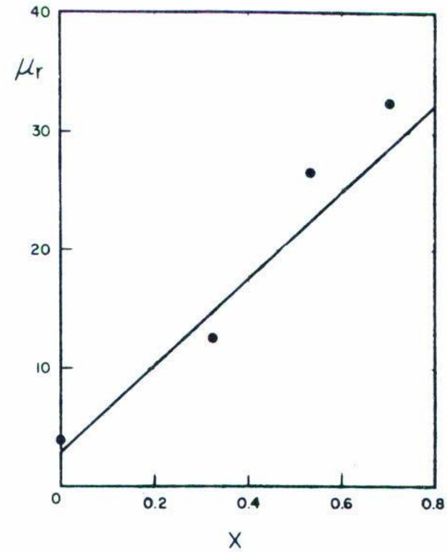


Fig. 4 The extrapolation of the linear dependence of the initial permeability, as a function of the composition. The straight line is the rotational permeability as determined by Gieraltowski[10] from ferromagnetic resonance experiments.

An interpretation of these results can be proposed in terms of an energy balance in each grain. Two main terms have to be considered: the magnetostatic energy and the wall energy. The latter is normaly negligible as compared to the former; however, for the case of a very small grain, the wall energy term can be as important as the magnetostatic energy and then it becomes more favorable for the grain to eliminate the wall. This is called a "monodomain" sample as each grain is in fact a magnetic domain. Obviously, as there is no wall, the wall contribution to the initial permeability disappears and the rotational contribution is the only one to be expected. This contribution is a constant for a given composition (at constant temperature) and independent of the mean grain diameter.

CONCLUSION

The low frequency value of the initial magnetic permeability in polycrystalline ferrites has two contributions: the wall contribution that is granular-structure dependent and the rotational contribution which depends only on the composition. Generally, the value of the latter is considerably lower than those of the former, except for the case of very small grains.

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