# Preparation and Dielectric Studies of $BiFe_{1-x+y}Ba_xCo_yO_3$ (x, y = 0.1, 0.2, 0.3, 0.4) Nanoceramic Samples Using Solution Combustion Method

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***Abstract*—This paper presents the formulation of Ba and Co doping at Fe site in the $BiFeO_3$ ceramics such as $BiFe_{0.8}Ba_{0.1}Co_{0.1}O_3$, $BiFe_{0.6}Ba_{0.2}Co_{0.2}O_3$, $BiFe_{0.4}Ba_{0.3}Co_{0.3}O_3$ and $BiFe_{0.2}Ba_{0.4}Co_{0.4}O_3$ samples by using solution combustion method. These ceramic samples $BiFe_{0.8}Ba_{0.1}Co_{0.1}O_3BiFe_{0.6}Ba_{0.2}Co_{0.2}O_3$, $BiFe_{0.4}Ba_{0.3}Co_{0.3}O_3$ and $BiFe_{0.2}Ba_{0.4}Co_{0.4}O_3$ were prepared using metal nitrates and glycine fuel as primary resources. These chemically produced powder samples were ground in an acetone medium, calcined in a furnace at various temperatures, and then pelletized. The dielectric constant as a function of temperature studies were carried out at 1 kHz, 3 kHz and 5kHz frequencies for the $BiFe_{0.8}Ba_{0.1}Co_{0.1}O_3$, $BiFe_{0.6}Ba_{0.2}Co_{0.2}O_3$, $BiFe_{0.4}Ba_{0.3}Co_{0.3}O_3$ and $BiFe_{0.2}Ba_{0.4}Co_{0.4}O_3$ ceramics.**

***Index Terms*—Multiferroics, $BiFeO_3$, Co and Ba codopants, SCM, Dielectric, applications.**

## I. INTRODUCTION

Materials that exhibit many ferroic orders like ferroelectricity, ferromagnetism, ferroelasticity, and ferro-toroidicity at the same time are known as multiferroic materials [1]. An antiferromagnetic Neel temperature ($T_N$=643K) and ferroelectric Curie temperature ($T_C$=1103 K) of bismuth ferrite ($BiFeO_3$) [2]. The multiferroic $BiFeO_3$ have number of important applications like information storage [3], photovoltaics, optical filters [4], sensors [5], catalytic [6], piezoelectric devices, photosensitizers [7], multistate storage [8] and high density microactuators [9].$BiFeO_3$ multiferroic ceramics have been synthesized using a variety of formulating techniques, particularly solid state reaction route [10], combustion technique [11], auto-combustion method [12] and sol-gel auto combustions method [13].In this article, we have synthesized the $BiFe_{0.8}Ba_{0.1}Co_{0.1}O_3$, $BiFe_{0.6}Ba_{0.2}Co_{0.2}O_3$, $BiFe_{0.4}Ba_{0.3}Co_{0.3}O_3$ and $BiFe_{0.2}Ba_{0.4}Co_{0.4}O_3$ multiferroic ceramics through solution combustion method.

## II. EXPERIMENTAL PROCEDURE

1. Initial Materials

The first beginning materials were glycine, bismuth nitrate, ferric nitrate, cobalt nitrate, and barium nitrate.

2. Synthesis Process:

The preparation of $BiFe_{0.8}Ba_{0.1}Co_{0.1}O_3$, $BiFe_{0.6}Ba_{0.2}Co_{0.2}O_3$, $BiFe_{0.4}Ba_{0.3}Co_{0.3}O_3$ and $BiFe_{0.2}Ba_{0.4}Co_{0.4}O_3$ ceramic samples were carried out using the precursors such as bismuth nitrate, ferric nitrate, barium nitrate, cobalt nitrate as an oxidizers while glycine was used as a fuel. The oxidizing and reducing valences of the metal nitrates and fuel were used to precisely determine the oxidizer (O) to fuel (F) ratio so as to develop the sample mixture [14].

Distilled water was used to dissolve stoichiometric amounts of bismuth nitrate, ferric nitrate, cobalt nitrate, barium nitrate, and glycine in different beakers. After that, these solutions were combined, moved to a Pyrex dish, and heated using a gas burner. Afterwards the continuous heating, the water gets evaporated and finally a combustion takes place with formation of $BiFe_{0.8}Ba_{0.1}Co_{0.1}O_3$, $BiFe_{0.6}Ba_{0.2}Co_{0.2}O_3$, $BiFe_{0.4}Ba_{0.3}Co_{0.3}O_3$ and $BiFe_{0.2}Ba_{0.4}Co_{0.4}O_3$ powders. Chaudhari et al. provided the experimental approach [15], these powders were grinded in an acetone medium and finally calcined at 450°C, 460°C, 470°C, 480°C for 2 hours in a furnace and finally carried out for pellet formation.

