

Formulation of $\text{Bi}_{1-x}\text{Ca}_x\text{Fe}_{1-y}\text{Pb}_y\text{O}_3$ ($X, Y = 0.2-0.8$) Multiferroics through Solution Combustion Method

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Abstract:

This paper presents the synthesis of Ca doping at Bi site and Pb doping at Fe site samples such as, $\text{Bi}_{0.8}\text{Ca}_{0.2}\text{Fe}_{0.8}\text{Pb}_{0.2}\text{O}_3$, $\text{Bi}_{0.6}\text{Ca}_{0.4}\text{Fe}_{0.6}\text{Pb}_{0.4}\text{O}_3$, $\text{Bi}_{0.4}\text{Ca}_{0.6}\text{Fe}_{0.4}\text{Pb}_{0.6}\text{O}_3$ and $\text{Bi}_{0.2}\text{Ca}_{0.8}\text{Fe}_{0.2}\text{Pb}_{0.8}\text{O}_3$ multiferroic ceramics via solution combustion method (SCM). These $\text{Bi}_{0.8}\text{Ca}_{0.2}\text{Fe}_{0.8}\text{Pb}_{0.2}\text{O}_3$, $\text{Bi}_{0.6}\text{Ca}_{0.4}\text{Fe}_{0.6}\text{Pb}_{0.4}\text{O}_3$, $\text{Bi}_{0.4}\text{Ca}_{0.6}\text{Fe}_{0.4}\text{Pb}_{0.6}\text{O}_3$ and $\text{Bi}_{0.2}\text{Ca}_{0.8}\text{Fe}_{0.2}\text{Pb}_{0.8}\text{O}_3$ ceramic materials were formulated by using metal nitrates and glycine fuel as an initial starting precursors. All these formulated powder samples were grinded in acetone medium, calcined at higher temperatures. Afterwards, all these powder samples were pelletized in the form of pellets.

Keywords: Multiferroics, Ca and Pb, doping BiFeO_3 , SCM, applications.

Introduction:

Due to the strong interaction of electric, magnetic, and structural order parameters that results in the simultaneous occurrence of ferroelectricity, ferromagnetism, and ferroelasticity [1]. The multiferroic BiFeO_3 shows ferroelectric transition around 1103 K and antiferromagnetic transition at the Neel temperature around 643 K [2]. The multiferroic BiFeO_3 material has number of prime applications in various fields like magnetic field sensors, detectors, photovoltaics, optical filters [3], spin field effect transistors, electrical switching, nanoelectronics, magnetoelectric random access memories (MERAM), high frequency filters, sensors [4], Piezoelectric devices, Photosensitizers [5], multistate storage [6], quantum electromagnets, photonics, electronics [7], satellite communications, smart devices [8].

The number of techniques have been used for the formulation of pure, doped and codoped BiFeO_3 ceramic samples such as citrate method [9], auto-combustion method [10], citrate combustion reaction method [11], hydrothermal technique [12], solid state method [13], sol gel technique [14] and solution combustion synthesis route [15]. In this present article we

have prepared the $\text{Bi}_{0.8}\text{Ca}_{0.2}\text{Fe}_{0.8}\text{Pb}_{0.2}\text{O}_3$, $\text{Bi}_{0.6}\text{Ca}_{0.4}\text{Fe}_{0.6}\text{Pb}_{0.4}\text{O}_3$, $\text{Bi}_{0.4}\text{Ca}_{0.6}\text{Fe}_{0.4}\text{Pb}_{0.6}\text{O}_3$ and $\text{Bi}_{0.2}\text{Ca}_{0.8}\text{Fe}_{0.2}\text{Pb}_{0.8}\text{O}_3$ ceramics samples through solution combustion method.

Experimental Procedure:

The preparation of $\text{Bi}_{0.8}\text{Ca}_{0.2}\text{Fe}_{0.8}\text{Pb}_{0.2}\text{O}_3$, $\text{Bi}_{0.6}\text{Ca}_{0.4}\text{Fe}_{0.6}\text{Pb}_{0.4}\text{O}_3$, $\text{Bi}_{0.4}\text{Ca}_{0.6}\text{Fe}_{0.4}\text{Pb}_{0.6}\text{O}_3$ and $\text{Bi}_{0.2}\text{Ca}_{0.8}\text{Fe}_{0.2}\text{Pb}_{0.8}\text{O}_3$ multiferroic ceramics were formulated using solution combustion method (SCM).

