IJCRT.ORG ISSN : 2320-2882

INTERNATIONAL JOURNAL OF CREATIVE RESEARCH THOUGHTS (IJCRT)

An International Open Access, Peer-reviewed, Refereed Journal

Solution Combustion Approach For The Synthesis Of Bife$_{1\text{-}X}$pb$_x$o$_3$ (X = 0, 0.05, 0.15, 0.25, 0.35) Multiferroic Ceramic Samples Using Nitrates And Urea Fuel As Primary Precursors: Studies Related With Dielectric Characteristics

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ABSTRACT:

This paper presents the synthesis of samples such as, $BiFeO_3$, $BiFe_{0.95}Pb_{0.05}O_3$, $BiFe_{0.85}Pb_{0.15}O_3$, $BiFe_{0.75}Pb_{0.25}O_3$ and $BiFe_{0.65}Pb_{0.35}O_3$ multiferroic ceramics via solution combustion method (SCM). These $BiFeO_3$, $BiFe_{0.95}Pb_{0.05}O_3$, $BiFe_{0.85}Pb_{0.15}O_3$, $BiFe_{0.75}Pb_{0.25}O_3$ and $BiFe_{0.65}Pb_{0.35}O_3$ ceramic materials were formulated by using metal nitrates and urea as an initial starting precursors. The temperature dependence of dielectric constant shows a dielectric anomalies at various temperatures in $BiFe_{0.95}Pb_{0.05}O_3$, $BiFe_{0.85}Pb_{0.15}O_3$, $BiFe_{0.75}Pb_{0.25}O_3$ and $BiFe_{0.65}Pb_{0.35}O_3$ ceramics at 1 kHz, 3 kHz and 5 kHz frequencies. Each of these powdered samples were ground in an acetone medium, then calcined and sintered at elevated temperatures before being pelletized.

Keywords: Multiferroics, Pure $BiFeO_3$, Pb doped $BiFeO_3$, SCM, Dielectric, applications.

I. INTRODUCTION:

Electrical and magnetic order occurring simultaneously in multiferroic materials [1]. $BiFeO_3$ has an antiferromagnetic Neel temperature (T_N) of 640 K and a ferroelectric Curie temperature (T_C) of 1100 K [2]. The multiferroic $BiFeO_3$ ceramics have number of potential applications in different sectors such as magnetocapacitive transducers [3], ferroelectric memory storage [4], microelectronic devices [5], photovoltaic devices [6], spin field effect transistors, nanoelectronics [7].

The pure and doped $BiFeO_3$ multiferroic ceramics have been synthesized using different formulation routes such as solid state reaction [8], sol- gel method [9], Pechini method [10], Auto-combustion Technique [11], combustion method [12] and hydrothermal method [13].

II. EXPERIMENTAL PROCEDURE:

The preparation of pure $BiFeO_3$ and Pb-doped samples such as $BiFe_{0.95}Pb_{0.05}O_3$, $BiFe_{0.85}Pb_{0.15}O_3$, $BiFe_{0.75}Pb_{0.25}O_3$ and $BiFe_{0.65}Pb_{0.35}O_3$ ceramics were formulated using solution combustion method (SCM).

MATERIALS:

The principal components are urea, ferric nitrate, lead nitrate, and bismuth nitrate.

SYNTHESIS PROCESS:

