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Preparation and Investigation of $(Ni_{0.18}Cu_{0.2}Zn_{0.2})\ Fe_2O_4$ Ferrites composites by Ball Milling

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ABSTRACT

Recently Magneto-electric nanomaterials are widely used for nanoelectronics, industrial effluent treatment and photoluminescence. In this field most of the research work can be enhancing in nanoelectronics. The preparation of high purity semiconductor metals (Fe_2O_4, Zno, Nio, Cuo) were prepared by using planetary ball milling process. It can be mainly focused the experimental studies by varying the effect of milling time, temperature and chemical composition were carried out and optimized the particle size and its distribution of the material. Through the wet milling size analysizer the semiconductor metal oxide nanomaterial was found to be optimized at a higher temperature of 1250°C(91.28nm).The strength and magnetic property of a material were stimulate through the effect of milling time, variation of impedence and inductance with frequency variation, permeability, loss factor, M-H graph, coercivity. Finally the planetary ball milling process were resulted in low coercivity was increased and the maximum flux density, low loss tangent and high initial permeability and it can withstand breakdown voltage up to 2MHZ frequency.

KEY WORDS: Ni-Cu-Zn ferrite, Soft Ferrites, Nano-milling, High frequency.

1. INTRODUCTION

Researches from a wide range of disciplines including magnetic fluids, biotechnology, biomedicine, magnetic resonance imaging, data storage and environmental remediation. Nano sized ferrite materials have received paramount attention due to their potential applications in ultra-high density recording, magnetic resonance imaging data processing devices, microwave and radiofrequency devices, bio separation, quantitative immunoassary, drug and gene delivery etc.

Planetary ball mills are used wherever the highest purity of fine particle size is required. It can be well-proven by mixing and size reduction processes, these mills also meet the size reduction grinding and to provide the energy input necessary for mechanical alloying. The centrifugal forces of a planetary ball mill result in very high pulverization energy and therefore short grinding time. Through this process the particle size was reduced along with the generation of new phases, surface properties and magneto electrical process. While compared to dry milling process to wet milling process have the variation of temperature with required nanoscale regimes and very efficient product yield.

2. MATERIALS AND METHODS

2.1. Materials: Starting materials for the synthesis of Ni, Cu, Zn ferrites were Ferric Oxide, Nickel Oxide, Zinc Oxide and Copper oxide powders. The chemicals and reagents were purchased from Merck and used for further experimental studies.

2.2. Preparation: The analytical grade used in preparation of $(Ni_{0.18}Cu_{0.2}Zn_{0.2})\ Fe_2O_4$ is Fe_2O_3, NiO, CuO and ZnO. The precursor materials were weighed according to the required chemical composition and intimately mixed and the resulting powders were ball milled using a planetary ball mill for 30hrs. After drying, the mixtures were pre-sintered at different temperatures (ie) 700,800,900 and 1000◦C for 2 hours air. The particle size of milled powders was determined. Then the calcined powders were again wet milled for 30 hours and dried. The particle size and particle size distribution of the powders were determined. The milled powders were dried and sieved to obtain a uniform particle size. The green powder thus obtained was pressed using a suitable die in the form of torroids of dimensions 1.2cm OD 0.8cm ID and 0.4cm thickness and pellets of dimensions 1.2cm diameter and 0.3cm thickness with a hydraulic press using 2% PVA solution as a binder and the samples were finally sintered at 1250°C for 2hrs in air and cooled to room temperature inside the electric furnace.

2.3. Characterization: The particle size of a sample was determined by using the particle size analyzer. The initial permeability, (μ_i) of these ferrite torroids were evaluated using the standard formulae from the inductance measurements carried out at 10 kHz using a computer controlled impedance analyzer (AGILLENT-E-4890A and core type TORROID 6.5*4*5). The magnetic characteristics were measured with U19720 Magnetic material Dynamic Analyzer. These measurements were carried out in the temperature range around 31°C. The impedance (Z) and the loss factor (tanδ) values was measured using the impedance analyzer in the frequency ranges 1 KHz-2000 KHz.

3. RESULTS AND DISCUSSION

3.1. Effect of milling time on particle size: Figure 1 can be seen that, as the milling time increases,there was a reduction in particle size. After 30hours of milling, the particle size increased and it might be due to the agglomeration of the particles.The particle size and particle size distribution for the powders wet milled at different milling time.