Materials:

The primary materials used are bismuth nitrate, calcium nitrate, ferric nitrate, lead nitrate and the fuel glycine.

Synthesis Process:

The preparation of $\text{Bi}_{0.8}\text{Ca}_{0.2}\text{Fe}_{0.8}\text{Pb}_{0.2}\text{O}_3$, $\text{Bi}_{0.6}\text{Ca}_{0.4}\text{Fe}_{0.6}\text{Pb}_{0.4}\text{O}_3$, $\text{Bi}_{0.4}\text{Ca}_{0.6}\text{Fe}_{0.4}\text{Pb}_{0.6}\text{O}_3$ and $\text{Bi}_{0.2}\text{Ca}_{0.8}\text{Fe}_{0.2}\text{Pb}_{0.8}\text{O}_3$ ceramic samples were carried out using the precursors such as bismuth nitrate, calcium nitrate, ferric nitrate, lead nitrate as oxidizers while glycine was used as a fuel. Using the oxidizing and reducing valences of the metal nitrates and fuel, the oxidizer (O) to fuel (F) ratio was exactly taken consideration when producing the sample mixture [16].

The bismuth nitrate, calcium nitrate, ferric nitrate, lead nitrate and glycine taken in a stoichiometric quantity and were dissolved in a distilled water in a separate beakers after that, these solution were mixed collected and taken in a pyrex dish for heating on a gas burner. Subsequently the constant heating, the water gets evaporated and lastly a combustion takes place with formulation of the $\text{Bi}_{0.8}\text{Ca}_{0.2}\text{Fe}_{0.8}\text{Pb}_{0.2}\text{O}_3$, $\text{Bi}_{0.6}\text{Ca}_{0.4}\text{Fe}_{0.6}\text{Pb}_{0.4}\text{O}_3$, $\text{Bi}_{0.4}\text{Ca}_{0.6}\text{Fe}_{0.4}\text{Pb}_{0.6}\text{O}_3$ and $\text{Bi}_{0.2}\text{Ca}_{0.8}\text{Fe}_{0.2}\text{Pb}_{0.8}\text{O}_3$ ceramic samples. The experimental procedure was provided by Chaudhari et.al. [17], these powders were grinded in an acetone medium and calcination was carried out at 400°C, 430°C, 460°C, 490°C for 2 hours in a furnace and finally pellet formulation. Fig.1 presents the flowchart of synthesis of Ca and Pb doped BiFeO_3 ceramic samples. Fig.2 describes the experimental methodology of formulation of Ca and Pb doped BiFeO_3 ceramics. Fig.3 (a), (b), (c), (d) depicts the synthesized powders of $\text{Bi}_{0.8}\text{Ca}_{0.2}\text{Fe}_{0.8}\text{Pb}_{0.2}\text{O}_3$, $\text{Bi}_{0.6}\text{Ca}_{0.4}\text{Fe}_{0.6}\text{Pb}_{0.4}\text{O}_3$, $\text{Bi}_{0.4}\text{Ca}_{0.6}\text{Fe}_{0.4}\text{Pb}_{0.6}\text{O}_3$ and $\text{Bi}_{0.2}\text{Ca}_{0.8}\text{Fe}_{0.2}\text{Pb}_{0.8}\text{O}_3$ multiferroic ceramics. Fig.4 (a), (b), (c), (d) shows the pellets of the synthesized powder samples such as $\text{Bi}_{0.8}\text{Ca}_{0.2}\text{Fe}_{0.8}\text{Pb}_{0.2}\text{O}_3$, $\text{Bi}_{0.6}\text{Ca}_{0.4}\text{Fe}_{0.6}\text{Pb}_{0.4}\text{O}_3$, $\text{Bi}_{0.4}\text{Ca}_{0.6}\text{Fe}_{0.4}\text{Pb}_{0.6}\text{O}_3$ and $\text{Bi}_{0.2}\text{Ca}_{0.8}\text{Fe}_{0.2}\text{Pb}_{0.8}\text{O}_3$ ceramics.

