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Study of Electrical and Magnetic Properties of Zn-Co-Ferrite Nanocomposites

R Santhosh Kumar* Rashmi and Lalithamba H.S

Assistant Professor, Dept. of EEE, DBIT, Bengaluru. E-mail: rsanthosh25@gmail.com
Professor and Head, Dept. of EEE, Siddaganga Institute of Technology, Tumkuru. E-mail: rash_mysore@sit.ac.in
Associate Professor & Head, Dept. of Chemistry, Siddaganga Institute of Technology, Tumkuru. E-mail: hsl@sit.ac.in

Abstract

The ferromagnetic material exhibits better magnetic properties as compared to other magnetic materials. Cobalt and ferrites have superior soft magnetic properties such as high permeability and magnetic susceptibility. A nanocomposite is prepared using Zinc, Cobalt and Ferrite by combustion synthesis method and the composition is $Fe_{0.5}Co_{0.25}Zn_{0.25}$*. The morphological properties are studied using FESEM images and XRD. The electrical and magnetic properties are studied from 10 Hz to 8 MHz frequency range using LCR meter at ambient temperature. The results show that with increase in frequency, the resistivity as well as permeability decreases. The values of electrical resistivity and dielectric constant suggest the suitability of the nanocomposites in power electronics devices.*

Key words: *Soft magnetic materials, combustion synthesis method, permeability, resistivity and dielectric constant.*

1.0 Introduction

Ferrites are homogeneous ceramic compounds with various oxides containing iron oxide as the basic component. The research on ferrites is increasing rapidly in past few decades due to its surge in all electronic devices [1]. The ferrite is one of the materials which provides exceptional electrical, magnetic as well as insulation properties [2]. The possibility of enhancing and obtaining unique properties from ferrites by synthesizing it as nanocomposite material, with other compounds like Zn, Mg, Co, Ni etc., has opened a new and exciting research area. The ferrite crystalline structure, phase purity, electrical and magnetic properties are mainly dependent on the synthesis temperature [3]. Ferrites can be divided into two families based on the coercivity; they are:

i. Hard ferrites: have high value of coercivity and very difficult to demagnetize. These are used for preparing permanent magnets which are integral parts in applications like loud speakers, Motors, Data Processing, Energy Meter Disc and bio-surgical devices such as MRI scanner, Wound Closures.
ii. Soft ferrites: have low coercivity and can be demagnetized very easily. These are majorly used for magnetic cores in inductors and electrical machines, antennas, microwave devices etc.

Soft magnetic materials for inductor core applications is the main area of study. Presently $NiFe_2O_4$, Mn-Zn and Ni-Zn ferrites are most commonly used as core material for power converters up to 1MHz frequency [4]. It is well known that, as the frequency increases above MHz range, these ferrites are not suitable due to its poor saturation magnetization and higher eddy current and hysteresis losses. These drawbacks of traditional magnetic materials can be addressed by Cobalt or

