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Use of the Drag Method to Study the Magnetic Behavior ofMn-Zn Ferrite Nanoparticles

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---***ABSTRACT***---
The drag method was used to study the magnetic behavior of manganese-zinc (Mn-Zn) ferrites with different Zn concentrations. The results were similar to those obtained using a Vibrating Sample Magnetometer (VSM), showing that the drag method may be a simple, cheap way to investigate the magnetic properties of nanoparticles.

KEYWORDS:*drag method, nanoparticles, magnetization, manganese-zinc ferrite*

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I INTRODUCTION

Magnetic ceramics have different propertieswhen the particle size is in in the nanometric range, leading to new industrial, technological and biomedical applications[1-4]. The usual instrument for the study of the magnetic properties of nanoparticles is the Vibrating Sample Magnetometer (VSM)[5-9].The purpose of this work was to investigate the use of the drag method to study the magnetic behavior of Mn-Zn ferrite for different Zn concentrations.

II EXPERIMENTAL PROCEDURE

Nanoparticles of $MnFe_2O_4$, $Mn_{0.75}Zn_{0.25}Fe_2O_4$, $Mn_{0.50}Zn_{0.50}Fe_2O_4$, $Mn_{0.25}Zn_{0.75}Fe_2O_4$ and $ZnFe_2O_4$ were synthesized by the combustion method using manganese nitrate [$Mn(NO_3)_2.4H_2O$], zinc nitrate [$Zn(NO_3)_2.6H_2O$], iron nitrate [$Fe(NO_3)_3.9H_2O$] (all Aldrich, 98.0%) and glycine ($C_2H_5NO_2$) as fuel (Aldrich, 98.5%). Theglycine-nitrate (G/N) ratio was 1.0.

The nanoparticles were mixed with paraffin wax in a ratio of 1:10, at 60ºC, using a magnetic stirrer at 300 rpm for 10 min. For the drag measurements, four cylindrical samples 5mm high and 15 mm in diameter were producedfor each Zn concentration.

The samples were characterized by X-ray diffraction (XRD) in aPANalyticalX'PERT PRO diffractometer with CuKα radiation (λ = 1.5406 Å). The software TOPAS-Academic version 4.1 was usedto perform Rietveld refinements.

The VSM measurementswere performed at room temperature in a Princeton Applied Research Magnetometer model 155 with an applied field of 9 kOe.

The drag speed was determined calculating the ratio of the displacement (ΔS) to the time for the sample to undergo this displacement (Δt). The testswere performed in a 2,500cm² wave tank filled with 2.0 L of distilled water, enough to allow the specimen to be immersed in the water without touching the bottom of the tank.

The samples were positioned 10.0cm from a permanent magnet. The speed was determined for a displacement of 6.0cm. For each Znconcentration, each specimen was tested five times and four different samples were used. The drag speed was thus an average of 20 measurements.

III EXPERIMENTAL RESULTS

Figure1shows the XRD patterns of $MnFe_2O_4$, $Mn_{0.75}Zn_{0.25}Fe_2O_4$, $Mn_{0.50}Zn_{0.50}Fe_2O_4$, $Mn_{0.25}Zn_{0.75}Fe_2O_4$ and $ZnFe_2O_4$ nanoparticles.The index cards used for the Rietveld analysis were ICSD-155275 for $MnFe_2O_4$, ICSD-28516 for $Mn_{0.75}Zn_{0.25}Fe_2O_4$, ICSD-28514 for $Mn_{0.50}Zn_{0.50}Fe_2O_4$, ICSD-28513 for $Mn_{0.25}Zn_{0.75}Fe_2O_4$, ICSD-91827 for $ZnFe_2O_4$and ICSD-29272 for ZnO.