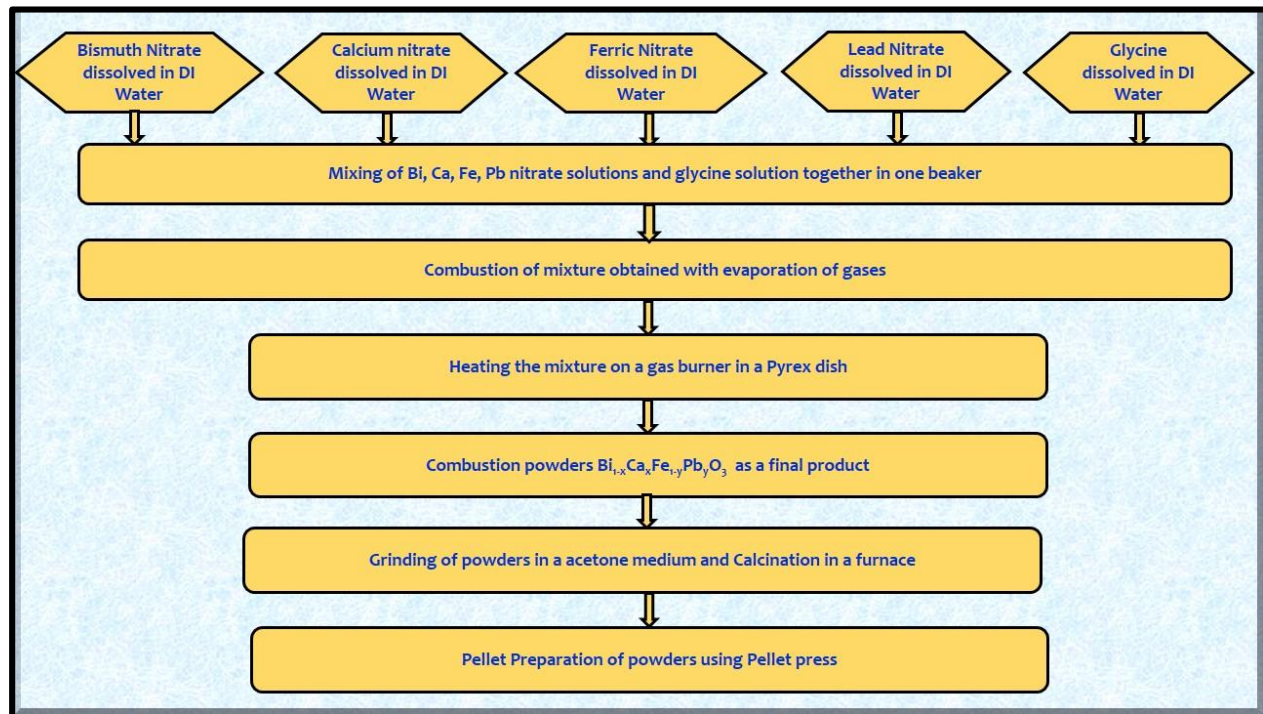


Fig.1. Flowchart of preparation of $\text{Bi}_{0.8}\text{Ca}_{0.2}\text{Fe}_{0.8}\text{Pb}_{0.2}\text{O}_3$, $\text{Bi}_{0.6}\text{Ca}_{0.4}\text{Fe}_{0.6}\text{Pb}_{0.4}\text{O}_3$, $\text{Bi}_{0.4}\text{Ca}_{0.6}\text{Fe}_{0.4}\text{Pb}_{0.6}\text{O}_3$ and $\text{Bi}_{0.2}\text{Ca}_{0.8}\text{Fe}_{0.2}\text{Pb}_{0.8}\text{O}_3$ ceramic samples by SCM.