*Corresponding Author

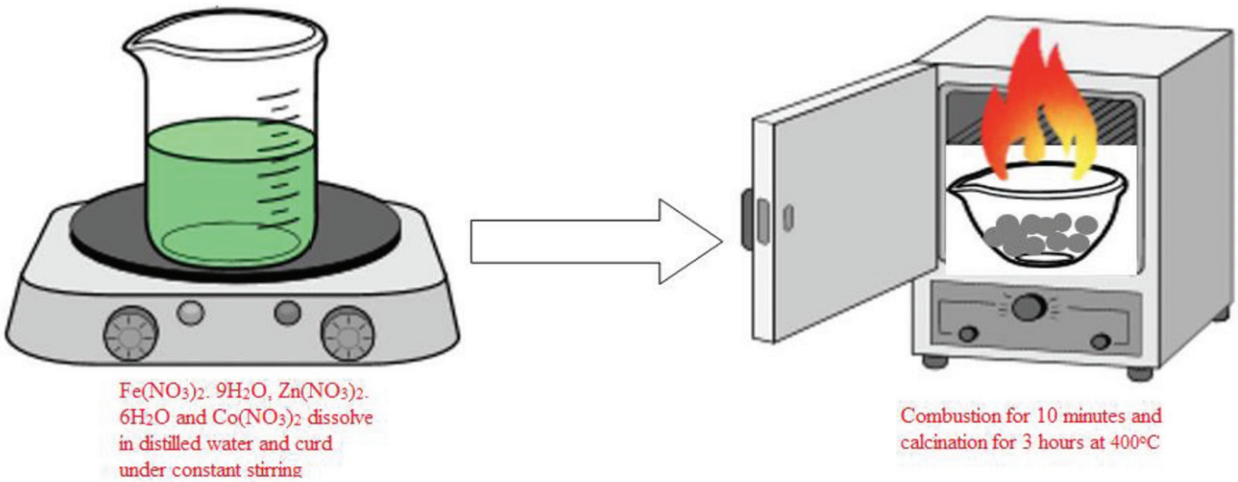

Figure 1: Pictorial representation of Combustion synthesis

iron-based nanocomposites.

Out of the spinel ferrites, $CoFe_2O_4$ is one among the most significant ferro-magnetic materials which have distinctive properties like higher values of coercivity, Curie temperature, mechanical strength, chemical stability and magneto crystalline anisotropy along with moderate saturation magnetization [5-6]. Zinc ferrites is the preferable material for past two decades due to its unique properties like stability in chemical and thermal characteristics and also its magnetic properties can be fine tuned by varying the grain size [7]. Due to these advantages the zinc ferrites are dominating the applications like MRI, Data storage devices, various sensors, magneto-optical devices and bio medical devices [8]. Nickel ferrite exhibits excellent magnetic, electrical and optical properties. This material has excellent magnetic properties like high saturation magnetization, resistivity and permeability and less coercivity which are the desired properties of soft magnetic materials [9]. Magnesium ferrite is a cubic structure and a normal spinel type material. These Mg ferrites have very attractive electrical and magnetic properties along with thermal and chemical stabilities like Zinc ferrites [10]. Among all other ferrites, Ni-Zn ferrites are the most versatile materials which can be used for wide range of frequency

