# Dielectric response of Zn incorported $BiFeO_3$ samples formulated using solution combustion method at optimised conditions

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***Abstract*—In this manuscript, the Zn substituted $BiFeO_3$ samples such as $BiFe_{0.9}Zn_{0.1}O_3$, $BiFe_{0.85}Zn_{0.15}O_3$ and $BiFe_{0.8}Zn_{0.2}O_3$ were synthesized by solution combustion method under optimised preparative parameters. The x-ray diffraction (XRD) pattern specifies that, the synthesized ceramic samples have rhombhohedral structure. The temperature dependance of dielectric constant of all the ceramic samples were recorded at various frquencies like 1kHz, 3kHz and 5kHz. The $BiFe_{0.9}Zn_{0.1}O_3$, $BiFe_{0.85}Zn_{0.15}O_3$ and $BiFe_{0.8}Zn_{0.2}O_3$ samples manifests a dielectric anomalies around 425ºC, 520ºC and 450ºC at 1 kHz frequency.**

***Keywords:*** **Ceramics, Zn doped $BiFeO_3$, SCM, structural studies, dielectric studies.**

## I. INTRODUCTION

At a particular temperature range the multiferroic material shows simultenous existance of ferroelectricity, ferromagnetism and ferroelasticity order [1]. The antiferromagnetic Neel temperature (TN = 643 K) and ferroelectric Curie temperature (TC = 1103 K) of $BiFeO_3$ [2]. The $BiFeO_3$ compound exhibits a rhombohedral perovskite structure [3]. The $BiFeO_3$ have number of applications in microwave, satellite communication [4], memory sensor and ultrasonic technologies [5].

The number of methods can be used for the synthesis of $BiFeO_3$ ceramics such as solid state reaction [6], sol-gel method [7], hydrothermal method [8], Pechini method [9] and polymeric precursor method [10]. In this connection, we have formulated the Zn doped $BiFeO_3$ samples, with different Zn doping concentration in $BiFeO_3$ through solution combustion method (SCM).

## 2. EXPERIMENTAL PROCEDURE

### *2.1. STARTING MATERIALS:*

For the formulation of Zn incorporated $BiFeO_3$ ceramic samples the bismuth nitrate,ferric nitrate, zinc nitate and glycine were used as a primary materials.

### *2.2. PREPARATION OF $BI_{1-X}Zn_XFeO_3$ (X = 0.1-0.2):*

The $BiFe_{0.9}Zn_{0.1}O_3$, $BiFe_{0.85}Zn_{0.15}O_3$ and $BiFe_{0.8}Zn_{0.2}O_3$ samples were prepared through solution combustion method (SCM). The bismuth nitrate, ferric nitrate and zinc nitrate are used as a oxidizers and the glycine was used as fuel for combustion reaction. The oxidizer (O): fuel (F) ratio was calculated based on the oxidizing valencies of metal nitrates and reducing valency of fuel [11].

The bismuth nitrate, ferric nitrate and zinc nitrate were dissolved in distilled water in a separate glass beakers. The fuel glycine was also dissolved in distilled water in another beaker. After complete dissolving all the nitrates and glycine in a distilled water. All this solutions were mixed together in a Pyrex dish and kept on a burner for heating till the excess of water get vaporised and spontaneous ignition occurred followed by the formation of the combustion powders of $BiFe_{0.9}Zn_{0.1}O_3$, $BiFe_{0.85}Zn_{0.15}O_3$ and $BiFe_{0.8}Zn_{0.2}O_3$ samples. All these $BiFe_{0.9}Zn_{0.1}O_3$, $BiFe_{0.85}Zn_{0.15}O_3$ and $BiFe_{0.8}Zn_{0.2}O_3$ powders were grinded in an acetone medium and carried out for calcinations in a furnace at 700ºC for 5 hours. After this, the $BiFe_{0.9}Zn_{0.1}O_3$, $BiFe_{0.85}Zn_{0.15}O_3$ and $BiFe_{0.8}Zn_{0.2}O_3$ powders were again grinded with addition of binder in this powder samples and finally pellets are prepared. The $BiFe_{0.9}Zn_{0.1}O_3$, $BiFe_{0.85}Zn_{0.15}O_3$ and $BiFe_{0.8}Zn_{0.2}O_3$ pellets were carried out for sintering at higher temperatures such as 800ºC, 850ºC and 900ºC

respectively. The experimental synthesis procedure is also reported by Chaudhai et.al. [12].