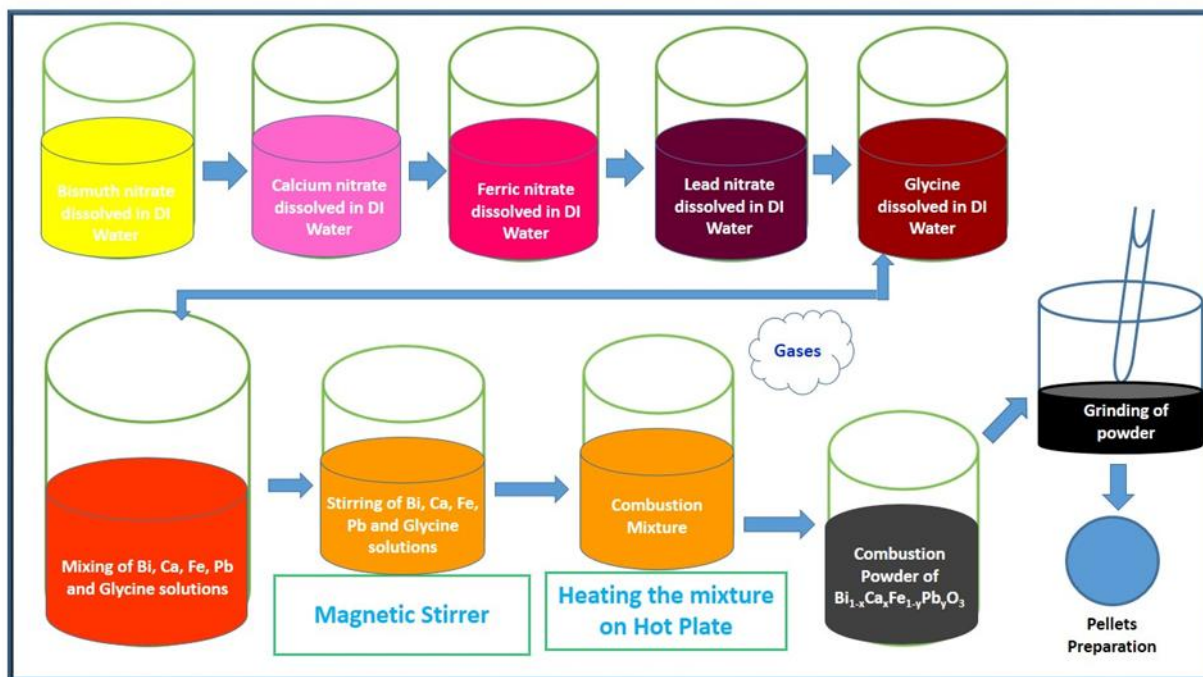


Fig. 2. Experimental procedure for the preparation of $\text{Bi}_{0.8}\text{Ca}_{0.2}\text{Fe}_{0.8}\text{Pb}_{0.2}\text{O}_3$, $\text{Bi}_{0.6}\text{Ca}_{0.4}\text{Fe}_{0.6}\text{Pb}_{0.4}\text{O}_3$, $\text{Bi}_{0.4}\text{Ca}_{0.6}\text{Fe}_{0.4}\text{Pb}_{0.6}\text{O}_3$ and $\text{Bi}_{0.2}\text{Ca}_{0.8}\text{Fe}_{0.2}\text{Pb}_{0.8}\text{O}_3$ ceramic samples by SCM.