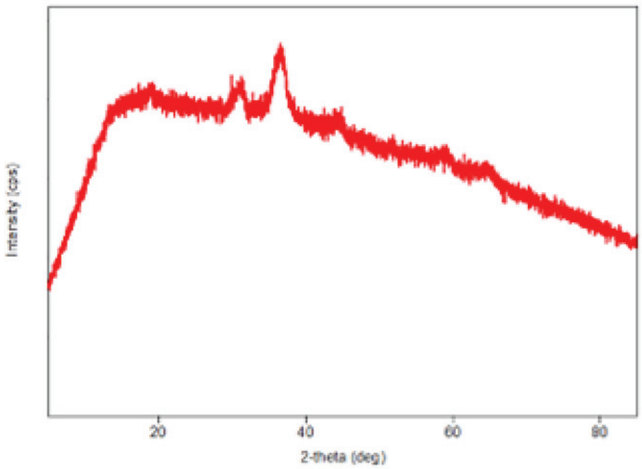

Figure 2: XRD Result of nanoparticle

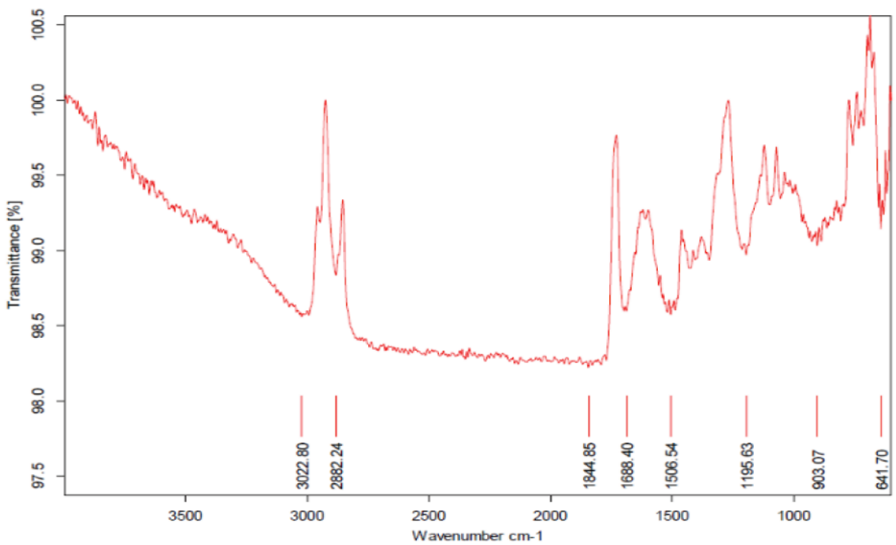

Figure 3: FTIR Result of nanoparticle

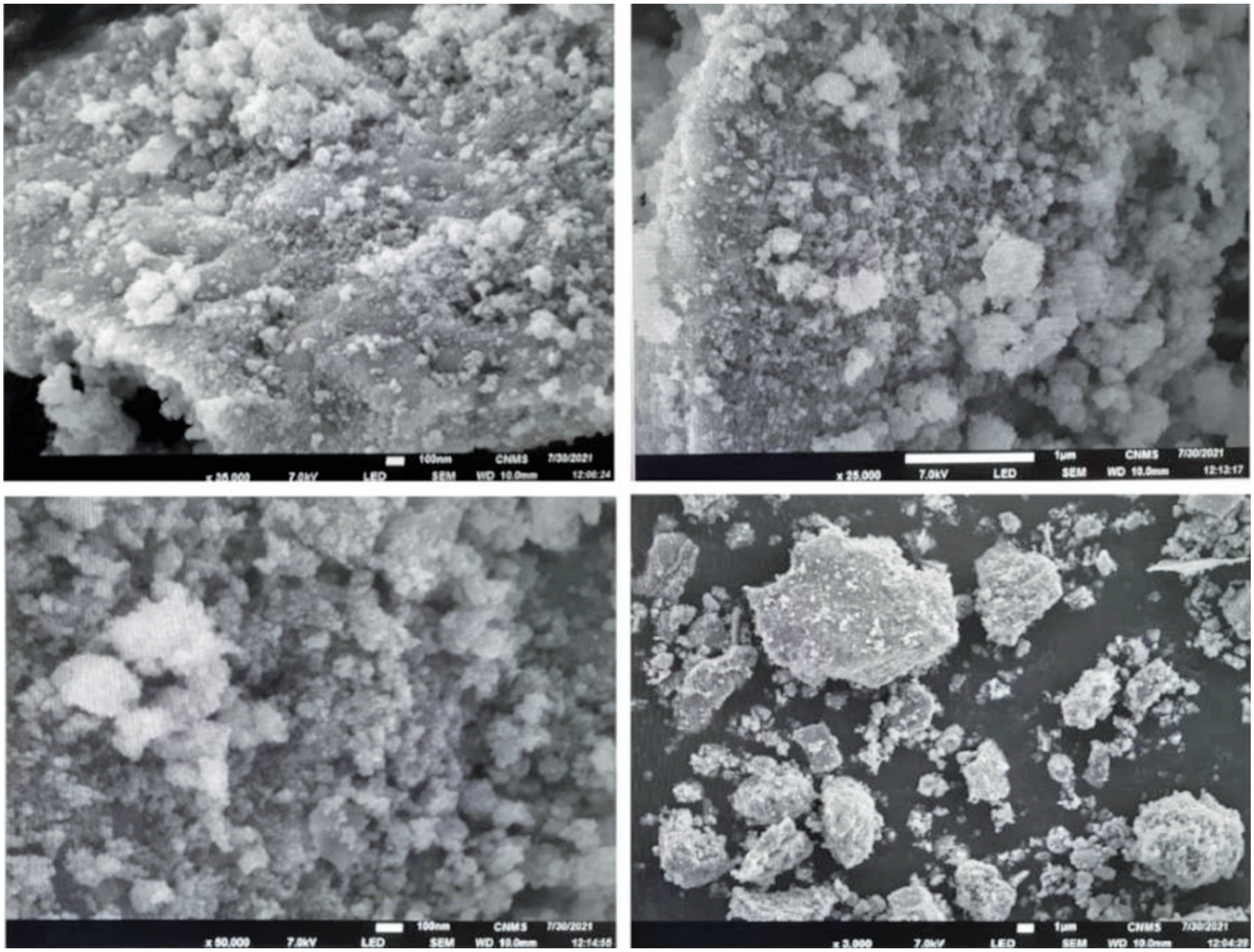

Figure 4: FESEM images of nanoparticles

applications as magnetic material [11].

This study aims at developing a novel soft magnetic material with desired properties [12] of soft magnetic material for higher frequency applications. It is chosen that the combination of cobalt and zinc, where cobalt gives high saturation magnetization and zinc provides stable magnetic properties at high frequencies above MHz range. Zinc ferrites material belongs to a class of typical spinel structure and Cobalt ferrites belongs to a class of inverse spinel, Zn-doped Co-ferrites results in structure called mixed spinel composition.

There are various chemical methods of synthesizing ferrite nanoparticles such as sol-gel [13], co-precipitation [14], hydrothermal [15] combustion synthesis [16]. Combustion synthesis is having a lot of advantages compared to other methods like reduced time, energy and cost consumption and hence this method is chosen for synthesis of required nanoparticles.

2.0 Synthesis Method