*2.3.CHARACTERIZATION & MEASUREMENTS:*

The synthesized pellets of $BiFe_{0.9}Zn_{0.1}O_3$, $BiFe_{0.85}Zn_{0.15}O_3$ and $BiFe_{0.8}Zn_{0.2}O_3$ ceramic samples were carried out for x-ray diffraction (XRD) studies and dielectric meaurements in the temperature range 25ºC to maximum temperature upto 500ºC.

## 3. RESULTS AND DISCUSSION

*3.1. X –RAY DIFFRACTION:*

Fig. 1. A), B) and C) presents the room temperature (RT) x-ray diffraction (XRD) pattern of $BiFe_{0.9}Zn_{0.1}O_3$, $BiFe_{0.85}Zn_{0.15}O_3$ and $BiFe_{0.8}Zn_{0.2}O_3$ samples. The XRD pattern reveals that, all the Zn doped $BiFeO_3$ samples crystallises in a rhombohedral perovskite phase. The XRD pattern of all the samples expresses the presence of impurity phases (indicated by #) around 30º. In all prepred samples, it has been seen that, with increasing Zn doping level in $BiFeO_3$ and incresing sintering temperature, the intensity of impurity phase slightly increases. The XRD pattern matches with the results reported by Chaudhari et.al. [12].

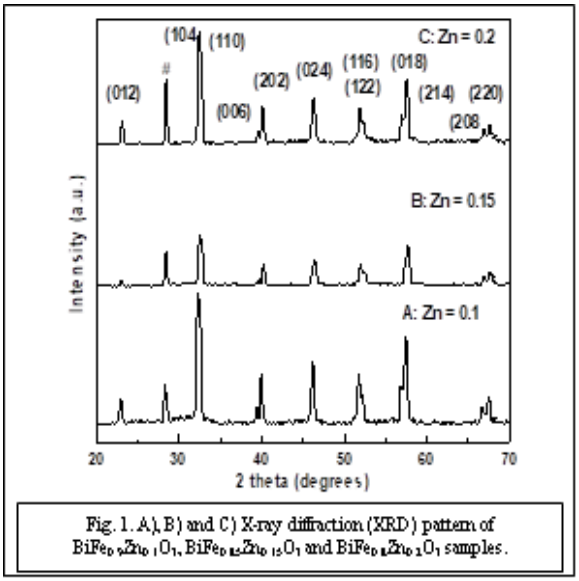


Fig. 1. A), B) and C) X-ray diffraction (XRD) pattern of $BiFe_{0.9}Zn_{0.1}O_3$, $BiFe_{0.85}Zn_{0.15}O_3$ and $BiFe_{0.8}Zn_{0.2}O_3$ samples.

*3.2.TEMPERATURE DEPENDANT DIELECTRIC STUDIES:*

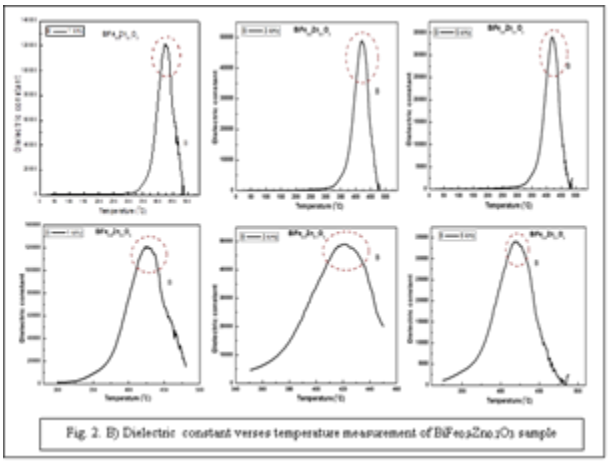

Fig. 2. B) Dielectric constant verses temperature measurement of $BiFe_{0.9}Zn_{0.1}O_3$ sample