The preparation of $BiFeO_3$, $BiFe_{0.95}Pb_{0.05}O_3$, $BiFe_{0.85}Pb_{0.15}O_3$, $BiFe_{0.75}Pb_{0.25}O_3$ and $BiFe_{0.65}Pb_{0.35}O_3$ ceramic samples were carried out using the precursors such as bismuth nitrate, lead nitrate, ferric nitrate as oxidizers while urea was used as a fuel. The oxidizer (O) to fuel (F) ratio was precisely taken into account when producing the sample combination using the oxidizing and reducing valences of the metal nitrates and fuel [14]. Distilled water was used to dissolve stoichiometric amounts of bismuth nitrate, lead nitrate, ferric nitrate, and urea in various beakers. These solutions were then mixed and boiled on a gas burner in a Pyrex dish. Subsequently the constant heating, the water gets evaporated and lastly a combustion takes place with formation of $BiFeO_3$, $BiFe_{0.95}Pb_{0.05}O_3$, $BiFe_{0.85}Pb_{0.15}O_3$, $BiFe_{0.75}Pb_{0.25}O_3$ and $BiFe_{0.65}Pb_{0.35}O_3$ ceramic samples. The experimental procedure was provided by Chaudhari et.al. [15], these powders were grinded in an acetone medium, finally calcined and sintered at 425°C, 450°C, 475°C, 500°C, 525°C for 3 hours in a furnace and lastly carried out for pelletization. The process of producing $BiFeO_3$ ceramic samples is shown in Fig.1. Fig.2 presents the experimental procedure used for developing $BiFeO_3$ ceramics. Figure 3 displays the $BiFeO_3$ samples in powdered form, and Figure 4 displays the $BiFeO_3$ pellet that was formed. The $BiFe_{0.95}Pb_{0.05}O_3$, $BiFe_{0.85}Pb_{0.15}O_3$, $BiFe_{0.75}Pb_{0.25}O_3$, and $BiFe_{0.65}Pb_{0.35}O_3$ ceramic samples are synthesized using the flowchart in Fig.5, and the experimental approach to produce doped $BiFe_{0.95}Pb_{0.05}O_3$, $BiFe_{0.85}Pb_{0.15}O_3$, $BiFe_{0.75}Pb_{0.25}O_3$, and $BiFe_{0.65}Pb_{0.35}O_3$ ceramic samples is shown in Fig. 6. Fig.7 (a), (b), (c), (d) shows the synthesized powder samples of the $BiFe_{0.95}Pb_{0.05}O_3$, $BiFe_{0.85}Pb_{0.15}O_3$, $BiFe_{0.75}Pb_{0.25}O_3$ and $BiFe_{0.65}Pb_{0.35}O_3$ ceramic samples and the developed pellets of the doped $BiFe_{0.95}Pb_{0.05}O_3$, $BiFe_{0.85}Pb_{0.15}O_3$, $BiFe_{0.75}Pb_{0.25}O_3$ and $BiFe_{0.65}Pb_{0.35}O_3$ ceramic samples are displayed in Fig. 8 (a), (b), (c), (d). Fig. 9 (a), (b), (c), (d) and (e) presents the temperature dependence of dielectric constant for the $BiFe_{0.95}Pb_{0.05}O_3$, $BiFe_{0.85}Pb_{0.15}O_3$, $BiFe_{0.75}Pb_{0.25}O_3$ and $BiFe_{0.65}Pb_{0.35}O_3$ samples at 1kHz, 3kHz and 5kHz frequencies. The dielectric studies exhibits a dielectric anomalies in at different temperatures in $BiFe_{0.95}Pb_{0.05}O_3$, $BiFe_{0.85}Pb_{0.15}O_3$, $BiFe_{0.75}Pb_{0.25}O_3$ and $BiFe_{0.65}Pb_{0.35}O_3$ ceramics at different frequencies like 1 kHz, 3 kHz and 5 kHz are given in the table 1.