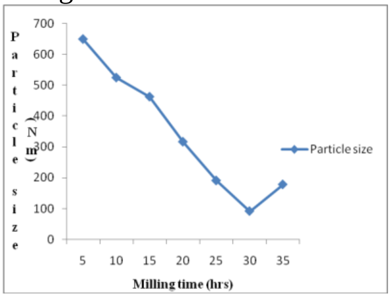

Figure.1.Effect of milling time on particle size

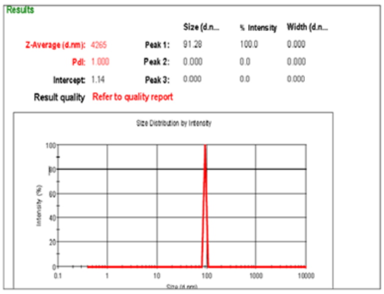

Figure 2.Wet milling particle size range for 30 hrs (Size 91.28nm)

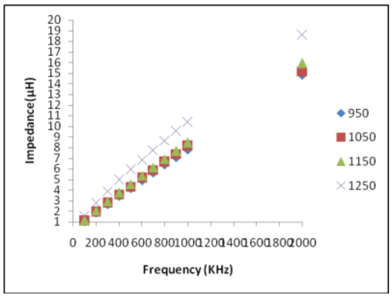

Figure 3.Frequency variation of Impendence of $(Ni_{0.18}Cu_{0.2}Zn_{0.2})$ Fe_2O_4Samples

Figure 2 can clearly be seen,that the particle size for 30 hours milled sample was around 91.28nm and a narrow distribution was obtained as a result of fine granulation.

3.2. Variation of impedance with frequency: Figure 3 Shows the impedance values of the samples obtained as the frequency was varied from 1 kHz to 2000 kHz at different temperatures. It is clearly seen that impedance value increases as the frequency was varied from 1 kHz to 2000 kHz. It is also seen that the impedance value is maximum at 1250˚C. From this result it can be seen that these compositions can be used for high frequency applications.

3.3. Variation of inductance with frequency: Figure 4 Shows the variation of inductance as the frequency was varied from 1 kHz to 2000 kHz at different temperatures. From the values obtained, it is clearly seen that inductance value decreases as the frequency was varied from 1 kHz to 2000 kHz. It was also seen that the impedance value decreases with increasing temperature.

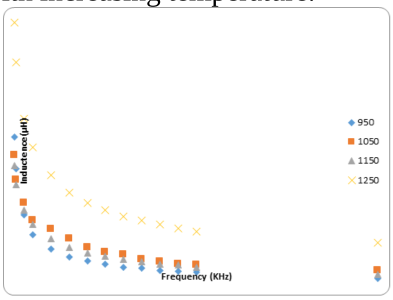

Figure 4.Frequency variation of Inductance of $(Ni_{0.18}Cu_{0.2}Zn_{0.2})$ Fe_2O_4Samples

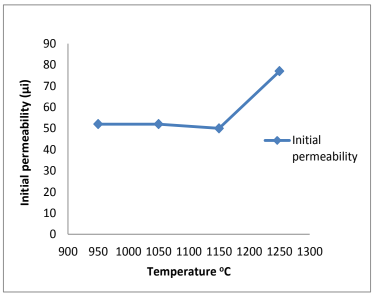

Figure.5.Temperature variation of Initial Permeability of $(Ni_{0.18}Cu_{0.2}Zn_{0.2})$ Fe_2O_4 Samples

3.4. Variation of Permeability: Figure 5 increase in permeability (μ_i) is observed for all the samples and the highest value was obtained at 1250˚C. The permeability can be expressed as $\mu=1+\chi_{spin}+\chi_{dw}$, where χ_{spin}-susceptibility due to spin, χ_{dw}–susceptibility due to domain wall motion. Hence in this present study due to the substitution of Cu for Ni multi domain particles are obtained which results in higher permeability values due to the contribution of the domain wall. The important factor which gives rise to increase the permeability and density of the sample at 1250˚C.Finally the result has been shown, while reducing the demagnetizing field due to pores which in turn increases the permeability.

3.5. Variation of loss factor with temperature: Figure 6 shows the variation of loss factor with temperature, the values of loss factor reveals that if reached a minimum level of $8.9*10^{-6}$ at 1250˚C. A substantial decrease in loss factor can be contributed to the increase in resistivity. The eddy current loss was reduced due to increase in resistivity is due to the main loss mechanism at MHz frequency region.

3.6. M-H Measurements: In figure 7 magnetic hysteresis loop were performed to study about the magnetic property of the sample. The data presented in Table 1 and figure.8 show a decrease in H_c with increasing sintering temperature. From the temperature 950˚C -1250˚C reduces the value of Hc by about 20%.The M-H graph can be attributed mainly to an increase in the sample grain size. The effect of grain size and the sintering temperature were simultaneously increased. When Zn promotes in to sintering process and to increase the required nanoscale regimes. As the number of walls increase with grain size and the contribution of wall movement to magnetization or demagnetization is greater than that of domain rotation. Therefore samples with larger grains are expected and have lower coercivity H_c.

