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THE ELECTROMAGNETIC PROPERTIES OF Mg-Mn FERRITES

D. Y. LEE, S. I. CHO, H. J. SHON, W. D. HUR
R & D Lab, Samwha Electronics Co., Ltd., Osan, Korea

Abstract-The magnetic properties of Mg-Mn ferrites were investigated in the composition range of $Mg_aMn_bFe_cO_{4\pm\delta}$ (a+b+c=3) with the addition of Al_2O_3. In MgO-MnO-Fe_2O_3 ternary system, the spinel single phase existed within the composition range of MgO-50 mol%, MnO-70 mol% and Fe_2O_3-60 mol%. The saturation magnetic flux density increased with the increase of Fe_2O_3 content and showed the maximum at the stoichiometric composition of (Mg, Mn)Fe_2O_4.

In $Mg_xMn_{1-x}Fe_2O_4$(x=0.2~0.8) system, the saturation magnetic flux density showed the maximum at $Mg_{0.2}Mn_{0.8}Fe_2O_4$. The addition of Al_2O_3 resulted in the decrease of saturation magnetic flux density but increased the electrical resistivity.

I .INTRODUCTION

The Mg-Mn ferrite has been studied for microwave materials and applied to the devices of isolator, circulator, phase shifter, filter, and absorber, etc.. For example, the phase shifter of phased array radar is a device which controls the phase of microwave, and the Mg-Mn ferrite is the main component of the phased array radar.

Microwave materials should have proper saturation magnetic flux density, narrow magnetic resonance linewidth, good temperature stability, excellent complex permittivity, and optimal spin wave linewidth to get high power capacity[1].

Many researchers have studied on the electrical resistivity with sintering condition[2], the sintering temperature and oxygen partial pressure[3], the atomic structure and magnetic property[4], the characteristic of magnetic hysteresis[5][6], the phase equilibrium and phase stability[7], and Al content dependence of magnetic properties for Mg-Mn ferrites[8][9].

The electromagnetic properties of Mg-Mn ferrites are controlled by the intrinsic factors of crystal structure and metal ion distribution, and the extrinsic factors such as grain, grain boundary, pore and second phase. The intrinsic factors of Mg-Mn ferrite can be arbitrarily controlled by MgO, MnO and Fe_2O_3 content.

The purpose of this study was to investigate the magnetic properties of MgO-MnO-Fe_2O_3 ternary system and Al_2O_3 effect to develop Mg-Mn ferrite material for phase shifter (X-band).

II .EXPERIMENTAL

The samples were prepared by usual ceramic method and the magnetic properties of Mg-Mn ferrites were investigated in the composition range of $Mg_aMn_bFe_cO_{4\pm\delta}$(a+b+c=3). The experimental procedures are as follows. The raw materials were mixed together in a stainless-steel ball mill for 2 hours. The mixtures were calcined at 900℃ for 2 hours in air and added with 0~8wt% of Al_2O_3, then milled again. A pressure of 1 ton/cm^2 was applied to form the milled powder as toroidal samples. The toroids were sintered at 1250 ℃ for 4 hours in air. Crystal structure was investigated by a X-ray diffractometer(XRD). The saturation magnetic flux density was measured by a vibrating sample magnetometer(VSM). B-H characteristics were measured by an AC B-H loop analyzer at 2 kHz and 5 Oe. The linewidth was measured by ferromagnetic resonance(FMR) for sphere type samples.

III.RESULTS AND DISCUSSION

Fig. 1 shows the spinel region of MgO-MnO-Fe_2O_3 system at the sintering temperature of 1250 ℃. The MgO and spinel phase coexisted in the composition range higher than MgO-50 mol%. The α-Fe_2O_3 and spinel phase coexisted in the composition range higher than Fe_2O_3-60 mol%. The magnesium and manganese oxide, and spinel phase coexisted in the composition range higher than MnO-70 mol%. The single phase spinel structure existed within the composition range of MgO-50 mol%, MnO-70 mol%, and Fe_2O_3-60 mol%. These correspond with the results of J. Smit[10] on MgO-MnO-Fe_2O_3 system.

Fig. 2 shows the composition dependence of saturation magnetic flux density in MgO-MnO-Fe_2O_3 system. The saturation magnetic flux density depended on the composition and showed maximum at the stoichiometric composition of (Mg,Mn)Fe_2O_4. The closer the composition is $MnFe_2O_4$, the higher the saturation magnetic flux density. The saturation magnetization flux density decreased with the increase of MgO content. This is believed due to the decrease of magnetic moment by the substitution of Mg ion for Mn ion.

Fig. 3 shows the variation of Curie temperature. The Curie temperature largely depended on the Fe_2O_3 content and varied a little with MgO and MnO content. The increase of Curie temperature with the increase of Fe_2O_3 is considered due to the strong superexchange between A and B site of Fe ion.