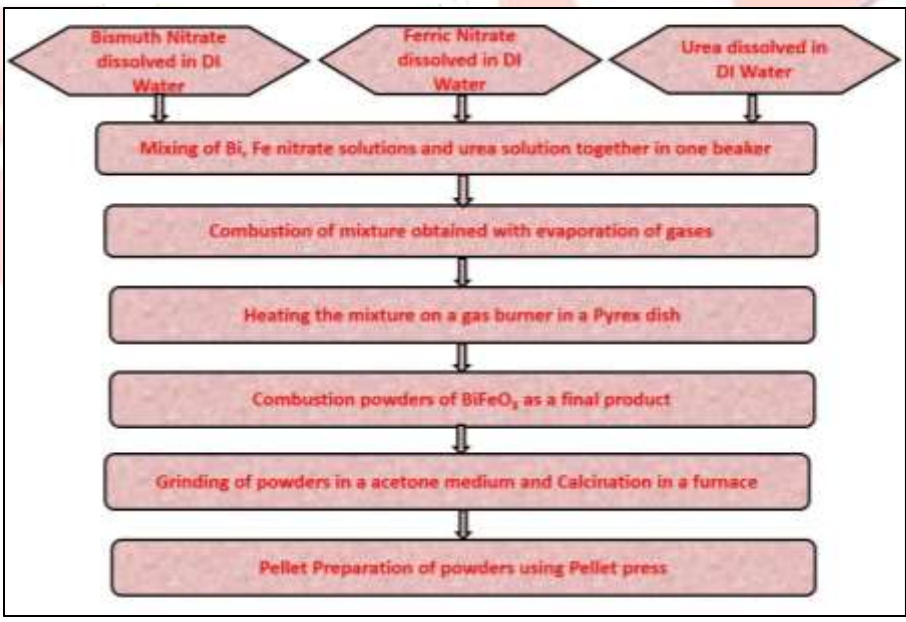

Fig.1. Flowchart of synthesis of $BiFeO_3$ samples by SCM.

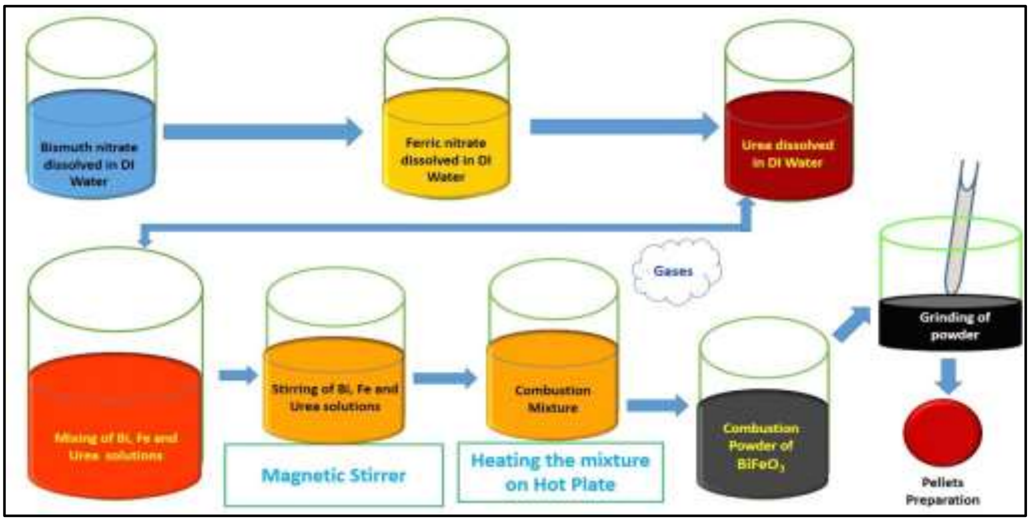

Fig. 2. Experimental procedure of synthesis of $BiFeO_3$ nanoceramic samples by SCM.

Fig.3. Synthesized $BiFeO_3$ powder samples

Fig.4. Pellet of $BiFeO_3$ powder sample.

