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Magnetization and cation distribution in $Co_xMg_{1-x}Fe_2O_4$ system

S M KADAM, S I PATIL, S H PATIL and B K CHOUGULE
Department of Physics, Shivaji University, Kolhapur 416004, India

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Abstract. Magnetic parameters such as saturation magnetization (σ_s), coercive force (H_c), remanence ratio (σ_r/σ_s) etc of $Co_xMg_{1-x}Fe_2O_4$ ($0 \leqslant x \leqslant 1$) ferrites were measured at 300 and 80 K. The values of σ_s, H_c and (σ_r/σ_s) increased as the content of cobalt increased. The magnetic moment μ_B was calculated using the σ_s data. The cation distribution has been suggested on the basis of these results.

Keywords. Saturation magnetization; cation distribution; Co–Mg–Fe–O ferrite.

1. Introduction

Ferrites have been the subject of extensive study in recent years because of their applications and their importance in understanding the theory of magnetism. The magnetic parameters such as saturation magnetization (σ_s), remanence ratio (σ_r/σ_s), coercive force (H_c) etc are directly related with its hysteresis behaviour. Hysteresis study of ferrites provides invaluable data on all these magnetic parameters. Venkatesh Rao and Keer (1982) studied magnetization of $Co_xMg_{1-x}Fe_2O_4$ with x in the range 0 to 0·33. Studies on higher concentration of cobalt ($x > 0{\cdot}33$) are, however, lacking. In this paper, we report magnetic parameters and cation distribution of $Co_xMg_{1-x}Fe_2O_4$ ferrites system with x in the range 0 to 1.

2. Experimental

$Co_xMg_{1-x}Fe_2O_4$ ($0 \leqslant x \leqslant 1$) ferrite samples were prepared by a standard ceramic method using AR grade oxides as starting materials. Presintering was carried out at 800°C for 10 h and powdering of formed products was followed by final sintering at 1250°C for 40 h. Pellets of compositions $x = 0$, 0·2, 0·4, 0·6, 0·8 and 1·0 were prepared by pressing the powders in a hydraulic press, sintered at 1250°C for 40 h and cooled at 80°C/h. The completion of solid state reaction was confirmed by the X-ray diffraction measurements which were done at the Indian Institute of Technology, Bombay on computerized X-ray diffractometer (Philips PW 1820) using filtered FeK_α radiations ($\lambda = 1{\cdot}936$ Å). The magnetic parameters were measured from hysteresis loops taken at 300 and 80 K with the help of high field loop tracer at the Tata Institute of Fundamental Research, Bombay.

3. Results and discussion

The relevant magnetic properties along with the lattice parameters for six samples are listed in table 1. X-ray analysis indicated all compositions to be single-phase cubic spinels. There was no appreciable change in the lattice parameters of these ferrites

Table 1. Structural and magnetic parameters of $Co_xMg_{1-x}Fe_2O_4$ ferrites.

Composition	Lattice parameter (Å)	Saturation magnetization (emu/g) (300 K)	(80 K)	Magneton No. μ_B (300 K)	(80 K)	Remanence ratio (σ_r/σ_s)	Coercive force H_c(gauss)	Curie temperature (K)
$MgFe_2O_4$	8·377	27·9	31·1	1·00	1·11	0·32	50	710
$Co_{0\cdot2}Mg_{0\cdot8}Fe_2O_4$	8·376	28·3	31·3	1·04	1·15	0·38	200	723
$Co_{0\cdot4}Mg_{0\cdot6}Fe_2O_4$	8·373	36·8	40·2	1·41	1·54	0·44	600	742
$Co_{0\cdot6}Mg_{0\cdot4}Fe_2O_4$	8·370	52·4	57·2	2·07	2·26	0·50	750	755
$Co_{0\cdot8}Mg_{0\cdot2}Fe_2O_4$	8·368	69·9	75·9	2·85	3·10	0·52	800	768
$CoFe_2O_4$	8·366	85·5	90 6	3·59	3·81	0·53	850	793

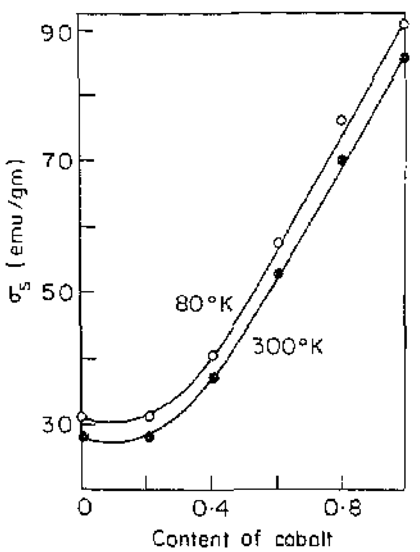

Figure 1. Variation of σ_s with content of cobalt.