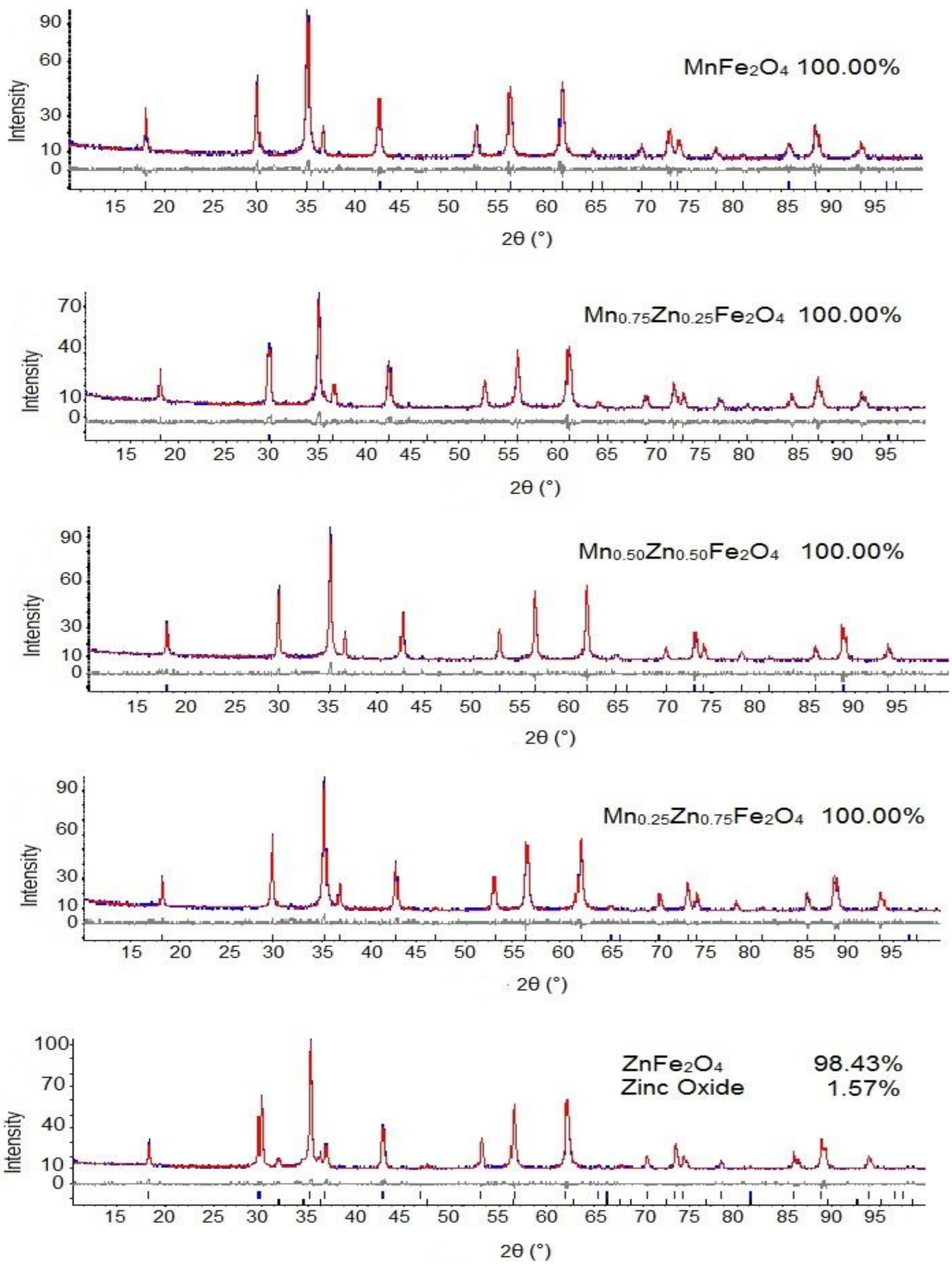

Figure 1– Diffractograms of the samples.

The values of mean crystallite size (D), specific mass (ρ) and lattice parameter (a andc) obtained from the Rietveld refinements are shown in Table 1.

The decrease of the lattice parameter a with increasing Zn concentration is consistent with that fact that the ionic radius of Mn^{2+} (0.83 Å) is larger than that of Zn^{2+} (0.74Å).

The cation distributions obtained from the Rietveld refinements are shown in Table 2 and are consistent with results reported in the literature [10].

Table 1 Parameters obtained from the XRD patterns

Zinc (%)	Formed phase	Crystal structure	D (nm)	ρ (g/cm³)	a (Å)	c (Å)
0	$MnFe_2O_4$	cubic	69.43	5.04	8.47	-
25	$Mn_{0.75}Zn_{0.25}Fe_2O_4$	cubic	61.64	5.06	8.49	-
50	$Mn_{0.50}Zn_{0.50}Fe_2O_4$	cubic	81.83	5.15	8.47	-
75	$Mn_{0.25}Zn_{0.75}Fe_2O_4$	cubic	76.78	5.23	8.46	-
100	$ZnFe_2O_4$	cubic	80.37	5.33	8.44	-
	ZnO	hexagonal	33.29	17.01	3.25	5.21

Table 2 Cation distributions obtained from the XRD patterns

Zinc (%)	A site	B site
0	$Mn^{2+}_{0.85}Fe^{3+}_{0.15}$	$Mn^{2+}_{0.15}Fe^{3+}_{1.85}$
25	$Mn^{2+}_{0.72}Zn^{2+}_{0.2}Fe^{3+}_{0.08}$	$Mn^{2+}_{0.04}Zn^{2+}_{0.04}Fe^{3+}_{1.92}$
50	$Mn^{2+}_{0.50}Zn^{2+}_{0.50}Fe^{3+}_{1}$	Fe^{3+}_{1}
75	$Mn^{2+}_{0.25}Zn^{2+}_{0.75}Fe^{3+}_{1}$	Fe^{3+}_{1}
100	$Zn^{2+}_{1}Fe^{3+}_{1}$	Fe^{3+}_{1}

Figure2 shows the magnetization of the samples as a function of the applied field, measured using the VSM technique. The absence of hysteresis confirms that the particles are superparamagnetic due to their small size.