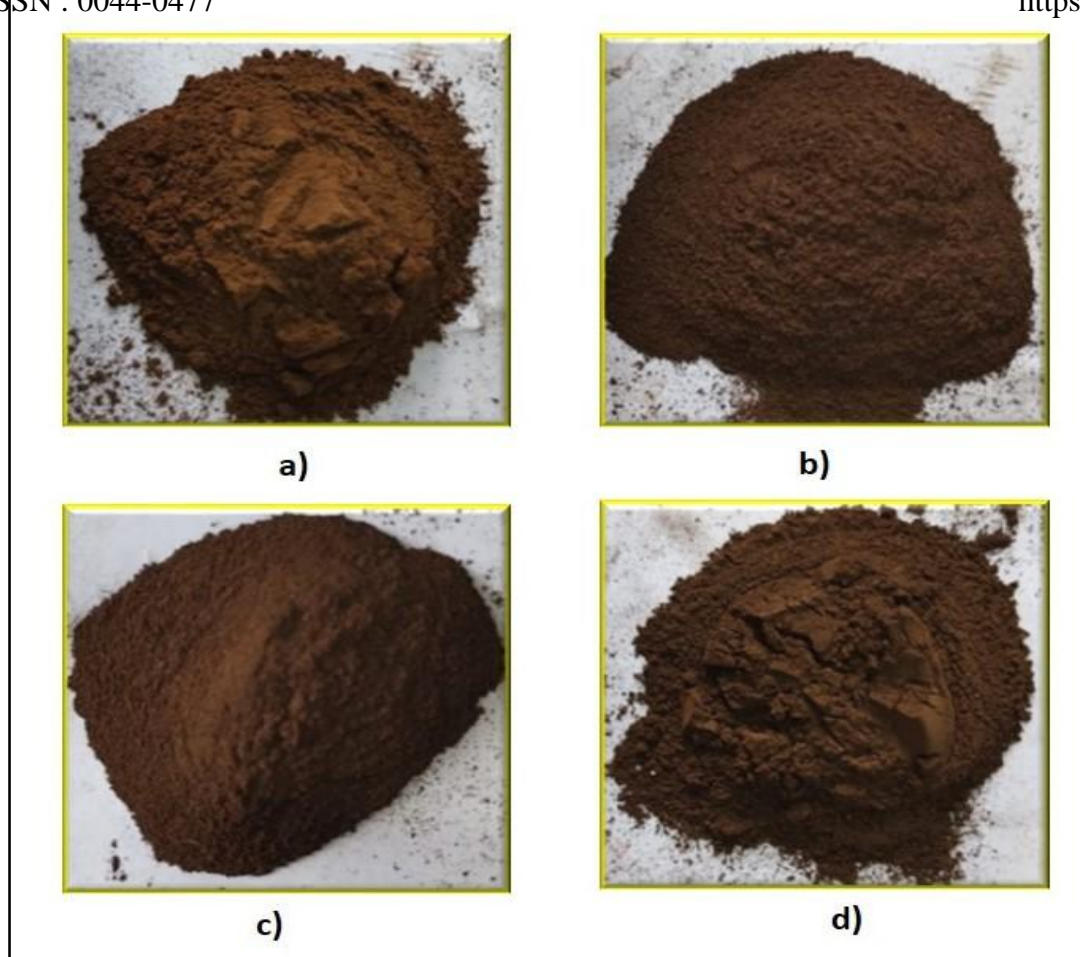


Fig. 3. Synthesized Powder samples of a) $\text{Bi}_{0.8}\text{Ca}_{0.2}\text{Fe}_{0.8}\text{Pb}_{0.2}\text{O}_3$ b) $\text{Bi}_{0.6}\text{Ca}_{0.4}\text{Fe}_{0.6}\text{Pb}_{0.4}\text{O}_3$, c) $\text{Bi}_{0.4}\text{Ca}_{0.6}\text{Fe}_{0.4}\text{Pb}_{0.6}\text{O}_3$ and d) $\text{Bi}_{0.2}\text{Ca}_{0.8}\text{Fe}_{0.2}\text{Pb}_{0.8}\text{O}_3$ ceramics.

