SYNTHESIS METHODS OF MULTIFERROIC MATERIALS: A REVIEW

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ABSTRACT: The multiferroic $BiFeO_3$ compound exhibits the multiferroism at room temperature. The bismuth ferrite shows the coexistence of electric as well as magnetic phases are mutually with a perovskite structure. The numerous material formulation methods are described in this review paper for the preparation of $BiFeO_3$ materials, including Mechano-chemical synthesis, rapid liquid sintering, mechanical activation method, hydrothermal synthesis as well as microwave hydrothermal synthesis route.

KEYWORDS: Multiferroics, Bismuth Ferrite, Synthesis methods, Literature review

I. INTRODUCTION

The type of materials described as multiferroics exhibits two or more ferroic phases at the same moment [1]. At room temperature, the bismuth ferrite ($BiFeO_3$) is supposed to be one of the more essential materials that possesses multiferroic properties [2]. The bismuth ferrite is often seen in which the magnetization can be caused via electric field and electric polarization can be driven by an applied magnetic field [3].

It is really a hard task to produce a single phase bismuth ferrite ($BiFeO_3$) material because of appearance of secondary phases formation such as $Bi_{12}(Bi_{0.5}Fe_{0.5})O_{19.5}$, $Bi_{12}NiO_{19}$, Bi_2O_3 and $Bi_2Fe_4O_9$ [4,5]. The bismuth ferrite has a Curie temperature about T_C = 1103 K and a Neel temperature T_N = 643 K [6]. The bismuth iron oxide based materials have been studied extensively in a number of forms such as bulk materials, nanostructures as well as thin films [7]. The bismuth ferrite material has substantial number of applications in various fields like data storage, photocatalyst, communication technology [8], thin-film capacitors, photo electrochemical cells [9], transformers [10]. The bismuth ferrite ($BiFeO_3$) in powder forms were formulated using number of preparative routes such as solution combustion method, sol-gel, solid state, solution chemistry, mechano-chemical, hydrothermal and sonochemical method [4, 11].

The present review paper introduces the synthesis procedure of bismuth ferrite materials using different methods such as mechano-chemical method, rapid liquid sintering, mechanical activation method, hydrothermal and microwave hydrothermal methods.

II. PREPARATION ROUTES:

1. Mechano-chemical method:

Mechano-chemical synthesis technique is used for the formulation of chemical, agricultural and metallurgical materials. This method often employs ball milling or high-energy ball milling (HEBM) [12]. A pestle and mortar were used to perform the first Mechano-chemical reactions [13].

Z. Marinkovic Stanojevic et. al. [14] reported the preparation of bismuth ferrite $BiFeO_3$ nanocrystalline materials using mechano-chemical method followed by ball milling with the appearance of addition of secondary phases like $Bi_2O_2CO_3$, Fe_2O_3 and Bi_2O_3.

Brankovic et.al. described the formulation of $BiMnO_3$ samples using a ball mill based mechanochemical method [15].

Perejon et.al. [16] reported the preparation of bismuth ferrite ceramics using mechanochemical method.

2. Rapid Liquid Sintering

The liquid phase sintering route enables faster synthesis of materials, makes sintering smoother as well as prevents the growth of a secondary phases in the materials [17]. The major technological advances in liquid phase sintering due to emergence of following materials like Cemented carbides, porous bronze, tungsten heavy alloys, copper steels, and cermets were synthesized through the liquid phase sintering process [18].

Kumar et.al.[19] reported the Mn incorporated $BiFeO_3$ ceramics by rapid liquid sintering method and observed the improved electric polarisation in the synthesized ceramics.

The pure and Pb doped $BiFeO_3$ ceramics at different doping concentration levels were formulated through rapid liquid phase sintering and their ferroelectric as well as magnetic properties were reported by Chauhan et.al. [20].

Zhu et.al. [21] reported the preparation of Co and Nd doped bismuth ferrite ceramics through rapid liquid phase sintering route.

Song et. al. reported the dielectric properties of La doped $BiFeO_3$ ceramics formulated via rapid liquid phase sintering method [22].

Singh et. al. reported the formulation of Sm incorporated $BiFeO_3$ ceramics prepared via rapid liquid phase sintering technique [23].

3. Mechanical Activation

The synthesis of Yb doped $BiFeO_3$ ceramics at different doping concentration by applying mechanical activation method by Eva Gil-Gonzalez et. al. [24]. Jartych et.al. [25] reported the formulation of solid solutions of $(BiFeO_3)_{1-x}$-$(BaTiO3)_x$ by using mechanical activation method.

4. Hydrothermal Synthesis

The hydrothermal method is most useful method for the formulation of different materials. Wei et.al.[26] reported the successful preparation of microcrystals of undoped bismuth ferrite $BiFeO_3$ using hydrothermal technique. Kobayashi et al. [27] reported the formulation of single phase fine $BiFeO_3$ particles by employing hydrothermal method using Bi- nitrate and Fe- nitrate in a KOH solution as initial precursors. Syed et.al. [28] reported the occurrence of dielectric anomaly around 1093 K in bismuth ferrite microspheres prepared by using hydrothermal method. Yan et.al. reported the preparation of La-doped bismuth ferrite using hydrothermal method [29]. Hojamberdiev et.al. [30] reported the preparation of bismuth ferrite nanoparticles using hydrothermal method.

5. Microwave Hydrothermal Synthesis

The microwave - hydrothermal route is more effective formulation technique for the preparation of various materials. Biasotto et.al. [31] reported the bismuth ferrite nanoparticles preparation using microwave hydrothermal method. Tan et.al. reported the preparation of bismuth ferrite ceramics by hydrothermal method using KOH mineralizer [32].

III. Conclusion:

This review article describes the various preparative techniques for the synthesis of multiferroic bismuth ferrites**.**

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