Magnetic Properties of Nanocrystalline Cobalt Substituted Nickel Zinc Ferrite

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Abstract

Nanocrystalline cobalt substituted nickel zinc ferrite have been synthesized by coprecipitation technique using oxalate precursors. The variation of coercive force Hc with the cobalt content is minimum at x=0.01 and it is increases for x≥0.03. The wall energy (Ew) and magnetic crystalline anisotropy K_1 increases with increases of cobalt as a result the coercive force Hc exhibit similar trend. In thermal variation of initial permeability, it is observed that μ_i and its real part μ' increases slightly with increase in temperature up to Tc and then falls sharply to zero. The frequency variation of μ' and μ'' clearly indicate the low frequency dispersion which may be attributed to domain wall movement. The frequency variation of loss factor remains almost constant in frequency range 10kHz to 100kHz. The temperature variation of loss factor was found to be constant in the temperature range 25°C to near Tc while for temperature beyond Tc, the loss factor increases exponentially.

Keywords: coprecipitation, permeability, ferrite.

INTRODUCTION

Nickel-zinc ferrite is a technologically important material system utilized in a wide variety of power electronics and radio frequency (RF) applications due to its combination of relatively high permeability and resitivity. These properties allow their use as a low loss inductor and transformer cores as well as electromagnetic interference (EMI) suppression devices at higher frequencies [1]. Ni-Co-Zn ferrites are widely used in wave absorbers to suppress the electromagnetic interference among the devices up to microwave frequencies [2], high frequency switching magnets and magnetic pulse compressors [3,4], antenna rods for radios [5], transformers, reactor cores etc. Ni-Co-Zn ferrite exhibits enhanced magnetic properties and hence they are useful as ferromagnetic core materials. We have the synthesized ferrites by oxalate precursor method, since it yield a homogenous product in short time.

1. EXPERIMENTAL

The aim of present work is to study the magnetic properties of $Zn_{0.35}Ni_{0.60-x}Co_xFe_{2.05}O_4$, (x=0.00 to 0.06) ferrite prepared by coprecipitation technique using oxalate precursors. The oxalates were prepared by a method suggested by Wickham [6]. A calculated amount of AR grade iron metal powder was heated with glacial acetic acid in CO_2 atmosphere until the state of quantitative dissolution is reached. The calculated amounts of Nickel acetate, zinc acetate, cobalt acetate and the above synthesized iron acetate (total metal ion concentration = 0.45 M) were slowly added to ammonium oxalate solution(0.60 M). The co- precipitated oxalates were decomposed in the air at 650^0C for 1 hour and finally sintered at 1000^0C. The magnetic measurements were carried out using a high field loop tracer used to display hystresis loop.

2.RESULTS AND DISCUSSION

The calculated values for average crystalline size of sintered powder determined by X-ray diffraction using the Debye Scherrer formula is 25-27 nm. The saturation magnetization were carried out using EG and G Princeton applied research model - 4500 vibrating sample magnetometer is 382-415 emu at room temperature were given in our previous report [7]. The data on coercive force (Hc), wall energy (Ew), Y-K angle (α_{Yk}), curie temperature (Tc) are summarized in table 1. The values of coercive force are high for x≥0.03. The Hc is found to be minimum at x=0.01, where two anisotropies compensate. Similar results are in good agreement with the obtained result by Nobuhiro Matsushita etal[8].

Table 1

x	Hc Oe	$-K_1 \times 10^4$ erg / cc	Wall energy(Ew)	α_{Yk} at R.T	Tc ^OC
0.00	51	-3.78	11.91	$40^0$37' 57"	356
0.01	35	-0.717	5.14	$40^0$29' 20"	345
0.02	40	2.3465	9.22	39^0 4' 19"	342
0.03	53	5.409	13.99	$40^0$50' 14"	335
0.04	104	8.472	17.36	$40^0$35' 42"	325
0.05	119	11.535	20.08	$44^0$47' 27"	312
0.06	134	14.598	22.44	$42^0$27' 26"	305

From table 1, it is seen that wall energy (Ew) and Magnetocrystalline anisotropy (K_1) increases with increase of cobalt as a result the coercive force (Hc) exhibit a similar trend. This apparent variation agrees with that reported by earlier worker S.R. Sawant etal[9]. In our system Zn ion is maintained constant hence it is expected that α_{yk} will not very much. As the magnetic moment of cobalt 3.7μB which is larger than the magnetic moment of nickel (2.3μB), α_{yk} is expected to decrease with addition of cobalt ion. But as cobalt is added in small quantity so α_{yk} remains almost constant.

Figure1-3 shows the initial permeability (μ_i), its real part (μ'), and imaginary part (μ'') vary with temperature in the range from room temperature to the Curie temperature (Tc). Near Tc, both μ_i and μ' drops to zero sharply. A sharp decrease in μ_i and μ' suggests single-phase formation of the ferrite material. This observation supports the conclusion drawn from the XRD analysis that all the compositions are single phase.