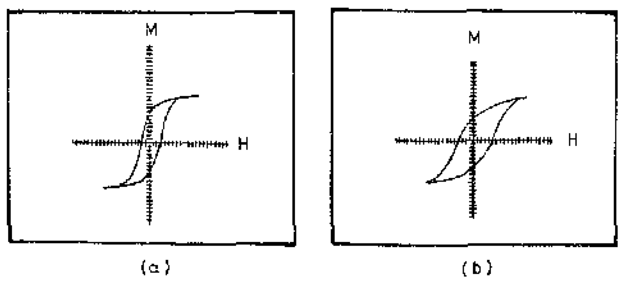

Figure 2. Representative hysteresis loop for sample **a.** $MgFe_2O_4$ and **b.** $Co_{0\cdot2}Mg_{0\cdot8}Fe_2O_4$ (oscilloscope patterns).

presumably due to the closeness of the ionic radii of Mg^{2+} (0·65 Å) and Co^{2+} (0·74 Å). Our lattice parameter values agree well with those of Venkatesh Rao and Keer (1982).

Compositional variation of saturation magnetization and representative hysteresis patterns were observed (figures 1 and 2). Also, as the cobalt content increased, the σ_s

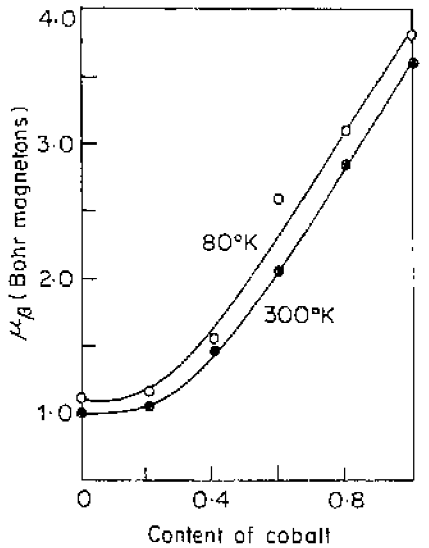

Figure 3. Variation of μ_B (Bohr magnetons) with content of cobalt.

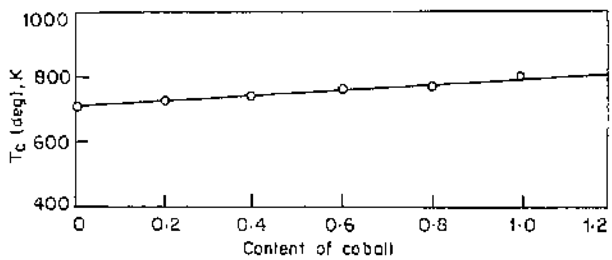

Figure 4. Variation of Curie temperature with content of cobalt.

values also increased almost linearly. The magneton number (μ_B) varied with increasing cobalt content (figure 3) in the same manner as σ_s. Figures 1 and 3 also show that the values of σ_s and μ_B at 80 K were greater than the values at 300 K.

The Curie temperature (T_c) varied with increasing cobalt content (figure 4). It was also observed that T_c increased linearly as the concentration of cobalt increased. A similar trend was exhibited by the variation of magnetization and Curie temperature (Sankpal *et al* 1988). Table 1 shows that the remanence ratio (σ_r/σ_s) and the coercive force (H_c) increased as the cobalt content was increased. Thus, in the Co–Mg ferrite system all the magnetic parameters increased as cobalt concentration increased. This increase in magnetic parameter was not contrary to expectation because the presence of Co^{2+} ions gives rise to large induced anisotropy due to relatively high (unquenched) orbital contribution to the magnetic moment.

The cation distribution in spinel ferrites was available from the studies on X-ray diffraction (Cervinka and Sisma 1970), Mössbauer effect (Bharati *et al* 1980), magnetization (Sawant and Patil 1983) and Curie temperature (Milligan *et al* 1963). Magnetization and Curie temperature methods gave a fair degree of accuracy to the cation distribution. We have used magnetization method to propose cation distribution in the present case and this is given in table 2.

Table 2. Cation distribution in $Co_xMg_{1-x}Fe_2O_4$ ferrites.

Composition	Cation distribution		Magneton number (μ_B) (Bohr magneton) from	
	A-site	B-site	Magnetization	Cation distribution
$MgFe_2O_4$	$Fe_{0.9}Mg_{0.1}$	$Fe_{1.1}Mg_{0.9}$	1·00	1·00
$Co_{0.2}Mg_{0.8}Fe_2O_4$	$Fe_{0.94}Mg_{0.04}Co_{0.02}$	$Fe_{1.06}Mg_{0.76}Co_{0.18}$	1·04	1·08
$Co_{0.4}Mg_{0.6}Fe_2O_4$	$Fe_{0.95}Mg_{0.01}Co_{0.04}$	$Fe_{1.05}Mg_{0.59}Co_{0.36}$	1·41	1·46
$Co_{0.8}Mg_{0.2}Fe_2O_4$	$Fe_{0.95}Mg_{0.04}Co_{0.01}$	$Fe_{1.05}Mg_{0.16}Co_{0.79}$	2·85	2·84
$Co_{0.6}Mg_{0.4}Fe_2O_4$	$Fe_{0.95}Mg_{0.02}Co_{0.03}$	$Fe_{1.05}Mg_{0.38}Co_{0.57}$	2·07	2·12
$CoFe_2O_4$	$Fe_{0.85}Co_{0.15}$	$Fe_{1.15}Co_{0.85}$	3·59	3·6

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