Fig. 1 shows the flowchart of the experimentation process utilized for generating these powder samples.

Fig.2 (a), (b), (c), (d) shows the actual experimental process of preparation of $BiFe_{0.8}Ba_{0.1}Co_{0.1}O_3$, $BiFe_{0.6}Ba_{0.2}Co_{0.2}O_3$, $BiFe_{0.4}Ba_{0.3}Co_{0.3}O_3$ and $BiFe_{0.2}Ba_{0.4}Co_{0.4}O_3$ samples. Fig.3 (a), (b), (c), (d) shows the prepared solutions of $BiFe_{0.8}Ba_{0.1}Co_{0.1}O_3$, $BiFe_{0.6}Ba_{0.2}Co_{0.2}O_3$, $BiFe_{0.4}Ba_{0.3}Co_{0.3}O_3$ and $BiFe_{0.2}Ba_{0.4}Co_{0.4}O_3$ ceramics. Fig.4 (a), (b), (c), (d) shows the formulated powder samples of $BiFe_{0.8}Ba_{0.1}Co_{0.1}O_3$, $BiFe_{0.6}Ba_{0.2}Co_{0.2}O_3$, $BiFe_{0.4}Ba_{0.3}Co_{0.3}O_3$ and $BiFe_{0.2}Ba_{0.4}Co_{0.4}O_3$ ceramics. Fig.5 (a), (b), (c), (d) shows prepared pellets of $BiFe_{0.8}Ba_{0.1}Co_{0.1}O_3$, $BiFe_{0.6}Ba_{0.2}Co_{0.2}O_3$, $BiFe_{0.4}Ba_{0.3}Co_{0.3}O_3$ and $BiFe_{0.2}Ba_{0.4}Co_{0.4}O_3$ ceramic samples. Fig. 6 (a), (b), (c), (d) shows the temperature dependence of dielectric constant of the $BiFe_{0.8}Ba_{0.1}Co_{0.1}O_3$, $BiFe_{0.6}Ba_{0.2}Co_{0.2}O_3$, $BiFe_{0.4}Ba_{0.3}Co_{0.3}O_3$ and $BiFe_{0.2}Ba_{0.4}Co_{0.4}O_3$ samples at 1 kHz, 3 kHz and 5 kHz. The dielectric constant shows a dielectric anomaly at different temperatures at 1 kHz, 3 kHz and 5 kHz for $BiFe_{0.8}Ba_{0.1}Co_{0.1}O_3$, $BiFe_{0.6}Ba_{0.2}Co_{0.2}O_3$, $BiFe_{0.4}Ba_{0.3}Co_{0.3}O_3$ and $BiFe_{0.2}Ba_{0.4}Co_{0.4}O_3$ samples are given in Table 1.

| Samples | 1 kHz | 3 kHz | 5 kHz |
|---|---|---|---|
| $BiFe_{0.8}Ba_{0.1}Co_{0.1}O_3$ | 430ºC | 440ºC | 445ºC |
| $BiFe_{0.6}Ba_{0.2}Co_{0.2}O_3$ | 470ºC | 480ºC | 495ºC |
| $BiFe_{0.4}Ba_{0.3}Co_{0.3}O_3$ | 490ºC | 495ºC | 498ºC |
| $BiFe_{0.2}Ba_{0.4}Co_{0.4}O_3$ | 410ºC | 425ºC | 440ºC |

Table.1: Dielectric anomalies at 1 kHz, 3 kHz and 5 kHz for $BiFe_{0.8}Ba_{0.1}Co_{0.1}O_3$, $BiFe_{0.6}Ba_{0.2}Co_{0.2}O_3$, $BiFe_{0.4}Ba_{0.3}Co_{0.3}O_3$ and $BiFe_{0.2}Ba_{0.4}Co_{0.4}O_3$ samples.