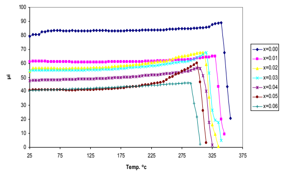

Figure 1

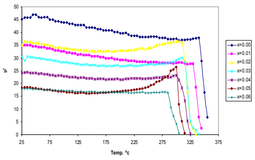

Figure 2

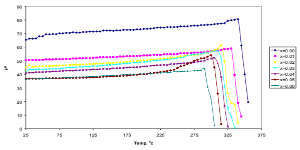

Figure 3

The Curie temperature data represented in table 1, it is observed that Curie temperature (Tc) decreases with increase in Co^{2+} concentration because Tc of $CoFe_2O_4$ (520^0C) is less than that of $NiFe_2O_4$ (585^0C) . Figure 4-5 shows variation of μ' and μ'' with frequency in the range 20 Hz to 1 MHz. The frequency variation of μ' and μ'' clearly indicate the low frequency dispersion which may be attributed to the domain wall movement. Figure 6, shows dispersions of loss factor (L. F.). The value of loss factor almost constant in the frequency range 10 KHz to 100 KHz, while the increase of frequency from 20Hz to 200Hz, the L. F. decreases. Figure 7, shows thermal variation of loss factor. In the temperature range 25^0C to near Tc, it is found that L.F. is almost constant. While above Tc, the loss factor increases exponentially. The thermal variation of tanδ seems to be responsible for increase in loss factor. In order to have low loss factor the ferrite must be operated below Curie temperature

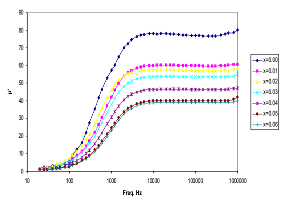

Figure 4

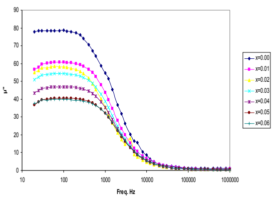

Figure 5

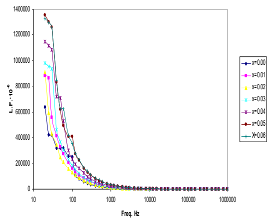

Figure 6

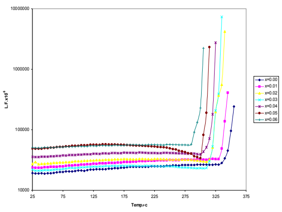

Figure 7

CONCLUSIONS

Nanocrystalline cobalt substituted nickel zinc ferrite have been synthesized by employing coprecipitation technique, using oxalate precursors.The variation of coercive force Hc with the cobalt content is minimum at x=0.01 and it is increases for x≥0.03. The wall energy (Ew) and magnetic crystalline anisotropy K_1 increases with increases of cobalt as a result the coercive force Hc exhibit similar trend. The Co^{2+} and Ni^{2+} being non Y-K type substituent is expected that Y-K type angle should remain almost invariant. From thermal variation of initial permeability, it is observed that μ_i and its real part (μ') increases slightly with increase in temperature up to Tc and then falls sharply to zero. Sharp decreases in initial permeability (μ_i), its real part (μ') suggest single phase formation of ferrite material. The frequency variation of μ' and μ″clearly indicate the low frequency dispersion which may be attributed to domain wall movement. The frequency variation of loss factor remains almost constant in frequency range 10 kHz to 100 kHz. The temperature variation of loss factor was found to be constant in the temperature range 25°C to near Tc. While for temperature beyond Tc, the loss factor increases exponentially.

REFERENCES

[1] A Daigle, JModest, A L Geiler, S Gillette,Y Chen, MGeiler,B Hu, S Kim, K Stopher, C Vittoria and V G Harris. Nanotechnology 22 (2011) 305708 (6pp)

[2] D.H. Kang, J.Y. Shin and J.H. Oh, Ferrites: Proceeding of ICF6, Tokyo and Kyoto.Japan 1992.

[3] R.S.Shinde,H.K. Bhasin & M.G.Karmarkar, J.Phys IV,France 7 (1997).

[4] R.S.Shinde, P. Pareek and R.R. Yadav. Proceeding of APAC 2004, Gyeongju, Korea.

[5] F.N. Bradly, Hyden New York 1971.

[6] D.G.Wickham, Inorganic Synthesis Vol.IX, Mc.GrawHill, NY, (1967) 152.

[7] J S. Ghodake, R.C. Kambale, S.D. Kulkarni, S.R. Sawant and S.S. Suryavanshi, Smart Mater. Struct. 18 (2009)

[8] Nobuhiro Matsushita, Tatsuro Nakamura & Masanori Abe Journal of Applied Physics volume 93, No 10 2003.

[9] S. R. Sawant, D.N.Bhosale, N.D.Chaudhari, P.P.Bakare, J. of mater. In electronics, 13 (2002) 277-283