Fig. 2. B), C) and D) shows the temperature dependance of dielectric constant at 1 kHz, 3 kHz and 5 kHz for the $BiFe_{0.9}Zn_{0.1}O_3$, $BiFe_{0.85}Zn_{0.15}O_3$ and $BiFe_{0.8}Zn_{0.2}O_3$ samples. The results showed that, the dielectric constant increases with increase in temperature in all ceramic samples. The dielectric constant as a function of temperature manifests a dielectric anomalies at different temperatures, in $BiFe_{0.9}Zn_{0.1}O_3$, $BiFe_{0.85}Zn_{0.15}O_3$ and $BiFe_{0.8}Zn_{0.2}O_3$ samples the dielectric anomalies appears around 425ºC, 520ºC and 450ºC at 1kHz frquency, this corresponds to antiferromagnetic to paramagnetic phase transition in $BiFeO_3$ [13]. The $BiFe_{0.9}Zn_{0.1}O_3$, $BiFe_{0.85}Zn_{0.15}O_3$ and $BiFe_{0.8}Zn_{0.2}O_3$ samples also indicates an dielectric anomalies at 3 kHz and 5kHz have been given in the following table 1.

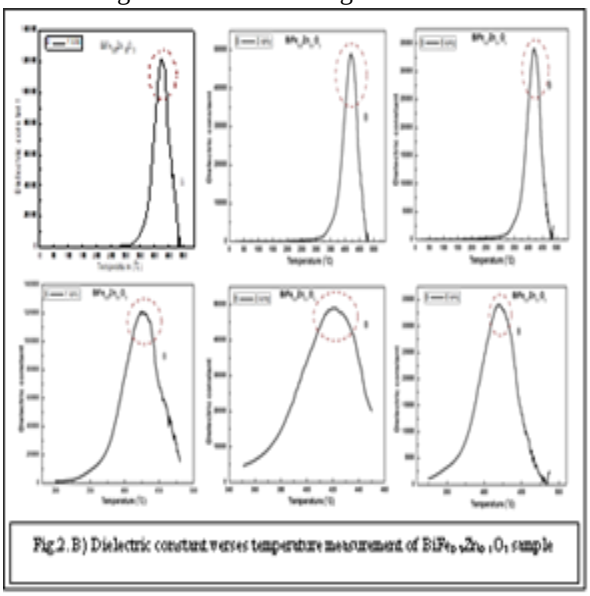

Fig.2. B) Dielectric constant verses temperature measurement of $BiFe_{0.9}Zn_{0.1}O_3$ sample

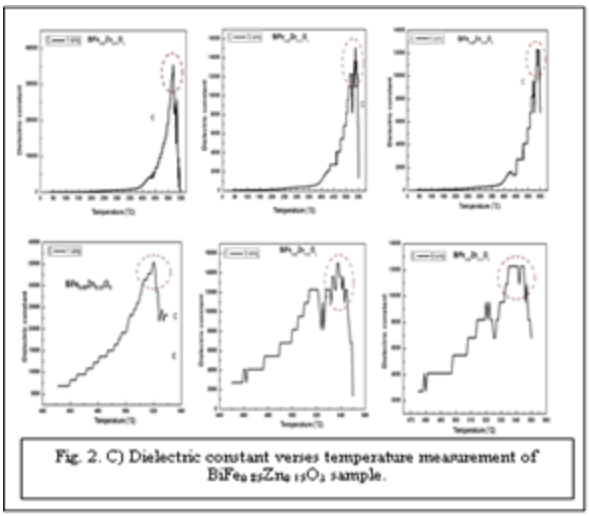

Fig. 2. C) Dielectric constant verses temperature measurement of $BiFe_{0.85}Zn_{0.15}O_3$ sample.

