

# The Electrical Properties of Barium Hexaferrite Nanopowders Using Co-Precipitation Method

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## The Electrical Properties of Barium Hexaferrite Nanopowders Using Co-Precipitation Method

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### Abstract

Barium hexaferrite BaFe<sub>12</sub>O<sub>19</sub> powders have been synthesized using co-precipitation method and examined LCR meter. Co-Zn were substituted barium ferrite nanocrystalline particles BaFe<sub>12-2x</sub>Co<sub>x</sub>Zn<sub>x</sub>O<sub>19</sub> with (0 < x < 1) were prepared by co-precipitation method, and their electrical properties and their temperature dependencies were studied. The ac conductivity measurements were performed within a temperature range 400-800<sup>o</sup>C. The ac conductivity showed a linear relation with the frequency power law for BaFe<sub>12</sub>O<sub>19</sub>. For all the samples it is observed that electrical conductivity is small in the lower frequency region and increases for higher frequencies and conductivity increases with temperature. It decreases with increasing temperature, indicating that the heterogeneous structures increase. Cationic substitution in M-type hexaferrites is considered to be an important tool for modification of their electrical properties. The results of the study demonstrate a relationship between the modulation of electrical properties of substituted ferrites and nature of cations and their lattice site occupancy. The effect of variation of composition, frequency and temperature on conductivity has been carried out. The ac conductivity increased with temperature showing semiconductor like nature of the samples..

**Keywords:** Barium Hexaferrite, electrical properties, co-precipitation, nanopowder

### 1. Introduction

Barium M-Hexaferrites (BaM) has a hexagonal molecular structure (BaFe<sub>12</sub>O<sub>19</sub>) is one material that attracts many researchers because it has electricity and magnetism parameter high. BaM has a high saturation magnetization (72 emu / g) [1], terrain large coercivity (6700 Oe) [2], and a high Curie temperature (502 ° C) [3]. This causes these materials have wide applications such as: as an electromagnetic wave absorbing material, memory devices, microwave devices, and recording media with high density [4-5]. As the wave absorbing material, BaM must have electrical properties such as high electrical resistivity, dielectric loss and magnetic loss low [6], while for applications as a storage medium or memory required a high density [7]. To produce a high density, the resulting crystals must be sized nano and uniform distribution so this is one of the challenges in research.

The other interesting thing of BaM is the nature of electricity and magnetism can be modified according to the application required by the researcher. Engineering can be done by way of substitution or doping. Some researchers have tried replacing the iron (Fe) with transition metal ions of the elements that have similar ionic radii such as La, Ti, Mn, Co, Ni and Zn [8-11]. This research will be conducted ion substitution with Co-Zn alloys. Selection of doping is based on previous research, namely: electrical conductivity increases with increasing temperature and the concentration of Zn ions [12] and the dielectric constant is largely influenced by the concentration of Co ions that decrease with increased frequency in a wide variety of temperature [13]. Frequency and temperature influence on the electrical

properties of a material would provide information about the charge transfer mechanism and dielectric properties of the materials. Therefore, this study aimed to investigate the influence of the frequency of the electrical properties of Bam on a wide variety of Co-Zn ion concentration and calcinations temperature variations.

In the synthesis of Bam there are several commonly used methods such as solid state reaction [14], solution combustion method [15], sol-gel [16-17], and co-precipitation [18,19]. The preferred method is co-precipitation research because it is easy to control the chemical composition and size of the crystals produced [20].

## **2. Materials and Methods**

### **2.1. The Synthesis of Barium Powder Process M-Hexaferrit (BaFe<sub>12-2x</sub>Co<sub>x</sub>Zn<sub>x</sub>O<sub>19</sub>)**