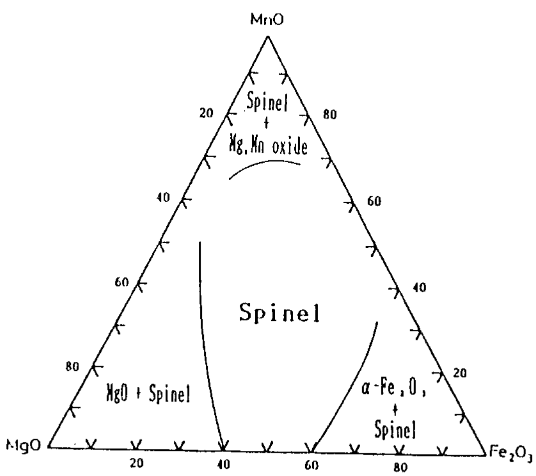

Fig. 1 Spinel structure region of MgO-MnO-Fe_2O_3 ternary system(mol%).

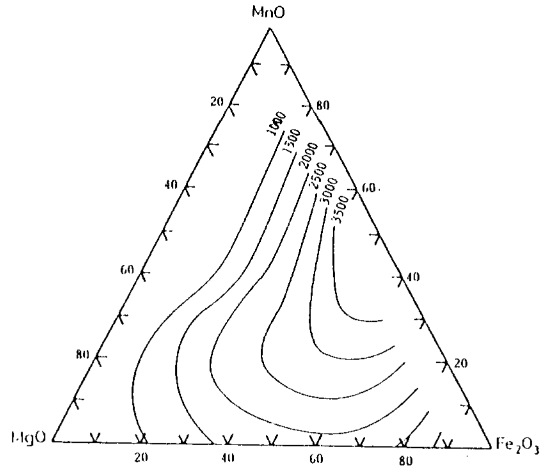

Fig. 2 Composition dependence of saturation magnetic flux density(gauss) for MgO-MnO-Fe_2O_3 ternary system (mol%).

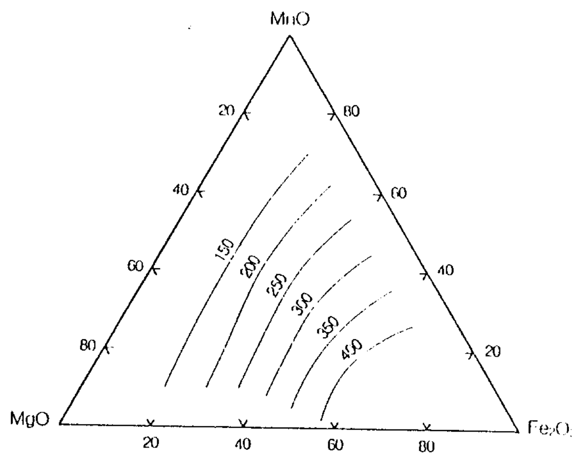

Fig. 3 Composition dependence of Curie temperature(℃) for MgO-MnO-Fe_2O_3 ternary system(mol%).

Fig. 4 shows the change of lattice parameter with the variation of MgO and Al_2O_3 content in $Mg_xMn_{1-x}Fe_2O_4$(x=0.2~0.8) system. The increase of MgO content x or Al_2O_3 resulted in the decrease of lattice parameter from 8.41 to 8.33Å. These are due to the substitution of Mn^{2+} or Fe^{3+} by smaller ionic radius of Mg^{2+} or Al^{3+}, respectively. Paladino[7] reported the lattice parameter of spinel structure depended on cation distribution. Baker[4] reported the increase of lattice parameter in Mg-Mn ferrite was due to the substitution of Mg^{2+} by Mn^{2+}. Sparvieri[8] and Marthy[11] et al. reported the similar results with our results for the change of lattice parameter with the addition of Al^{3+} and Mg^{2+}.

Fig. 5 shows the variation of saturation magnetic flux density with the addition of MgO and Al_2O_3. The saturation magnetic flux density showed maximum values of 3860 G at the composition of $Mg_{0.2}Mn_{0.8}Fe_2O_4$. The decrease of saturation magnetic flux density according to the increase MgO and Al_2O_3 content was believed due to the decrease of magnetic moment by the substitution of Mg^{2+} or Al^{3+} for Mn^{2+} or Fe^{3+}, respectively.

Fig. 6 shows the change of electrical resistivity with MgO and Al_2O_3 content. The electrical resistivity was increased by adding MgO and Al_2O_3.

