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One-dimensional nanoferroic rods; synthesis and characterization

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

[a] Material Science Lab. (1), Physics Department, Faculty of Science, Cairo University, Giza, Egypt
[b] Experimental Physics Department, Nuclear Research Center, Atomic Energy Authority, 13759, Cairo, Egypt
[c] Physics Department, Faculty of Girls, Ain Shams University, Cairo, Egypt

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ABSTRACT

One-dimensional nanoferroic rods of $BaTiO_3$ were synthesized by improved citrate auto-combustion technology using tetrabutyl titanate. X-ray diffraction (XRD), scanning electron microscopy (SEM), energy-dispersive X-ray (EDX), transmission electron microscopy (TEM), atomic force microscopy (AFM) and Fourier transform infrared spectroscopy (FTIR) have been used to characterize the prepared sample. The results indicated that the crystal structure of $BaTiO_3$ is tetragonal phase with an average crystallite size of 47 nm. SEM image gives a cauliflower-like morphology of the agglomerated nanorods. The stoichiometry of the chemical composition of the $BaTiO_3$ ceramic was confirmed by EDX. TEM micrograph exhibited that $BaTiO_3$ nanoparticles have rod-like shape with an average length of 120 nm and width of 43 nm. AFM was used to investigate the surface topography and its roughness. The topography image in 3D showed that the $BaTiO_3$ particles have a rod shape with an average particle size of 116 nm which in agreement with 3D TEM result.

1. Introduction

Nanomaterials have been broadly investigated for the fundamental scientific and technological interests in accessing new classes of functional materials with unique properties and applications [1,2]. Nanoscale one-dimensional materials, such as nanowires, nanorods, and nanotubes, have unique applications in fabrication of nanoscale electronic and photonic devices due to their high surface-to-volume ratio and the quantum confinement effect [2,3]. Ferroic material is that which either displays spontaneous magnetization (ferromagnetic), polarization (ferroelectric), or strain (ferroelastic) [4]. It can be used in variety of applications, such as capacitors and multilayer capacitors (MLCs). Barium titanate is a member of a large group of compounds normally perovskite. This material is very significant electronic materials and one of the most useful dielectric with low losses and ferroelectric properties. Its high purity, super fineness, and the narrow size distribution of the powder correspond to high technological applications such as MLCC [5], positive temperature coefficient (PTC) thermistors [6] and electro-optic devices.

Barium titanate gains its own ferroelectric character due to presence of the noncentrosymmetric unit cells [7–9]. Since nanomaterials show unusual properties compared with the traditional materials, therefore studies upon obtaining nanoparticles of $BaTiO_3$ gradually become attractive and so more attentions have been paid upon this area [8]. Ferroelectric properties and a high dielectric constant make $BaTiO_3$ useful in different arrays of applications [9] such as multilayer ceramic capacitors gate dielectrics waveguide modulators, IR detectors and holographic memory.

It is known that synthesis routes play a crucial role in preparing the target product and determining its properties. There are different synthesis techniques for preparing $BaTiO_3$ nanoparticles [10]. It is usually prepared via the conventional solid state reaction between titanium dioxide and barium carbonate at

* Corresponding author. Experimental Physics Department, Nuclear Research Center, Atomic Energy Authority, P.O. 13759, Cairo, Egypt.
E-mail addresses: nama_emam2018@yahoo.com, imam.eaea@gmail.com (N.G. Imam).

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relatively high temperature around 1100–1300 °C. On the other hand, chemical or wet routes with hydrolysis precursors are being developed to prepare $BaTiO_3$ at relatively low temperature 650–750 °C in order to produce $BaTiO_3$ in nanoscale form. In order to obtain nanoscale ceramics at relatively low temperature, various chemical synthesis techniques have been proposed and developed over the last few decades [11–14]. Usually, the techniques start from the preparation of a precursor solution, where the ions are well mixed on a molecular scale. Solid precursor compositions are then formed by co-precipitation and hydrothermal treatment [11–15].

In the present work, $BaTiO_3$ powder is synthesized via modified citrate auto-ignition technique using butyl titanate. The main goal of study is to investigate the influence of modified preparation method on the structural and microstructure of $BaTiO_3$ nanoparticles. This work contributes to the enhancement of the application possibilities of $BaTiO_3$ by introducing simple and effective synthesis technique which produces nanorod $BaTiO_3$.