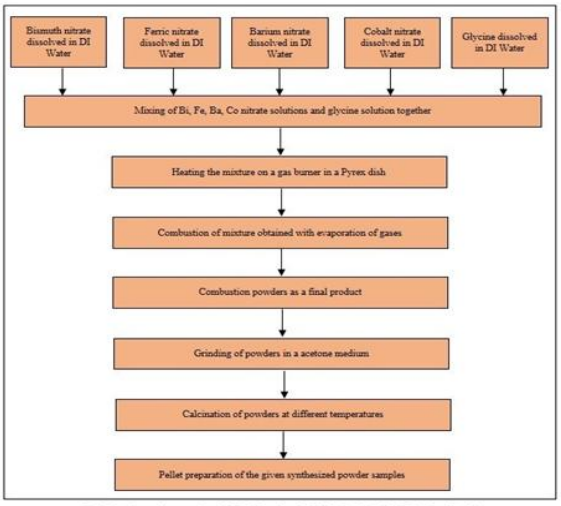


Fig.1. Flowchart of preparation of $BiFe_{0.8}Ba_{0.1}Co_{0.1}O_3$, $BiFe_{0.6}Ba_{0.2}Co_{0.2}O_3$, $BiFe_{0.4}Ba_{0.3}Co_{0.3}O_3$ and $BiFe_{0.2}Ba_{0.4}Co_{0.4}O_3$ multiferroic samples by SCM.

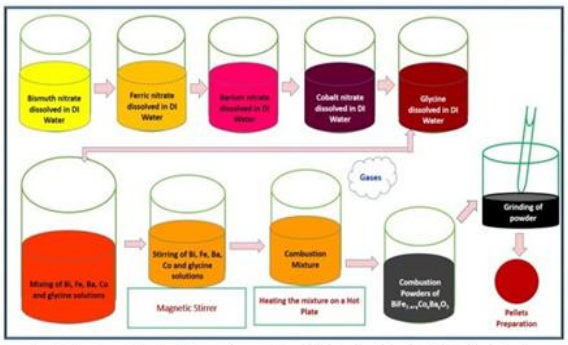


Fig.2. Experimental methodology of preparation of $BiFe_{0.8}Ba_{0.1}Co_{0.1}O_3$, $BiFe_{0.6}Ba_{0.2}Co_{0.2}O_3$, $BiFe_{0.4}Ba_{0.3}Co_{0.3}O_3$ and $BiFe_{0.2}Ba_{0.4}Co_{0.4}O_3$ ceramic samples.

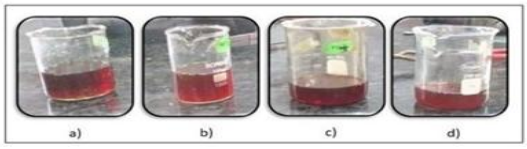


Fig.3 (a), (b), (c), (d) shows the solutions of $BiFe_{0.8}Ba_{0.1}Co_{0.1}O_3$, $BiFe_{0.6}Ba_{0.2}Co_{0.2}O_3$, $BiFe_{0.4}Ba_{0.3}Co_{0.3}O_3$ and $BiFe_{0.2}Ba_{0.4}Co_{0.4}O_3$ samples.

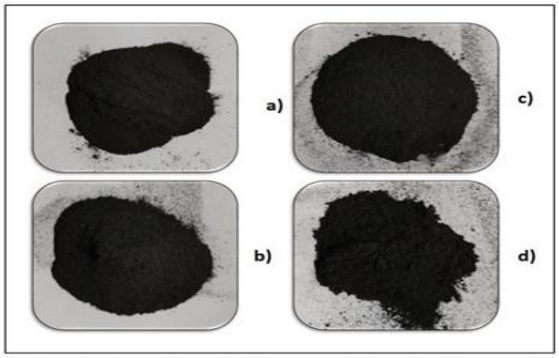


Fig.4 (a), (b), (c), (d) shows the synthesized powder samples of $BiFe_{0.8}Ba_{0.1}Co_{0.1}O_3$, $BiFe_{0.6}Ba_{0.2}Co_{0.2}O_3$, $BiFe_{0.4}Ba_{0.3}Co_{0.3}O_3$ and $BiFe_{0.2}Ba_{0.4}Co_{0.4}O_3$ ceramics by SCM.

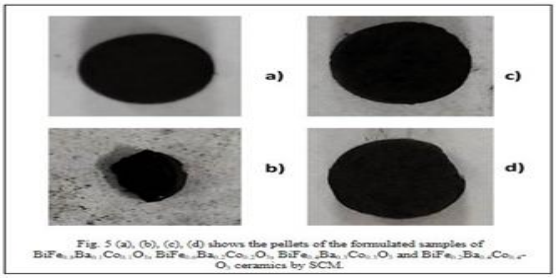


Fig. 5 (a), (b), (c), (d) shows the pellets of the formulated samples of $BiFe_{0.8}Ba_{0.1}Co_{0.1}O_3$, $BiFe_{0.6}Ba_{0.2}Co_{0.2}O_3$, $BiFe_{0.4}Ba_{0.3}Co_{0.3}O_3$ and $BiFe_{0.2}Ba_{0.4}Co_{0.4}O_3$ ceramics by SCM.