The materials used in this study for the synthesis of barium M-hexaferrit BaFe<sub>12-2x</sub>Co<sub>x</sub>Zn<sub>x</sub>O<sub>19</sub> are: Barium Carbonate Powder (BaCO<sub>3</sub>) with M = 197.34 g / mol, Iron (III) Chloride Hexahydrate (FeCl<sub>3</sub>.6H<sub>2</sub>O) as the base material With M=270.33 g/ mol, and CoCl<sub>2</sub> powder and Zn propanolis (PA) as a doping material with variations in the value of x = 0; 0.2; 0.4; 0.6; 0.8; 1. Synthesis of barium M-hexaferrit BaFe<sub>12-2x</sub>Co<sub>x</sub>Zn<sub>x</sub>O<sub>19</sub> performed by co-precipitation method comprising: Powder Barium carbonate (BaCO<sub>3</sub>) solution dissolved in HCl (0,1N), heated to a temperature of about 800C with hot plate and stirred using a magnetic stirrer for approximately 2 hours until the powder dissolved and the solution is clear white. Crystal Iron (III) chloride Hexahydrate (FeCl<sub>3</sub>.6H<sub>2</sub>O) diluted with distilled water, stirred with a magnetic stirrer without heating to obtain a solution with a blackish brown color. Zn powder was dissolved in HCl (0.1 N) and the CoCl<sub>2</sub> powder. The second solution diluted with distilled water acts as doping. The above three solutions are mixed and stirred with a magnetic stirrer until it becomes homogeneous (black and brown), without settling heated then added a solution of NH<sub>4</sub>OH (25%), to obtain a precipitate with high homogeneity (dark brown). After a few minutes of samples ranging look no deposits, after which the precipitate is filtered by using a filter paper and washed with distilled water up to 10 times until reached state neutral or reached pH = 7. After the sample is deposited so as to achieve a normal ph level, then the sample crushed so that we will get a fine powder samples.

## **3. Results and Discussion.**

For all the samples BaM with doping Co dan Co-Zn are observed that conductivity is small in the lower frequency region and increases for higher frequencies (Fig. 1(b) and 2 (b)). The electrical conductivity increases with temperature as shown in Fig. 1(b), 2(a) and 2(b). Therefore, the iron oxides are generally termed as 'semiconductors'. The lattice vibrations increase with temperature, giving rise to higher probability of the hopping of electrons at the octahedral sites, leading to enhanced mobility of charge carriers and hence the conductivity [12].

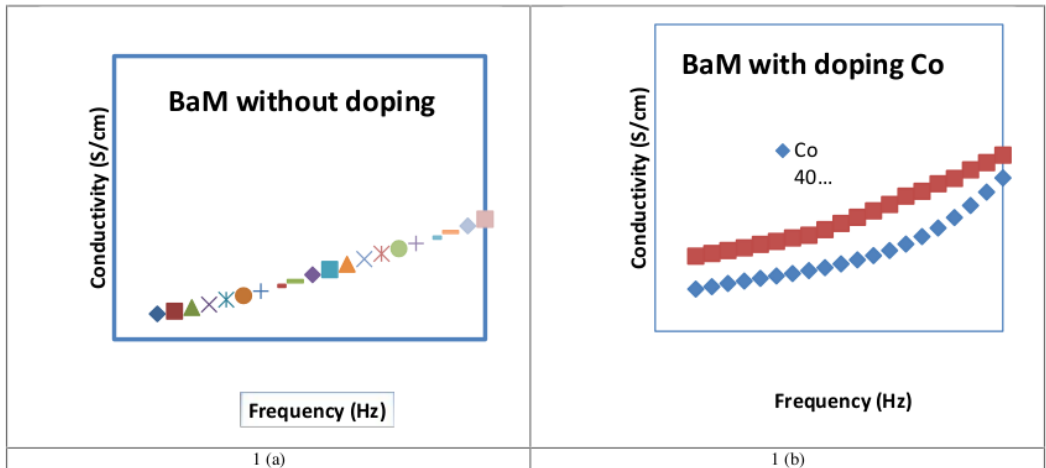


Figure 1. (a) log conductivity versus log frequency for BaM without doping and (b) log conductivity versus log frequency for BaM with doping Co