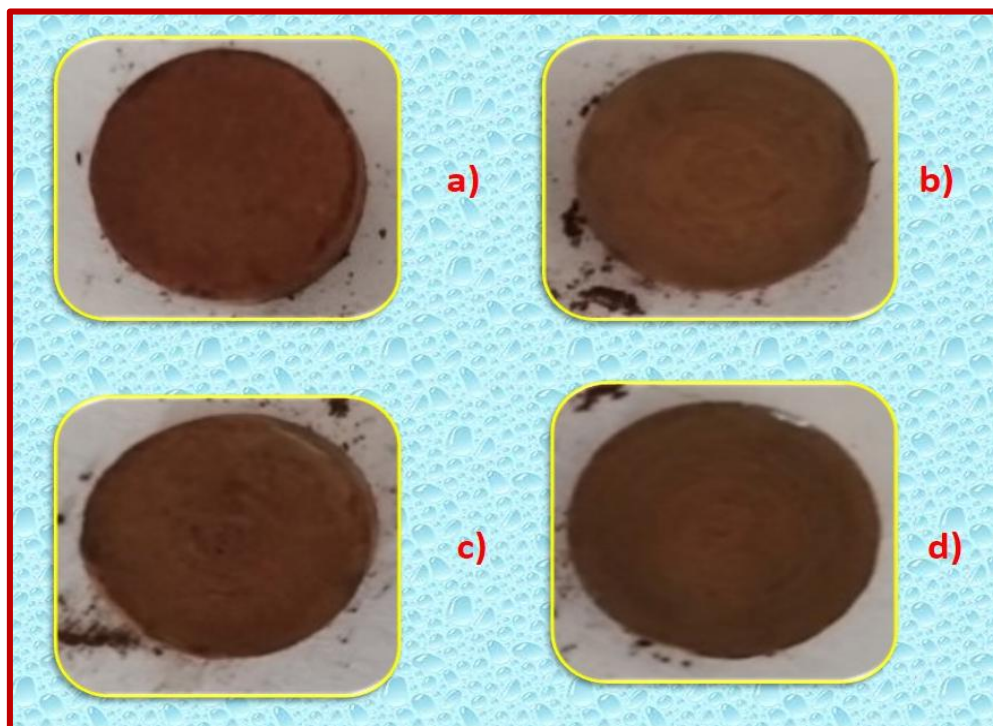


Fig. 4. Pellets of the synthesized powder samples of a) $\text{Bi}_{0.8}\text{Ca}_{0.2}\text{Fe}_{0.8}\text{Pb}_{0.2}\text{O}_3$, b) $\text{Bi}_{0.6}\text{Ca}_{0.4}\text{Fe}_{0.6}\text{Pb}_{0.4}\text{O}_3$, c) $\text{Bi}_{0.4}\text{Ca}_{0.6}\text{Fe}_{0.4}\text{Pb}_{0.6}\text{O}_3$ and d) $\text{Bi}_{0.2}\text{Ca}_{0.8}\text{Fe}_{0.2}\text{Pb}_{0.8}\text{O}_3$ ceramics.

Results and discussion:

Fig.1 presents the flowchart of synthesis of Ca and Pb doped BiFeO₃ ceramic samples. Fig.2 describes the experimental methodology of formulation of Ca and Pb doped BiFeO₃ ceramics. Fig.3 (a), (b), (c), (d) depicts the synthesized powders of Bi_{0.8}Ca_{0.2}Fe_{0.8}Pb_{0.2}O₃, Bi_{0.6}Ca_{0.4}Fe_{0.6}Pb_{0.4}O₃, Bi_{0.4}Ca_{0.6}Fe_{0.4}Pb_{0.6}O₃ and Bi_{0.2}Ca_{0.8}Fe_{0.2}Pb_{0.8}O₃ multiferroic ceramics. Fig.4 (a), (b), (c), (d) shows the pellets of the synthesized powder samples such as Bi_{0.8}Ca_{0.2}Fe_{0.8}Pb_{0.2}O₃, Bi_{0.6}Ca_{0.4}Fe_{0.6}Pb_{0.4}O₃, Bi_{0.4}Ca_{0.6}Fe_{0.4}Pb_{0.6}O₃ and Bi_{0.2}Ca_{0.8}Fe_{0.2}Pb_{0.8}O₃ ceramics.

Conclusions:

We have fruitfully prepared the Ca doping at Bi site and Pb doping at Fe site samples like Bi_{0.8}Ca_{0.2}Fe_{0.8}Pb_{0.2}O₃, Bi_{0.6}Ca_{0.4}Fe_{0.6}Pb_{0.4}O₃, Bi_{0.4}Ca_{0.6}Fe_{0.4}Pb_{0.6}O₃ and Bi_{0.2}Ca_{0.8}Fe_{0.2}Pb_{0.8}O₃ multiferroic ceramics via solution combustion method.

References:

1. Ghanshyam Arya, Ashwani Kumar, Mast Ram, Nainjeet Singh Negi, Structural, Dielectric, Ferroelectric and Magnetic Properties of Mn-Doped BiFeO₃ Nanoparticles Synthesized by Sol-Gel Method, International Journal of Advances in Engineering & Technology, 5 (2), 245-252 (2013).
2. Samar Layek, Santanu Saha, H. C. Verma, Preparation, structural and magnetic studies on BiFe_{1-x}Cr_xO₃ (x = 0.0, 0.05 and 0.1) multiferroic nanoparticles, AIP ADVANCES, 3, 032140 (2013).
3. E. Mostafavi, A. Ataie, Fabrication and characterization of nanostructured Ba-doped BiFeO₃ porous ceramics, Materials Science-Poland, 34 (1), 148-156 (2016).
4. Md. Masud Parvez, Synthesis of Yttrium Doped Bismuth Ferrites Nanoparticles by Modified Pechini Sol-Gel Method, SEU Journal of Science and Engineering, 11 (2), 41-48 (2017).
5. A. Haruna, I. Abdulkadir, S.O. Idris, Photocatalytic activity and doping effects of BiFeO₃ nanoparticles in model organic dyes, Heliyon, 6, e03237 (2020).
6. Heng Wu, Jun Zhou, Lizhi Liang, Lei Li, Xinhua Zhu, Fabrication, Characterization, Properties, and Applications of Low-Dimensional BiFeO₃ Nanostructures, Journal of Nanomaterials, Volume 2014, Article ID 471485, 14 pages (2014).
7. Shun Li, Riad Nechache, Ivan Alejandro Velasco Davalos, Gregory Goupil, Liliya Nikolova, Mischa Nicklaus, Jonathan Laverdiere, Andreas Ruediger, Federico Rosei, Ultrafast