Combustion synthesis is also known as self-propagating high-temperature synthesis (SHS) is chosen method for our study because of its advantages mentioned in previous section. Stoichiometric quantity of $Fe(NO_3)_2$. $9H_2O$, $Zn(NO_3)_2$. $6H_2O$ and $Co(NO_3)_2$. $6H_2O$ are dissolved in 10:8 ratios of distilled water and perished curd for about 20 min under constant stirring. Then, this mixed solution is kept in a muffle furnace at 400ºC. After 10 minutes a dark powder is obtained and which is calcinated at the same temperature for 3 hours. The pictorial representation of this process is shown in Fig.1.

Sample: $Fe_{0.5}Co_{0.25}Zn_{0.25}$
$(Fe(NO_3)_2 . 9H_2O)$ = 0.505g
$(Co(NO_3)_2 . 6H_2O)$ = 0.1818g
$(Zn(NO_3)_2 . 6H_2O)$ = 0.1859g

3.0 Results and Discussion

The crystal structure of the synthesised nanoparticles is investigated using XRD. The result of the XRD is shown in Fig.2. It is observed that the presence of wider peaks for Fe, Co and Zn. The broadened peak suggests the presence of smaller grain size particles.

The Surface composition of the nanoparticles can be obtained from FTIR analysis. The result is as shown in Fig.3.

The surface morphology is observed from FESEM images. The Fig.4. shows the FESEM images of the nanoparticles. It can be observed that the particles are non-uniform in shape. The size of the particles are less than 100 nm.

4.0 Electrical Properties

The plot of resistance and capacitance vs. frequency of synthesized nanoparticles are characterized using the LCR meter with a frequency range from 4Hz to 8MHz.