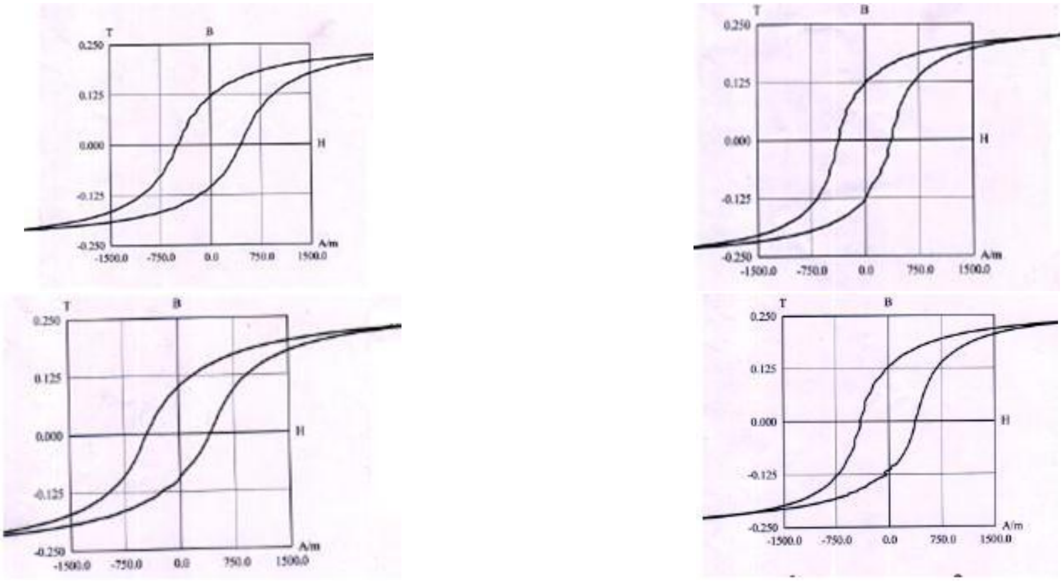

Figure.6.Room temperature M-H graph of Ni-Cu-Zn ferrite samples

3.7. Variation of Coercivity: Figure 8 shows the variation of coercivity Hc with temperatures of 950˚C, 1050˚C, 1150˚C, and 1250˚C.The values of Br and Bmax listed in Table1 correspond to the case in which the maximum applied field was 3000A/m.

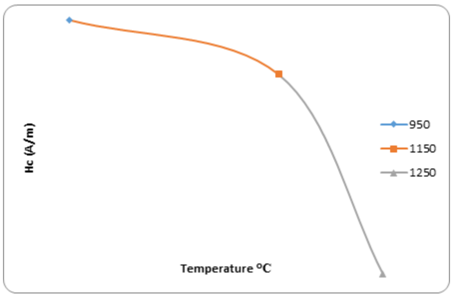

Figure.7.Variation of coercivity H_c with temperature

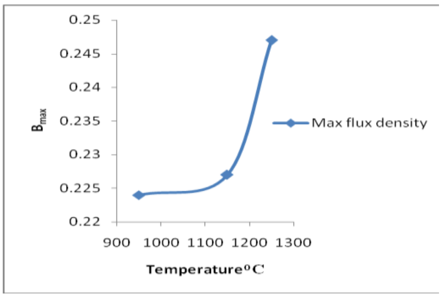

Figure.8.Variation of maximum flux density with temperature

Figure 8 reveals that the increase of sintering causes a considerable increase in maximum flux density B_{max}.

Table.1.Magnetic properties of Ni-Cu-Zn Fe_2O_4 samples at different temperatures

Magnetic Properties	Testing at Room Temperature			
	950°C	1050°C	1150°C	1250°C
H_c(A/m)	379.8	300.6	367.2	320.9
B_r(T)	0.113	0.119	0.099	0.125
B_{max}	0.224	0.232	0.227	0.247
P_c(w/cm^3)	6.67	5.32	6.03	5.78
B_r/B_{max}	0.51	0.51	0.44	0.51

Ni-Cu-Zn ferrite samples test results of various temperature sintered samples are shown in Table 2. The samples at 1250°C have lower loss tangent and high initial permeability. It can also be seen that these samples can withstand a breakdown voltage up to 2MHz.

Table.2.Properties of Ni-Cu-Zn ferrite at various calcined temperature

Parametric Variables	Testing at Room Temperature			
	950°C	1050°C	1150°C	1250°C
Breakdown voltage	2KV (2000V)	3KV(3000V)	4KV(4000V)	3KV(3000V)
Green density(g/cc)	3.5	3.5	3.5	3.5
Sintered density(g/cc)	4.96	5.03	5.12	5.24
Relative loss factor	$19.9*10^{-6}$	$19.2*10^{-6}$	$21.3*10^{-6}$	$8.9*10^{-6}$
Initial permeability	52	52	50	77

4. CONCLUSION

In this present study ($Ni_{0.18}Cu_{0.2}Zn_{0.2}$) Fe_2O_4 was prepared and its magnetic properties were analyzed. The particle sizes of the milled powders were found to be 91.28nm. A remarkable increase in the value of bulk density was found with Cu substitution for Ni. The samples resulted in low coercivity increased maximum flux density, low loss tangent and high initial permeability. It can be seen that these samples can withstand a breakdown voltage up to 2MHz frequency.

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