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MULTIFERROIC MATERIALS AND MATERIALS PREPARATION# TECHNIQUES

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Abstract

The materials which represents electric as well as magnetic nature together results in coexistence of ferro electricity and ferro magnetism. Due to coexistence of such property makes this class of materials as a key candidate for the technology. Currently research on multiferroic materials increased because most of the novel rare-earth oxides displays a coupling between electric as well as magnetic properties. The multiferroics materials plays an essential role in the growth of non-volatile memory devices and magnetic tunnel junctions. This present article focuses in brief about the multiferroic materials, applications and material preparation routes.

Keywords: Multiferroics, Magneto-electric, Multiferroics, Experimental Techniques, Applications

#General Article

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Introduction

Magnetism is a complex and crucial quantum phenomenon that has been successful to improve our everyday lives. Multiferroicsare useful in information storage devices such as computer hard drives, magnetoresistive random access memory (MRAM). The spontaneous polarization of a material can be reversed in the vicinity of applied electric field in ferroelectric materials. The phase transformation from paraelectric into ferroelectric possesses by ferroelectric materials. The ferroelectric materials are the oxides with a perovskite crystal structure ABX_3 [11]. These materials are useful in severalfieldslike capacitor, non-volatile memory, ferroelectric random access memory, electro-optic materials, switches, oscillators as well as filters. The spontaneous magnetization can be switched and saturated in the direction of applied magnetic field in ferromagnetism.

Multiferroic Materials

Multiferroicdisplays electric as well as magnetic nature together, which results in coexistence of ferroelectricity as well as magnetism in a single phase [1]. In this unique type of materials, there exists a strong coupling between electric and magnetic parameters which consequences into coexistence of magnetism and electricity in a single phase. Additionally, the interaction between electric as well as magnetic parameters, brings forth a unique phenomenon known as magneto-electric (ME)effect. In ME effect the magnetization can be switched using applied electric field and polarization can be changed by applying magnetic field. It gives an additional opportunity for spintronic, data storage devices, electromagnetic coupling, sensors [2], magnetoelectric devices, capacitors, non-volatile logic [3], microwave devices, satellite communication, audio–video devices, digital recording [4], high tech magnetic tape, photovoltaics [5], actuators [6], ferroelectric random-access memories [7], optical filters, photo-electrochemical cells, photo-catalysis [8], photosensitizers [9] andsolar cells [10].

Magnetoelectric Multiferroics

In ME effect the magnetization can be switched using applied electric field and polarization can be changed by applying magnetic field. These materials are very much convenient and the pillars for the design and fabrication of magnetoelectric devices.

The ABO_3 perovskite oxide families have been studied extensively to discover new exciting phenomena. They are known to possess a most diverse and interesting physical properties including electric, magnetic, ferroelastic, metallic, superconducting, insulating, dielectric as well as piezoelectric properties. This diverse set of physical properties can be achieved by structural and compositional modifications. The electrical properties of perovskite oxide materials are really sensitive with oxygen stiochiometry. For example, the stiochiometric $SrTiO_3$ is an insulator but oxygen-deficient $SrTiO_{3-x}$ become conducting or even superconducting (T_c< 0.5 K) [11, 12], paraelectric $SrTiO_3$ can be transformed to ferroelectric $BaTiO_3$ or $PbTiO_3$ by substitution of Sr with Ba or Pb. Some perovskite oxides such as $YMnO_3$ [13] and $BiFeO_3$ [14] are known as multiferroics because it simultaneously possesses ferroelectricity, ferromagnetism and ferroelasticity caused by coupling between electric, magnetic and structural order parameters.

Synthesis Techniques

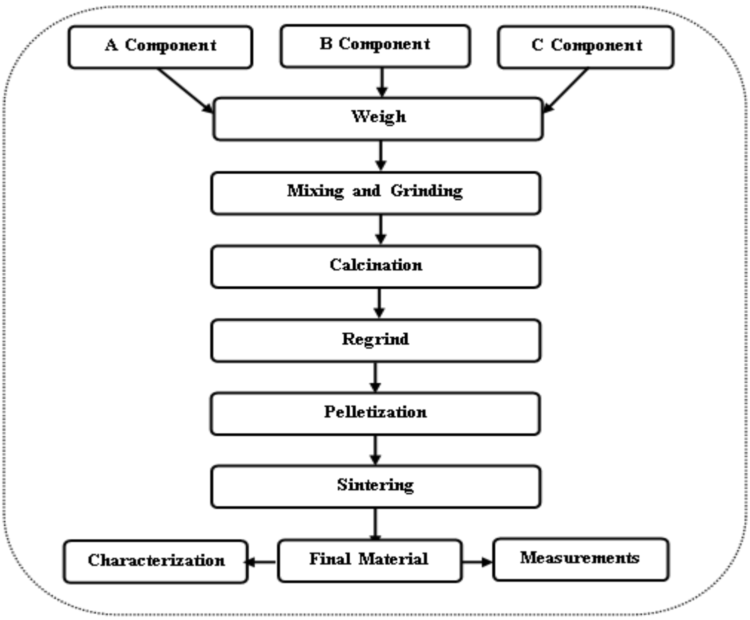
The multiferroic materials are prepared in the form of bulk materials using various methods out of which some methods are described hereby.