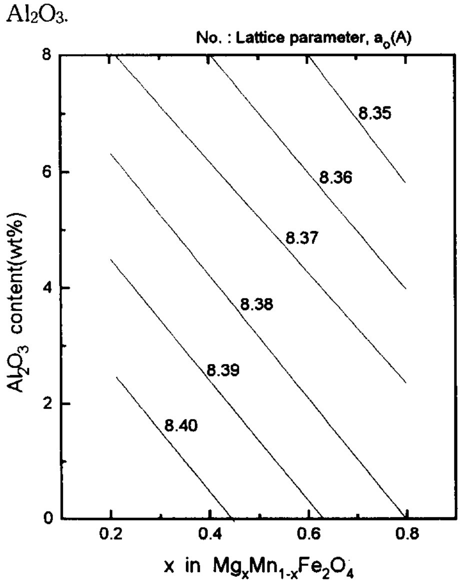

Fig. 4 Effect of MgO and Al_2O_3 content on the lattice parameter(Å) of Mg-Mn ferrite.

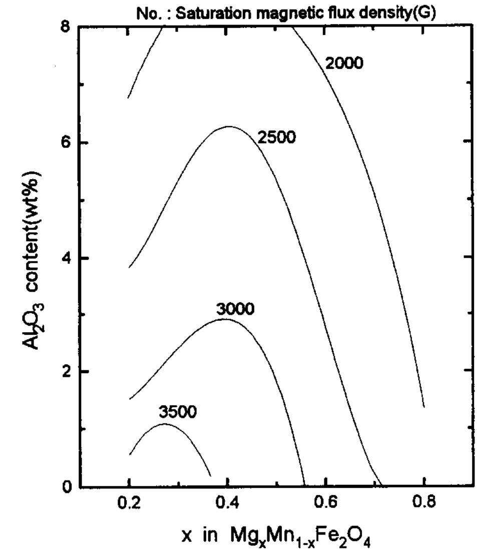

Fig. 5 Effect of MgO and Al_2O_3 content on the saturation magnetic flux density(gauss) of Mg-Mn ferrites.

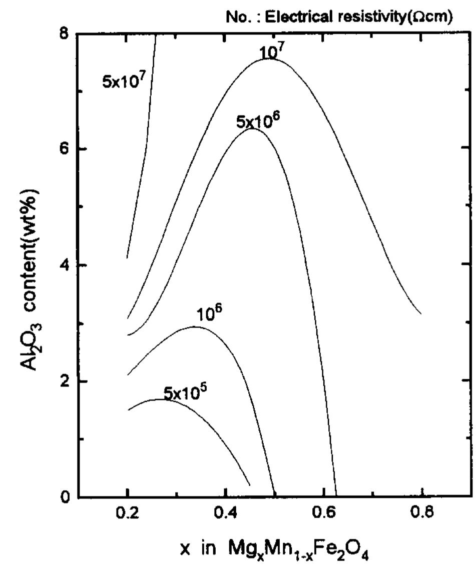

Fig. 6 Effect of MgO and Al_2O_3 content on the electrical resistivity(Ωcm) of Mg-Mn ferrites.

Table 1 shows the magnetic and microwave properties of $Mg_{1.034}Mn_{0.103}Fe_{1.862}O_{4\pm\delta}$ added with Al_2O_3-2wt% which was developed in the experiments for X-band application. As shown in the table, the material has low loss characteristic.

Table 1. Magnetic and microwave properties of $Mg_{1.034}Mn_{0.103}Fe_{1.862}O_{4\pm\delta}$ added with Al_2O_3-2wt%.

Characteristics	Symbol	Unit	Measurement condition	sample
Saturation magnetic flux density	$4\pi M_s$	G	10 kOe	2,100±5%
Curie temperature	T_c	℃	1 kOe	> 290
Maximum magnetic flux density	B_m	G	2 kHz, 5 Oe	1,500±5%
Residual magnetic flux density	B_r	G	2 kHz, 5 Oe	1,430±5%
Coercive force	H_c	G	2 kHz, 5 Oe	1.6±5%
Initial permeability	μ_{iac}	-	1 kHz, < 0.8 A/m	50
Linewidth	ΔH	Oe	10 GHz	290
Dielectric constant	ε	-	10 GHz	13
Loss tangent	$\tan\delta_\varepsilon$	-	10 GHz	0.00021

Ⅳ.CONCLUSIONS

In MgO-MnO-Fe_2O_3 ternary system, the spinel single phase existed within the composition range of MgO-50 mol%, MnO-70 mol% and Fe_2O_3-60 mol%. The saturation magnetic flux density increased with the increase of Fe_2O_3 content and showed the maximum at stoichiometric composition of $(Mg, Mn)Fe_2O_4$.

In $Mg_xMn_{1-x}Fe_2O_4(x=0.2\sim0.8)$ system, the saturation magnetic flux density showed the maximum at $Mg_{0.2}Mn_{0.8}Fe_2O_4$. The addition of Al_2O_3 resulted in the decrease of saturation magnetic flux density but increased the electrical resistivity. Through the experiments, a low loss material for X-band application was developed.

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