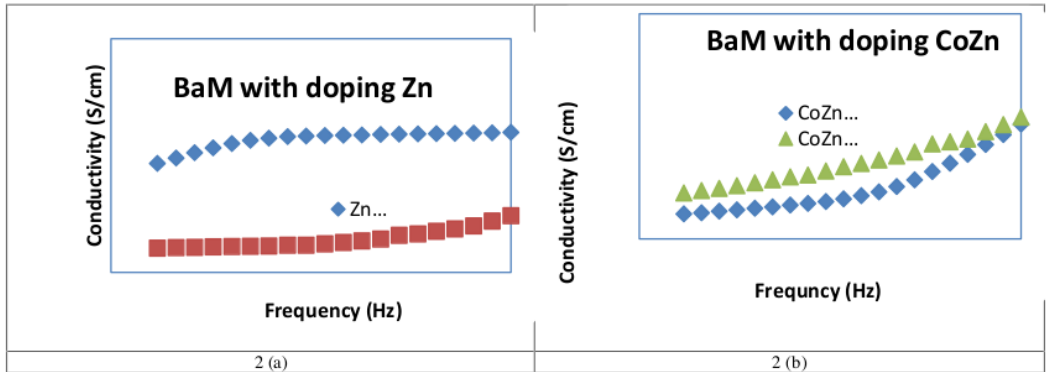


Figure 2. (a) log conductivity versus log frequency for BaM with doping Zn and (b) log conductivity versus log Frequency for BaM with doping Co-Zn

From Figure 1 (a) shows that the conductivity values without doping BaM shows the value increasing with increasing frequency of, showed that the increased conductivity occurs liner. At low frequencies the conductivity value of  $4.27 \cdot 10^{-7}$  S / cm at a frequency of  $10^5$  Hz, while the value of conductivity is  $9.32 \cdot 10^{-5}$  S / cm. From Figure 1 (b) - 2 (b) the value of the conductivity can be seen in the following table 1.

Table.1. Conductivity of samples in the range frequency below 100 Hz and above 100 to  $10^5$  Hz

Frequency (Hz)	Conductivity (S/cm)					
	Co (400 <sup>o</sup> C)	Co (800 <sup>o</sup> C)	Zn (400 <sup>o</sup> C)	Zn (800 <sup>o</sup> C)	Co-Zn (400 <sup>o</sup> C)	Co-Zn (800 <sup>o</sup> C)
0.5 – 100	$(4.8-9) \cdot 10^{-8}$	$(1.68-3.7) \cdot 10^{-7}$	$(5.3-7.1) \cdot 10^{-7}$	$(1.8 \cdot 10^{-4}-1.0 \cdot 10^{-3})$	$(3.6-6.14 \cdot 10^{-8})$	$(1-2) \cdot 10^{-7}$
>100 - $10^5$	$(1-3) \cdot 10^{-6}$	$(4.5-7.4) \cdot 10^{-6}$	$7.7 \cdot 10^{-7}-5 \cdot 10^{-6}$	$1.1 \cdot 10^{-3}-1.5 \cdot 10^{-3}$	$6.7 \cdot 10^{-8}-3.5 \cdot 10^{-6}$	$2.4 \cdot 10^{-7}-3.48 \cdot 10^{-6}$

From Table 1. show that conductivity increases with increasing temperature calcinations for all types of doping used. The conductivity also increased with increasing

frequency, at low-frequency conductivity tends to a constant value while at high frequencies the conductivity increases linearly. This may be interpreted in a way that at low range of frequency, the jumping of electrons between Fe<sup>2+</sup> and Fe<sup>3+</sup> is less but as frequency goes to the higher values, the hopping of electrons is increase and conductivity is also increased [4]. All samples exhibit a frequency-independent conductivity at low frequencies and a frequency-dependent conductivity at high frequencies due to ionic conductivity relaxation. The higher conductivities were attribute to the increase of ionic charge carries in the samples. The increment of temperature causes increase in conductivity due to the increase of free volume and their respective ionic and segmental mobility. Thus segmental motion, which is temperature dependent permits free charges hop from one site to another or provides a pathway for the transitional ionic motion. The conductivity increase as the temperature, indicating more ions gained kinetic energy via the thermally activated hopping of charge carrier between trapping sites that is temperature dependence and phonon-assisted quantum tunneling through a barrier separating two equilibrium positions, which is hopping distance dependent. Both mechanisms contributed to the ionic mobility and increase total conductivity. The conductivity in ferrites may be elaborated by Verwey's hopping mechanism. The electronic conduction in hexaferrites is mainly due to hopping of electrons between ions of the same element present in more than one valence states [6].

#### **4. Conclusion**

The results showed conductivity samples for doping Co, Zn and Co-Zn increases with increasing calcination temperature and conductivity also depends on the frequency, the low frequency tends to a constant value but at a higher frequency increased. Increase in conductivity with rise in temperature shows semiconducting nature of the samples.

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