1. Solid State Reaction

A solid state reaction is also known as conventional ceramic route method is a synthesis method used for the preparation of polycrystalline ceramic materials. The procedure for the production of materials through solid state reaction is as follows [15].

- The reactants are grinded, mixed and finally pelletized into pellets.
- These pellets are then heated in a chosen atmosphere at higher temperatures, or close to molten point of the sample.
- The heating and mixing is repeated until a homogeneous product formation is complete or when the crystallinity of the material is sufficient.

The reaction rate is limited by nucleation of product phase and diffusion of ions through newly formed product layer. Therefore, the reaction is promoted by a large surface area which is increased by repeated grinding, mixing and by elevated temperatures. The following flowchart summarises the material synthesis procedure using solid state reaction.



2. Precipitation Route

In precipitation process, formation of solid in a solution during chemical reaction and the solid formed is known as precipitate. Due to reaction there is a formation of precipitate takes place in the solution reaction [16].

3. Hydrothermal Method

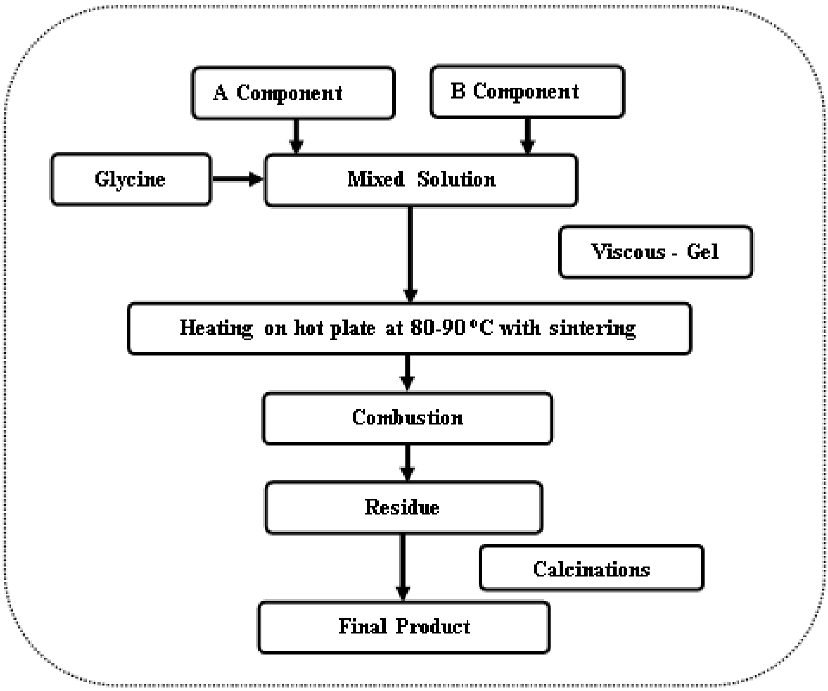
Hydrothermal method also termed as hydrothermal synthesis. It is useful to synthesize single crystal materials depending on the minerals solubility at pressure level in a hot water.To synthesize a materials using the above technique autoclave is required. The material we have to prepare by hydrothermal method must have an accurate known composition, homogeneous, pure and fine [17].

4. High Energy Ball Milling (HEBM)

A ball mill is one of the type of grinder to grind a material into extremely fine powders used in paints, pyrotechniques and ceramics. It is cylindrical used in grinding or mixing such as ores, paints and ceramic raw materials. The flint pebbles, ceramic balls and steel balls is used to the ball mills as well as in mechanical alloy process [18,19].

5. Glycine-Nitrate Combustion Synthesis

Take and weigh, the starting precursors in a desired stiochiometric proportions and mixed with fuel i.e. glycine. Add solvent to this mixed solution and gentle heating on a hot plate, a viscous gel method and finally the material ignites, froths and catches to fire thereafter a residue is formed. This residue is under calcinations and a final product is formed.



6. Microwave Synthesis

These microwave techniques have been proved successfully to reduce the reaction times, improve product yields and able to enhanced the product purities by reducing unwanted side reactions compared to other conventional heating techniques.

In this microwave – solid state synthesis (MW-SS) technique, samples are prepared by solid state reaction using microwaves and generally the synthesis is carried out in a domestic microwave oven. The synthesis of inorganic materials by using such technique is very crucial for several applications [20]. In this technique, a reaction is accelerated due to the selective absorption of microwaves by materials and compounds [21]. Initially, solid precursors are taken and weighed in a desired stochiometric proportions, the reaction is carried out in a domestic microwave oven by providing microwaves with sufficient frequency and a powder material is formed which is our desired product. This powder is then ground, pelletized and sintered at higher temperature with particular time-temperature profile thereafter, carried out for advance studies.

7. Sol-Gel Method

It is also known as wet chemical method or chemical solution deposition. This method has been employed for the preparation of materials such as metal oxides starts from a chemical solution which reacts to produce colloidal particles (sol) [22]. A sol is the dispersion of solid particles (~0.1-1μm) in a liquid where only Brownian method suspends the particles. When both solids and liquids are dispersed uniformly then it becomes a gel.

This sol-gel method consists of two distinct reactions such as hydrolysis of alcohol groups and condensation of resulting hydroxyl groups. The materials prepared by using this technique have several applications in the fields of optics, electronics, energy, space, biosensors, medicine and chromatography technology.This sol-gel technology is useful to prepare bulk, thin films and nano powders.

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