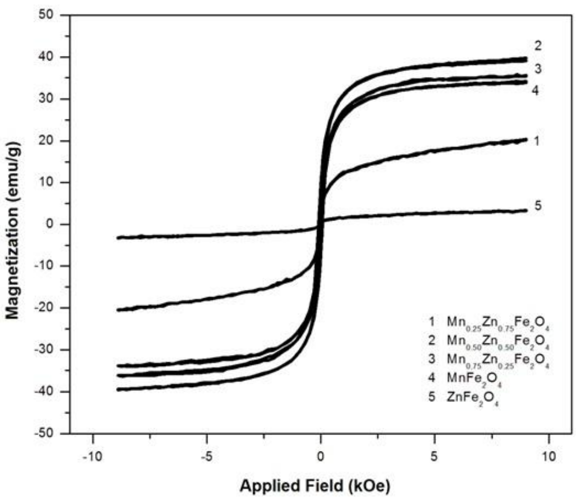

Figure 2– Magnetization of the samples as a function of the applied field.

Figure 3 shows the saturation magnetization of the samples, measured using the VSM technique. The highest average speed occurs for the $Mn_{0.50}Zn_{0.50}Fe_2O_4$.This is explained by the fact that, although Zn^{2+} is a nonmagnetic ion, its introductions changes the cation distribution of the Mn^{2+} and Fe^{3+} ions between the A and B sites, leading to configurations that, up to a certain Zn concentration, increase the net magnetic moment.

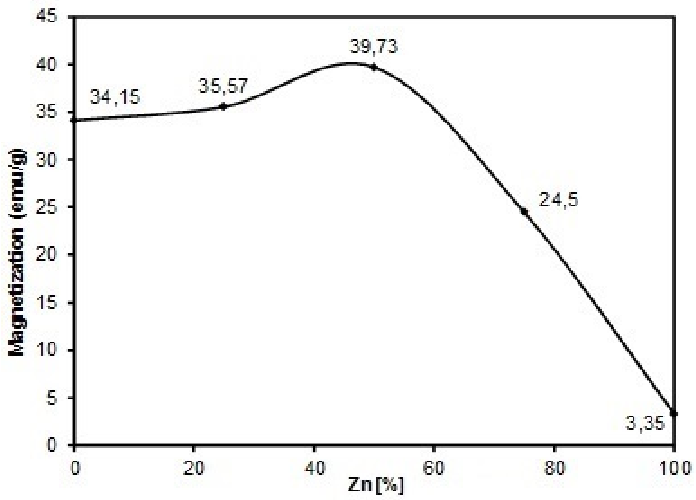

Figure 3– Saturation magnetization of the samples as a function of Zn concentration.

Figure 4 shows the results obtained using the drag method. The highest average speed also occurs for the $Mn_{0.50}Zn_{0.50}Fe_2O_4$. In addition, the overall change of the drag speed with Zn concentration is similar to that of the saturation magnetization.

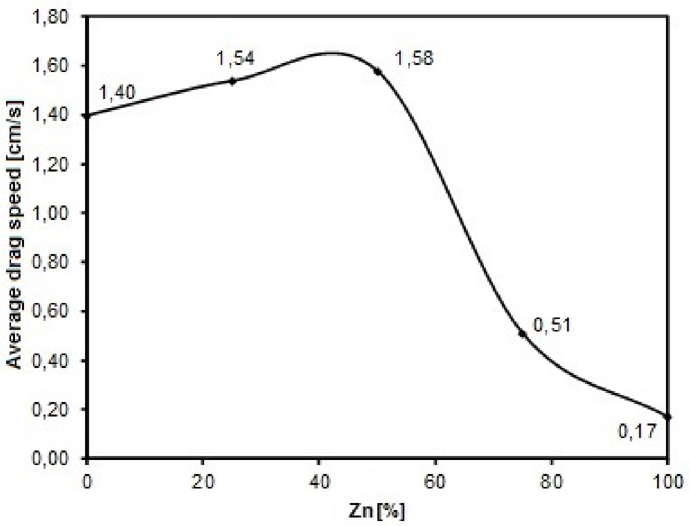

Figure 4– Average drag speed of the samples as a function of Zn concentration.

IV CONCLUSION

The results of this work suggest that the drag method may be a useful way to estimate the magnetic properties of magnetic nanoparticles, replacing, in some practical contexts, more sophisticated methods such as the VSM technique.

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