Journal of Magnetism and Magnetic Materials 324 (2012) 4136–4142

Contents lists available at SciVerse ScienceDirect

Journal of Magnetism and Magnetic Materials

journal homepage: www.elsevier.com/locate/jmmm

Modification of composite ceramics properties via different preparation techniques

M.A. Ahmed [a,*], N. Okasha [b], N.G. Imam [c]

[a] Materials Science Laboratory (1) Physics Department, Faculty of Science, Cairo University, Giza, Egypt
[b] Physics Department, Faculty of Girls, Ain Shams University, Cairo, Egypt
[c] Experimental Physics Department, Nuclear Research Center, Atomic Energy Authority, Cairo, Egypt

ARTICLE INFO

Article history:
Received 8 March 2012
Received in revised form
5 July 2012
Available online 3 August 2012

Keywords:
Multiferroics composite
Citrate technique
Ceramic technique
Ferromagnetic property
Ferroelectric property

ABSTRACT

Modifying the proportion of the base composition by substituting with suitable dopents and improving the preparation conditions is expected to change the performance of composites. In the present study, $0.5(Ni_{0.5}Zn_{0.5}Fe_2O_4)/0.5(BaTiO_3)$ composite was prepared by, the conventional ceramic technique and the citrate method. Ceramic particles, when prepared via different routes, would demonstrate different properties, even with the same starting compositions. With the help of X-ray diffraction, scanning electron microscope (SEM), magnetic properties, and electric properties of the composites have been compared. A critical comparison of those methods is needed to make the best choice for given boundary conditions of targeted eventual material properties, raw materials, investment, processing and waste disposal costs.

1. Introduction

Efforts are currently under way to develop materials that have superior properties to those currently existing. This has resulted in the development of composite materials that exhibit remarkable product properties, which are created by the interaction between the constituent phases. There are many advantages to using composite materials over more traditional materials, such as the possibility of weight or volume reduction in a structure while maintaining a comparable or improved performance level [1]. Pyroelectricity, which is achieved by combining a material with a large thermal expansion coefficient with a piezoelectric material, is used in numerous thermal-imaging devices and sensors. The composite can exhibit pyroelectricity even though neither of the constituents does [2]. The magnetoelectric coupling effect in composite materials consisting of a piezoelectric phase and a piezomagnetic phase has recently attracted attention due to the extensive applications for broadband magnetic field probes, electric packaging, acoustic, hydrophones, medical ultrasonic imaging, sensors, and actuators [3–7]. The analytical modeling of such composites provides the opportunity to study the effect of controlling and altering the response of composite structures that consist of composite materials [8].

The multiferroic materials combining several properties in the same structure in order to produce new or enhanced phenomena have stimulated much scientific and technological interest within the scientific community in the last years. One of the most interesting category of multiferroics systems are the magneto-electric (ME) multiferroics, i.e. systems with two order parameters (electrical polarization and magnetization) with a certain degree of coupling among them [9,10]. The study of multiferroics is one of the most active fields of the material science in the last decades [9,11,12]. One method to obtain artificial ME systems is based on the concept of "product property" [13]. According to this principle, a suitable combination of two phases such as a combination of piezomagnetic and piezoelectric phases or magnetostrictive and piezoelectric phases, can yield a desirable ME property. The search for such systems was promoted by practical needs, due to the low ME voltage coefficient of the single-phase materials making them inadequate for applications and by the low temperature range for the ME effect, mostly at cryogenic temperatures [12]. The challenge in preparing such materials is to find equilibrium ferroelectric and magnetic structures preserving both properties close to the room temperature. The main advantages to produce sintered ME composites are related to the easy and cheap fabrication and to the possibility to control the molar ratio of phases, grain size of each phase and densification.

Synthesis routes play a crucial role in preparing the target product and determining its properties. Traditionally, multi-component ceramics have been prepared by solid state methods, which involve physical mixing of hydroxide, oxide, carbonate, nitrate, or sulphate raw materials followed by high temperature treatment, approximately 1100 °C, for a lengthy period to enable the formation of the target compound. This method results in powders with

* Corresponding author. Tel./fax: +20 35693738.
E-mail address: moala47@hotmail.com (M.A. Ahmed).

0304-8853/$ - see front matter © 2012 Elsevier B.V. All rights reserved.
http://dx.doi.org/10.1016/j.jmmm.2012.07.032

coarse-grained, agglomerated structures with very low surface. High temperatures needed for solid state compound formation, give rise to poor sintering behavior, inhomogeneous microstructures, possibly abnormal grain growth and lack of control of cation stoichiometry.

In order to obtain nanoscale ceramics at relatively low temperature, various chemical synthesis techniques for nanoparticles with a proper morphology have been proposed and developed over the last few decades. Usually, the techniques start from the preparation of a precursor solution, in which the ions are well mixed on a molecular scale. Solid precursor compositions are then formed by co-precipitation, hydrothermal treatment [14], sol–gel method [15,16] and spray roasting [17]. The solid precursors may be amorphous or crystalline single phases with a homogeneous or inhomogeneous composition or physical mixtures of such phases. The precursors are heated to cause decomposition and chemical reaction to produce the desired multi-component oxide phase. The nature of the multi-component oxide, and in particular, its morphology will critically depend on solid state morphology developing during the entire synthesis route.

