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Effect of Additives on the Magnetic Properties in Mg-Cu-Zn Ferrite

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Abstract. The adding effect of NiO, Cr_2O_3 on magnetic properties in Mg-Cu-Zn ferrite was investigated. The samples were prepared with conventional ceramic process at the sintering temperature of 1080°C. The two dopants were added in small quantities in steps of 0.3, 0.6, 0.9, 1.2 wt%, respectively. Microstructure and magnetic properties depending on temperature were investigated. The introduction of additives NiO, Cr_2O_3 in Mg-Cu-Zn ferrite can successfully promote the temperature properties in lowering the relative temperature coefficient.

Key Words : Mg-Cu-Zn ferrite, initial permeability, relative temperature coefficient, curie temperature, saturation magnetization, magnetocrystalline anisotropy.

1. Introduction

Among the soft ferrites which were denoted $\text{MO} \cdot \text{Fe}_2\text{O}_3$ ($\text{M}=\text{Ni}, \text{Zn}, \text{Cu}, \text{Mg}, \text{Mn}$), Ni-Cu-Zn ferrite was widely used in electromagnetic parts material such as rotary transformer core, intermediate frequency transformer core, EMI core, deflection yoke core and so on.

However, among the raw materials in this composition, NiO is very expensive, therefore MgO is substituted for NiO for the purpose of cost reduction in industrial field. Comparing with Ni-Cu-Zn ferrite, Mg-Cu-Zn ferrite have similar magnetic properties in some range but the initial permeability is very unstable according to temperature.

The temperature dependence of initial permeability has been studied in Mn-Zn[1,2], or Ni-Zn ferrite[3,4] but it is never to be found on Mg-Cu-Zn ferrite. The motivation to investigate the Mg-Cu-Zn ferrite is lying on their low cost and their applications. The aim of this work is to develop the advantages of Mg-Cu-Zn ferrite and to improve temperature stability.

2. Experiment

The basic ferrite has a molecular composition $(\text{MgO})_{20.0}(\text{CuO})_{7.0}(\text{ZnO})_{24.0}(\text{Fe}_2\text{O}_3)_{49.0}$ to which 0.5wt% Li_2CO_3 and 0.03wt% Bi_2O_3 was added. The raw materials were mixed with attritor and dried in oven. After calcination at 900°C for 2hrs, the two dopants (NiO, Cr_2O_3) were added in milling process with attritor in small quantities in steps of 0.0, 0.3, 0.6, 0.9, 1.2wt%, respectively. The samples were spray dried along with binders and lubricants. The powders were each pressed into toroidals of approximate dimensions, $\Phi 30$ mm out diameter and $\Phi 18$ mm inner diameter at a pressing pressure of 1.0 ton/cm². Sintering of these toroidals was done in an air atmosphere box furnace at the soaking temperature of 1080°C for 1hr.

The initial permeability and $\tan \delta / \mu_1$ were measured at 1MHz with impedance analyzer (HP4194A) and temperature dependence of initial permeability was measured at 100kHz with HP4274A from room temperature to 150°C.

3. Results and Discussion

In fabrication of ferrite, many kinds of additives were used for the purpose of improving sinterability, permeability, temperature stability, frequency stability, low loss and so on.[5] In this experiment, we selected Bi_2O_3 which was wellknown as an accelerator of grain growth, and Li_2CO_3 was used for improving frequency stability of initial permeability. And the adding effect of NiO, Cr_2O_3 was studied for the purpose of improving temperature stability of initial permeability.

Table.1 shows variations of properties with NiO concentration. With increasing NiO concentration, initial permeability, relative loss factor, saturation magnetization and relative temperature coefficient were decreased

and T_c was increased. In general, initial permeability is explained with Globus's model $\mu_i \approx M_s^2 D_m / K_i$ where μ_i is initial permeability, M_s is the saturation magnetization, D_m is the average grain diameter and K_i is the magnetocrystalline anisotropy.[6]

Table.1. Properties of the NiO added Mg-Cu-Zn ferrite.

NiO(wt%)	μ_i	$\tan\delta/\mu_i$ ($\times 10^{-5}$)	$T_c(^{\circ}\text{C})$	$M_s(\text{mT}, 27^{\circ}\text{C})$	$\alpha_{\mu r}(\times 10^{-6}/^{\circ}\text{C}, 27\sim 100^{\circ}\text{C})$
0.0	567	9.47	129	270.0	15.48
0.3	541	8.30	133	267.5	13.67
0.6	518	8.23	134	265.4	13.36
0.9	510	8.21	136	261.2	11.30
1.2	478	7.82	146	260.8	10.26

Initial permeability was decreased with increase of concentration of Ni^{2+} ions which can be explained on the basis of Globus's model. Fig.1. shows microstructure variation according to the amount of NiO added.

Fig.1. Microstructure of samples. (a) NiO 0.0wt%, (b) NiO 0.6wt%, (c) NiO 12wt% — 20 μm

With increasing NiO concentration, average grain size was decreased. However, abnormal grain growth occurred in case of 1.2wt% addition. The temperature dependence of initial permeability according to the Ni^{2+} concentration was illustrated in Fig.2. As seen, the curve shapes vary gradually with increasing NiO and the slope of the curve reduced with increasing NiO. With increasing NiO content, the relative temperature coefficient was decreased.

Fig.2. Temperature dependence of initial permeability. The sample denoted by $\bullet, \circ, \blacksquare, \square, \diamond$ is NiO content of 0.0, 0.3, 0.6, 0.9, 1.2, respectively.

Temperature dependence of initial permeability is strongly affected by the variation of M_s and magnetocrystalline anisotropy(K_i) as a function of temperature. Generally, M_s is decreased with increasing temperature because of the disordering of magnetic spin due to the effect of heat. But magnetocrystalline anisotropy is increased with temperature increasing, more rapidly than the decreasing of M_s . We assumed that Ni^{2+} , Cr^{6+} ions entered crystal sites of Mg-Cu-Zn ferrite and varied magnetocrystalline anisotropy.

4. Conclusion

The introduction of the additives NiO, Cr_2O_3 in Mg-Cu-Zn ferrite can successfully promote the temperature properties in lowering the relative temperature coefficient.

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