2. Experimental techniques

2.1. Preparation of nano- $BaTiO_3$ powder

Citrate method utilizes poly-chelates between the C=O ligands of citric acid (CA) and metal ions. Improved citrate auto-

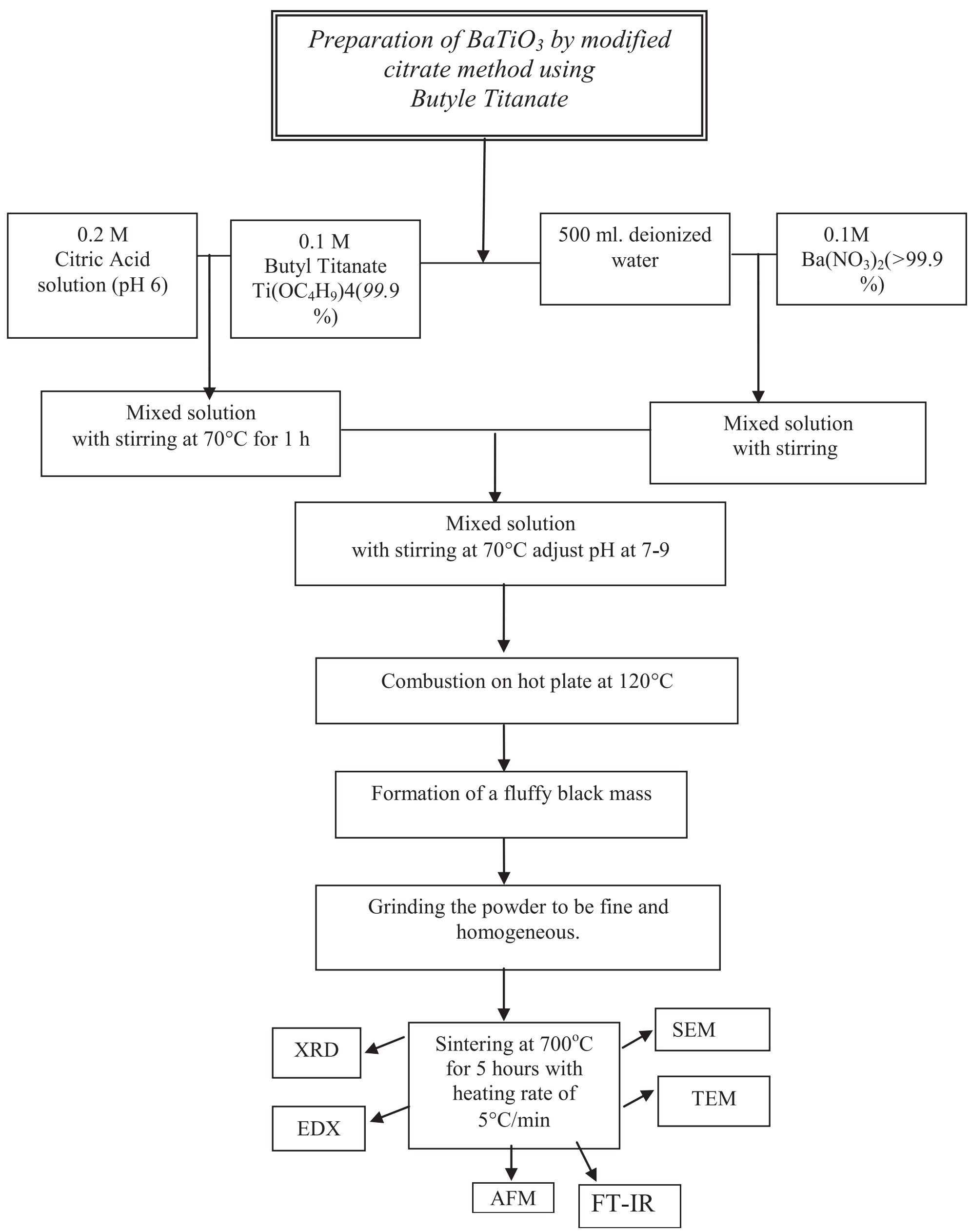

Fig. 1. Flow chart of the citrate autoignition procedure of synthesis $BaTiO_3$ nanoparticles.