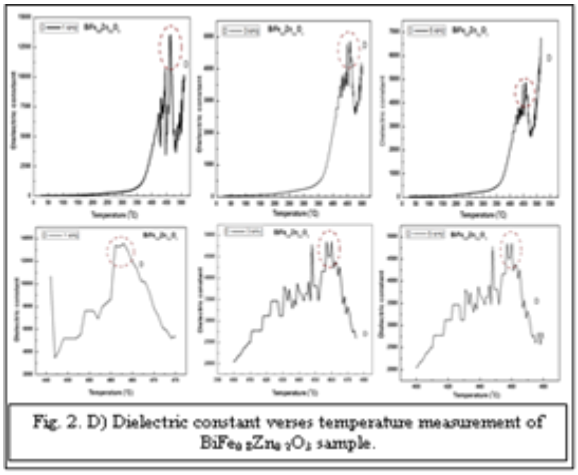

Fig. 2. D) Dielectric constant verses temperature measurement of $BiFe_{0.8}Zn_{0.2}O_3$ sample.

The dielectric constant as a function of temperature presents an dielectric anomalies at different temperatures and at different frequencies in the $BiFe_{0.9}Zn_{0.1}O_3$, $BiFe_{0.85}Zn_{0.15}O_3$ and $BiFe_{0.8}Zn_{0.2}O_3$ ceramic samples are given in the following table 1.

| Samples | Frequency | Dielectric anomalies at temperature (°C) |
|---|---|---|
| $BiFe_{0.9}Zn_{0.1}O_3$ | 1 kHz | 425 °C |
| | 3 kHz | 422 °C |
| | 5 kHz | 424 °C |
| $BiFe_{0.85}Zn_{0.15}O_3$ | 1 kHz | 520 °C |
| | 3 kHz | 540 °C |
| | 5 kHz | 550 °C |
| $BiFe_{0.8}Zn_{0.2}O_3$ | 1 kHz | 460 °C |
| | 3 kHz | 465 °C |
| | 5 kHz | 467 °C |

Table 1.: Dielectric anomalies in the Zn subsitutued $BiFeO_3$ at 1, 3 and 5 kHz.

The measurement of dielectric constants in the $BiFe_{0.9}Zn_{0.1}O_3$, $BiFe_{0.85}Zn_{0.15}O_3$ and $BiFe_{0.8}Zn_{0.2}O_3$ samples at room temperature (RT) and at higher temperature have been given in the following table 2.

| Samples | Frequency | Dielectric constant at room temperature (RT) | Dielectric constant at temperature between 400-500 °C |
|---|---|---|---|
| $BiFe_{0.9}Zn_{0.1}O_3$ | 1 kHz | 125 | 120000 |
| | 3 kHz | 130 | 34000 |
| | 5 kHz | 175 | 48000 |
| $BiFe_{0.85}Zn_{0.15}O_3$ | 1 kHz | 210 | 35000 |
| | 3 kHz | 225 | 15000 |
| | 5 kHz | 250 | 13000 |
| $BiFe_{0.8}Zn_{0.2}O_3$ | 1 kHz | 178 | 14000 |
| | 3 kHz | 198 | 4000 |
| | 5 kHz | 175 | 6000 |

Table 2.: Dielectric constant at room temperture and higher temperature.

## 4. CONCLUSION

This paper describes the formulation of $BiFe_{0.9}Zn_{0.1}O_3$, $BiFe_{0.85}Zn_{0.15}O_3$ and $BiFe_{0.8}Zn_{0.2}O_3$ ceramic samples through by solution combustion method (SCM) under optimised synthesis conditions. The x-ray diffraction (XRD) pattern specifies that, the formulated ceramic samples have rhombhohedral structure. The temperature dependance of dielectric constant of $BiFe_{0.9}Zn_{0.1}O_3$, $BiFe_{0.85}Zn_{0.15}O_3$ and $BiFe_{0.8}Zn_{0.2}O_3$ ceramic samples at different frequencies like 1 kHz, 3 kHz and 5 kHz indicates an dielectric anomalies correponds to antiferromagnetic to paramagnetic phase transition in $BiFeO_3$.

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