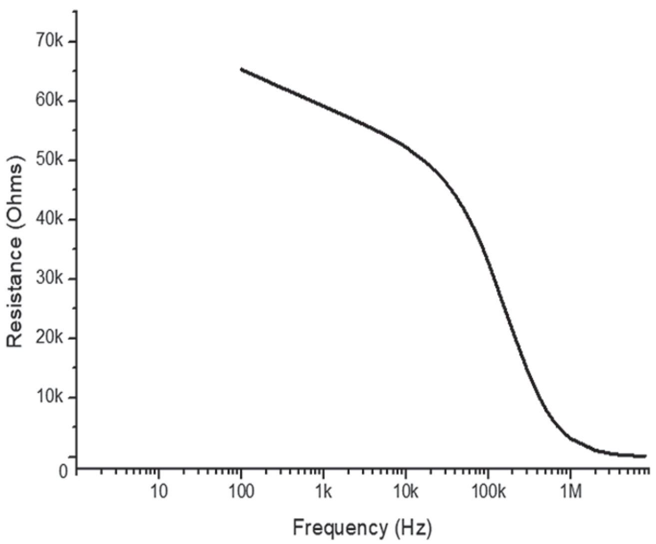

Figure 5: variation of Resistance with frequency for nanoparticle

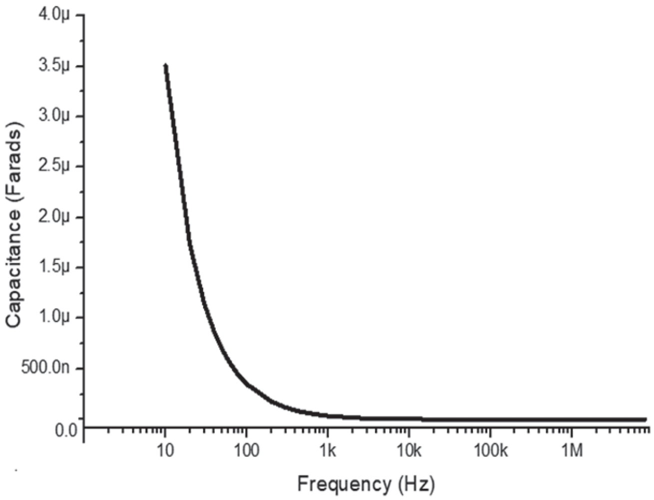

Figure 6: variation of Capacitance with frequency for nanoparticle

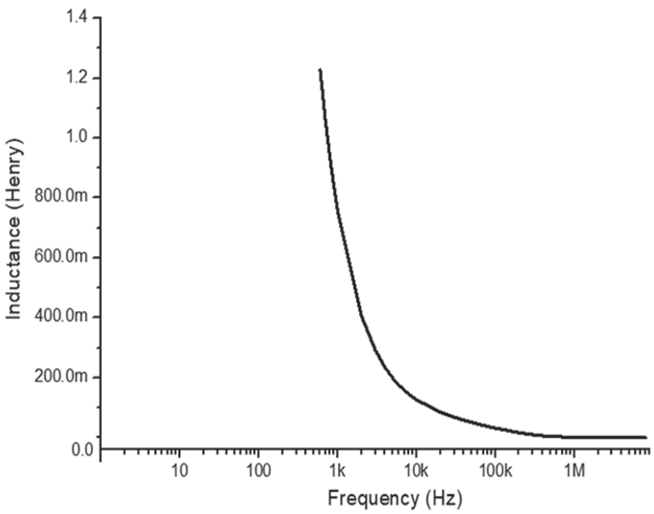

Figure 7: variation of Inductance with frequency for nanoparticle

the Resistance vs. frequency curve is as shown in Fig.5 and Capacitance vs Frequency curve is shown in Fig.6. From the plots we can see that as the frequency increases both capacitance and the resistance value decrease exponentially.

Magnetic properties

The inductance of the synthesized sample is characterized for its dependance for the frequency. The inductance vs frequency plot is shown below in Fig.7. From the graph, it is observed that the inductance as well as permeability both depends on the frequency. As the frequency increases the inductance decreases.

Conclusion

The zinc-cobalt ferrite nanoparticle is synthesized using combustion synthesis technique. The structural and surface morphology is studied using XRD analysis and FESEM. From plots of frequency vs. Resistance, Capacitance and inductance, it can be concluded that as frequency increases, the values of resistance, capacitance and inductance decreases. The value of capacitance is very small and hance cannot be used as dielectric material. The value of inductance at low frequency is very high and as frequency increases, permeability reduces but it is within acceptable and hence can be used as electromagnetic material for frequency applications.

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