Another group of synthetic techniques seeks to form a single, amorphous solid intermediate that is homogeneous on atomic scale, directly from the liquid precursor. For example, in the citrate processes [18], an intermediate amorphous solid complex forms, is subsequently decomposed and thermally reacted to yield multi-component oxide phases. The combustion process is rapid and may approach direct conversion from the molecular mixture of the precursor solution to the final oxide product, avoiding the formation of crystalline phases that require inter-crystallite diffusion for completion of the reaction. The reported chemical methods often require a high degree of sophistication and control, to obtain the desired powder properties.

In our present study, nanocomposite $0.5(Ni_{0.5}Zn_{0.5}Fe_2O_4)/0.5(BaTiO_3)$ powder has been synthesized by different techniques including conventional ceramic technique and citrate autocombustion technique to throw light on the influence of the different methods on the structural and physical properties of our nanostructured composites. The main focus was to clarify the correlation between the structure and properties of the composites owing to different preparation methods. The understanding of such relations is imperative in order to tailor the optimum method of the nanostructured composites where the challenge in preparing such materials is to find equilibrium ferroelectric and magnetic structures preserving both properties close to the room temperature.

2. Experimental procedures

2.1. Preparation methods

The powders with the nominal composition of $0.5(Ni_{0.5}Zn_{0.5}Fe_2O_4)+0.5\ (BaTiO_3)$ were synthesized by two different methods;

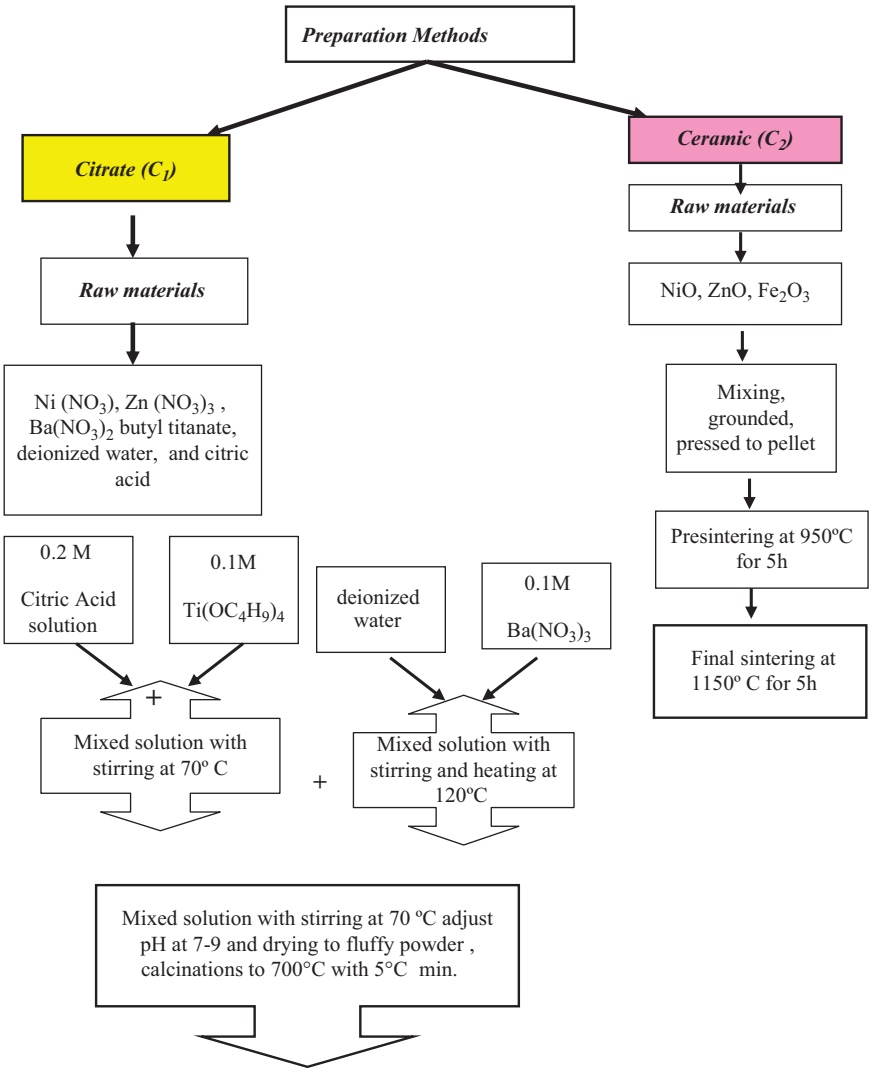

Fig. 1. Flow chart diagram of two different preparation methods (C_1 and C_2) of $0.5(Ni_{0.5}\ Zn_{0.5}\ Fe_2O_4)/0.5(BaTiO_3)$.