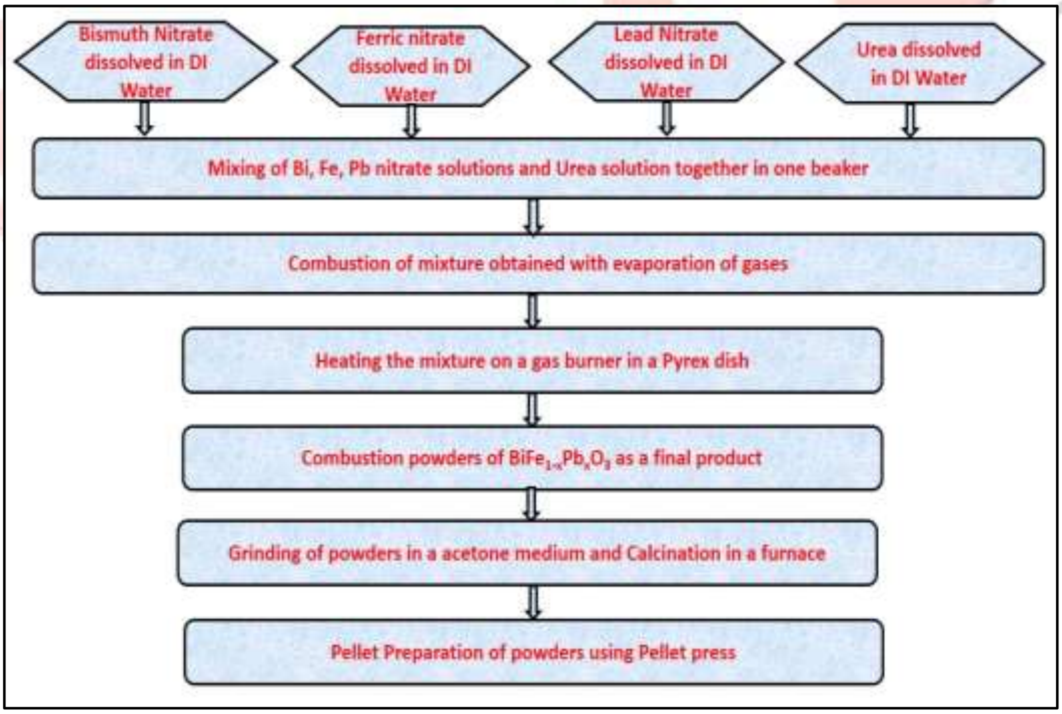

Fig.5. Flowchart of synthesis of $BiFe_{0.95}Pb_{0.05}O_3$, $BiFe_{0.85}Pb_{0.15}O_3$, $BiFe_{0.75}Pb_{0.25}O_3$ and $BiFe_{0.65}Pb_{0.35}O_3$ ceramic samples by SCM.

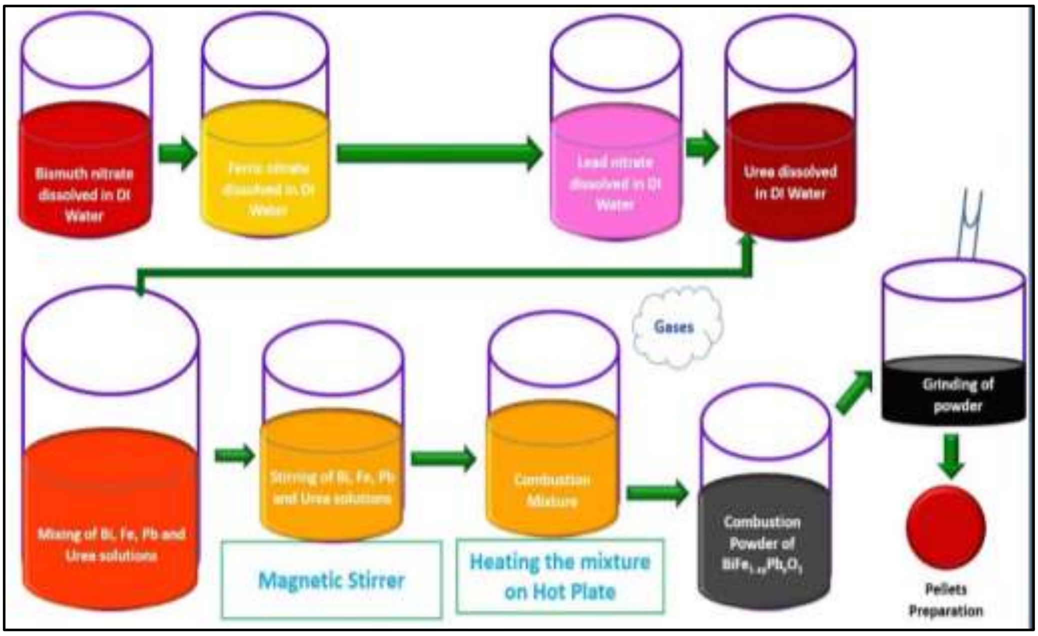

Fig.6. Experimental process of synthesis of $BiFe_{0.95}Pb_{0.05}O_3$, $BiFe_{0.85}Pb_{0.15}O_3$, $BiFe_{0.75}Pb_{0.25}O_3$ and $BiFe_{0.65}Pb_{0.35}O_3$ ceramic samples by SCM.