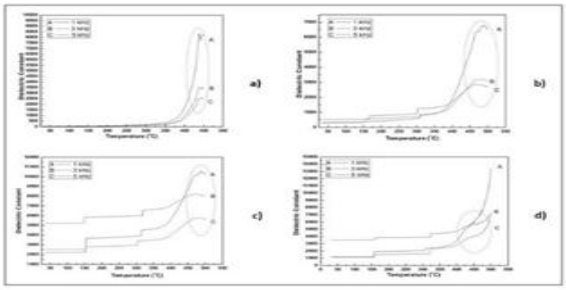


Fig. 6 (a), (b), (c), (d) shows the dielectric constant as a function of temperature at 1 kHz, 3 kHz and 5 kHz for $BiFe_{0.8}Ba_{0.1}Co_{0.1}O_3$, $BiFe_{0.6}Ba_{0.2}Co_{0.2}O_3$, $BiFe_{0.4}Ba_{0.3}Co_{0.3}O_3$ and $BiFe_{0.2}Ba_{0.4}Co_{0.4}O_3$ samples.

## III. RESULTS AND DISCUSSION

Fig.1. shows the flowchart of sample preparation of $BiFe_{0.8}Ba_{0.1}Co_{0.1}O_3$, $BiFe_{0.6}Ba_{0.2}Co_{0.2}$. $O_3$, $BiFe_{0.4}Ba_{0.3}Co_{0.3}O_3$ and $BiFe_{0.2}Ba_{0.4}Co_{0.4}O_3$ materials.Fig.2. describes the full experimental process of formulation of the powder samples. Fig.3 (a), (b), (c), (d) shows the prepared solutions of $BiFe_{0.8}Ba_{0.1}Co_{0.1}O_3$, $BiFe_{0.6}Ba_{0.2}Co_{0.2}O_3$, $BiFe_{0.4}Ba_{0.3}Co_{0.3}O_3$ and $BiFe_{0.2}Ba_{0.4}Co_{0.4}O_3$ samples. Fig.4 (a), (b), (c), (d) shows the synthesized $BiFe_{0.8}Ba_{0.1}Co_{0.1}O_3$, $BiFe_{0.6}Ba_{0.2}Co_{0.2}O_3$, $BiFe_{0.4}Ba_{0.3}Co_{0.3}O_3$ and $BiFe_{0.2}Ba_{0.4}Co_{0.4}O_3$ powder samples. Fig. 5 (a), (b), (c), (d) shows the pellets of the prepared $BiFe_{0.8}Ba_{0.1}Co_{0.1}O_3$, $BiFe_{0.6}Ba_{0.2}Co_{0.2}O_3$, $BiFe_{0.4}Ba_{0.3}Co_{0.3}O_3$ and $BiFe_{0.2}Ba_{0.4}Co_{0.4}O_3$ samples. These formulated powder samples were grinded in an acetone medium, calcined carried out at temperatures of 450°C, 460°C, 470°C, 480°C for 2 hours in a furnace. Fig. 6 (a), (b), (c), (d) shows the temperature variation of dielectric constant of the $BiFe_{0.8}Ba_{0.1}Co_{0.1}O_3$, $BiFe_{0.6}Ba_{0.2}Co_{0.2}O_3$, $BiFe_{0.4}Ba_{0.3}Co_{0.3}O_3$ and $BiFe_{0.2}Ba_{0.4}Co_{0.4}O_3$ samples at 1 kHz, 3 kHz and 5 kHz. The dielectric constant presents a dielectric anomaly at different temperatures at 1 kHz, 3 kHz and 5 kHz for $BiFe_{0.8}Ba_{0.1}Co_{0.1}O_3$, $BiFe_{0.6}Ba_{0.2}Co_{0.2}O_3$, $BiFe_{0.4}Ba_{0.3}Co_{0.3}O_3$ and $BiFe_{0.2}Ba_{0.4}Co_{0.4}O_3$ samples are given in Table 1.

## IV. CONCLUSION

In the present paper, we have successfully synthesized the multiferroic $BiFe_{0.8}Ba_{0.1}Co_{0.1}O_3$, $BiFe_{0.6}Ba_{0.2}Co_{0.2}$-$O_3$, $BiFe_{0.4}Ba_{0.3}Co_{0.3}O_3$ and $BiFe_{0.2}Ba_{0.4}Co_{0.4}O_3$ powder samples and finally pellets formation using solution combustion method, finally these powder samples were calcined at different temperatures.

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