- Microwave Hydrothermal Synthesis of BiFeO₃ Nanoplates, *J. Am. Ceram. Soc.*, 96 (10), 3155–3162 (2013).
8. Omid Amiri, Mohammad Reza Mozdianfar, Mahmoud Vahid, Masoud Salavati-Niasari, Sousan Gholamrezaei, Synthesis and Characterization of BiFeO₃ Ceramic by Simple and Novel Methods, *High Temp. Mater. Proc.* 35 (6), 551–557 (2016).
 9. Dao Viet Thang, Nguyen Manh Hung, Nguyen Cao Khang, Le Thi Mai Oanh, Structural and multiferroic properties of (Sm, Mn) co-doped BiFeO₃ materials, *AIMS Materials Science*, 7 (2), 160–169 (2020).
 10. J. A. Bhalodia, P. V. Kanjariya, S. R. Mankadia, G. D. Jadav, Structural and Magnetic Characterization of BiFeO₃ Nanoparticles Synthesized Using Auto-combustion Technique, *International Journal of ChemTech Research*, 6 (3), 2144-2146 (2014).
 11. Baljinder Kaur, Lakhbir Singh, V. Annapu Reddy, Dae-Yong Jeong, Navneet Dabra, Jasbir S. Hundal, AC Impedance Spectroscopy, Conductivity and Optical Studies of Sr doped Bismuth Ferrite Nanocomposites, *Int. J. Electrochem. Sci.*, 11, 4120 – 4135 (2016).
 12. Yonggang Wang, Gang Xu, Linlin Yang, Zhaohui Ren, Xiao Wei, Wenjian Weng, Piyi Du, Ge Shen, Gaorong Han, Hydrothermal synthesis of single-crystal bismuth ferrite nanoflakes assisted by potassium nitrate, *Ceramics International*, 35, 1285–1287 (2009).
 13. J D Suarez Londono, S Segura Pena, E H Sachica, A F Cruz Pacheco, A Sarmiento Santos, C A Parra Vargas, Structural and magnetic analysis of the Bi_{x-1}Sm_{0x}FeO₃ (x=0.04 and 0.07) system, *IOP Conf. Series: Journal of Physics: Conf. Series.*, 935,012007 (2017).
 14. G. M. Taha, M. N. Rashed, M. S. El-Sadek, M. A. Moghazy, Effect of Preheating Temperature on Synthesis of Pure BiFeO₃ via Sol–Gel Method, *Nanopages*, 1–11 (2019).
 15. V. Sesha Sai Kumar, K. Venkateswara Rao, Ch. Shilpa Chakra, A. Shiva Kishore Goud, T. Krishnaveni, Synthesis of Nanocrystalline Bismuth Ferrite by Solution Combustion Synthesis Method, *Journal of NanoScience, Nanoengineering & Applications*, 1 (2), 52-58 (2011).
 16. S. Saha, S. J. Ghanawat, R. D. Purohit, Solution combustion synthesis of nano particle La_{0.9}Sr_{0.1}MnO₃ powder by a unique oxidant-fuel combination and its characterization, *J. Mater. Sci.*, 41, 1939-1943 (2006).
 17. Yogesh A. Chaudhari, Chandrashekhar M. Mahajan, Ebrahim M. Abuassaj, Prashant P. Jagtap, Pramod B. Patil, Subhash T. Bendre, Ferroelectric and dielectric properties of

nanocrystalline BiFeO₃ multiferroic ceramics synthesized by solution combustion method (SCM), Materials Science-Poland, 31 (2), 221-225 (2013).