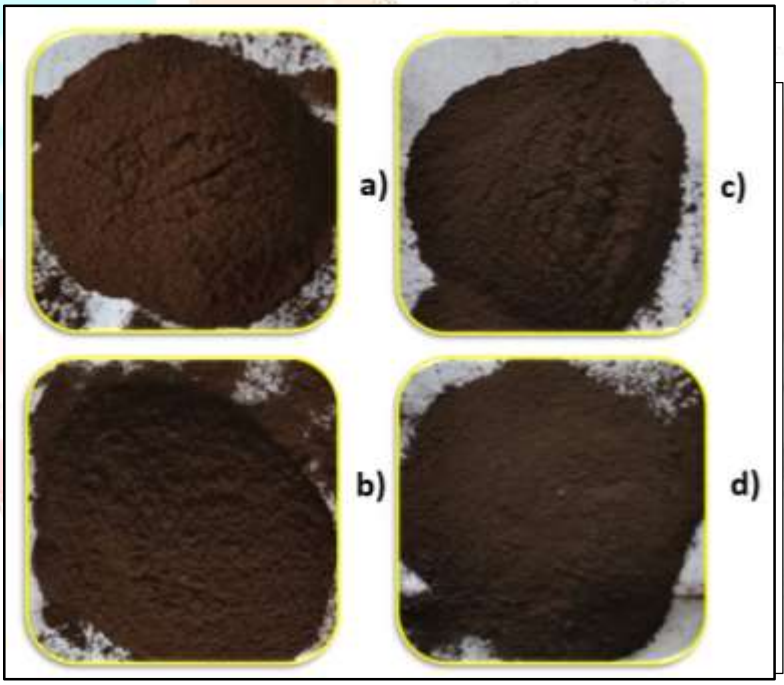

Fig.7. Synthesized powder samples of a) $BiFe_{0.95}Pb_{0.05}O_3$, b) $BiFe_{0.85}Pb_{0.15}O_3$, c) $BiFe_{0.75}Pb_{0.25}O_3$ and d) $BiFe_{0.65}Pb_{0.5}O_3$ ceramic samples.

samples.

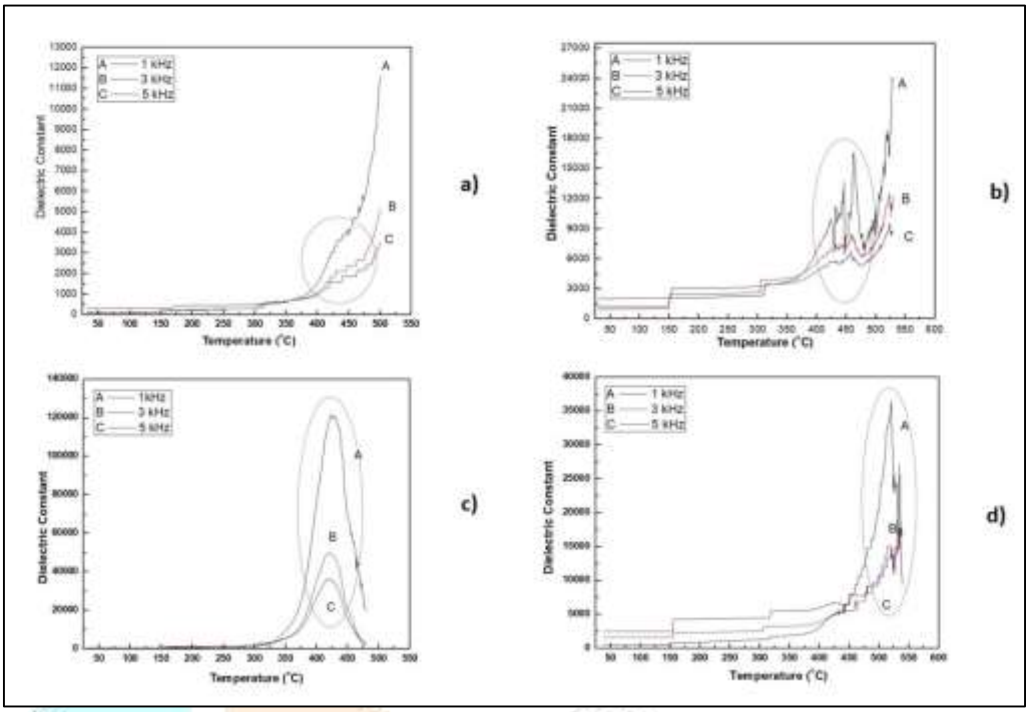

Fig. 9 shows the dielectric constant as a function of temperature a) $BiFe_{0.95}Pb_{0.05}O_3$, b) $BiFe_{0.85}Pb_{0.15}O_3$, c) $BiFe_{0.75}Pb_{0.25}O_3$ and d) $BiFe_{0.65}Pb_{0.5}O_3$ ceramic samples.

Sr. No.	Samples	1 kHz	3 kHz	5 kHz
1.	$BiFe_{0.95}Pb_{0.05}O_3$	450 °C	425 °C	415 °C
2.	$BiFe_{0.85}Pb_{0.15}O_3$	440 °C	450 °C	465 °C
3.	$BiFe_{0.75}Pb_{0.25}O_3$	430 °C	425 °C	410 °C
4.	$BiFe_{0.65}Pb_{0.5}O_3$	520 °C	530 °C	540 °C

Table 1. Temperature dependence of dielectric constant of a) $BiFe_{0.95}Pb_{0.05}O_3$, b) $BiFe_{0.85}Pb_{0.15}O_3$, c) $BiFe_{0.75}Pb_{0.25}O_3$ and d) $BiFe_{0.65}Pb_{0.5}O_3$ samples.

RESULTS AND DISCUSSION:

Fig. 1 displays the flowchart used to create the $BiFeO_3$ ceramic sample. The experimental procedure to make $BiFeO_3$ ceramics is described in Fig.2. The $BiFeO_3$ sample's synthesized powder is shown in Fig.3, and the produced $BiFeO_3$ pellet is shown in Fig.4. In Fig.5, the synthesis mechanism for the ceramic samples $BiFe_{0.95}Pb_{0.05}O_3$, $BiFe_{0.85}Pb_{0.15}O_3$, $BiFe_{0.75}Pb_{0.25}O_3$, and $BiFe_{0.65}Pb_{0.35}O_3$ is displayed. Fig. 6 shows the experimental procedure for creating doped $BiFe_{0.95}Pb_{0.05}O_3$, $BiFe_{0.85}Pb_{0.15}O_3$, $BiFe_{0.75}Pb_{0.25}O_3$ and $BiFe_{0.65}Pb_{0.35}O_3$ ceramic samples. The Fig.7 (a), (b), (c), (d) shows the synthesized powder samples of the $BiFe_{0.95}Pb_{0.05}O_3$, $BiFe_{0.85}Pb_{0.15}O_3$, $BiFe_{0.75}Pb_{0.25}O_3$ and $BiFe_{0.65}Pb_{0.35}O_3$ ceramic samples and Fig. 8 (a), (b), (c), and (d) display the fabricated pellets of the ceramic samples doped with $BiFe_{0.95}Pb_{0.05}O_3$, $BiFe_{0.85}Pb_{0.15}O_3$, $BiFe_{0.75}Pb_{0.25}O_3$ and $BiFe_{0.65}Pb_{0.35}O_3$. Fig. 9 (a), (b), (c), (d) and (e) presents the temperature dependence of dielectric constant for the $BiFe_{0.95}Pb_{0.05}O_3$, $BiFe_{0.85}Pb_{0.15}O_3$, $BiFe_{0.75}Pb_{0.25}O_3$ and $BiFe_{0.65}Pb_{0.35}O_3$ samples at 1kHz, 3kHz and 5kHz frequencies. The dielectric studies exhibits a dielectric anomalies in $BiFe_{0.95}Pb_{0.05}O_3$, $BiFe_{0.85}Pb_{0.15}O_3$, $BiFe_{0.75}Pb_{0.25}O_3$ and $BiFe_{0.65}Pb_{0.35}O_3$ samples at different temperatures at 1 kHz, 3 kHz and 5 kHz frequencies are given in the table 1.

CONCLUSIONS:

We have successfully prepared the pure $BiFeO_3$ as well as the Pb substituted $BiFeO_3$ samples like $BiFe_{0.95}Pb_{0.05}O_3$, $BiFe_{0.85}Pb_{0.15}O_3$, $BiFe_{0.75}Pb_{0.25}O_3$ and $BiFe_{0.65}Pb_{0.35}O_3$ ceramics were formulated through solution combustion method (SCM).

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