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Dielectric and magnetic characterization of barium hexaferrite ceramics

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Abstract

Barium hexaferrite (BHF) was obtained by high energy ball milling using milling power of 4:1 and 10:1 and milling times of 1 h and 10 h, hereinafter referred to as BHF411, BHF4110, BHF101 and BHF1010, respectively. After sintering at 1200 °C, the products were characterized by X-ray diffraction (XRD) and scanning electron microscopy (SEM). The magnetic and dielectric properties were examined using a permeameter (8.4 kOe) and an impedance analyzer (300 MHz–1.1 GHz), respectively. The properties of coercivity and magnetic saturation of the BHF41 samples increased with milling time, but decreased over time for BHF101. At low frequencies, both BHF41 samples showed a slight variation in relative permittivity (ε'), but this property remained almost constant at high frequencies. On the other hand, the initial permittivity of BHF101 samples varied significantly at low frequencies, but was almost constant at high frequencies. All the BHF samples showed a decreasing behavior of tanδ at the highest frequencies.

Keywords: C. Magnetic properties; C. Dielectric properties; Barium hexaferrites

1. Introduction

Type M hexaferrites (e.g., $BaFe_{12}O_{19}$) present a hexagonal crystal structure that makes them attractive for applications such as magnetic recording, microwave devices, electrical machines and sensors [1–2]. Due to their crystal structure, barium hexaferrites (BHF) have high saturation magnetization, chemical stability, high coercivity, high uniaxial magnetic anisotropy and low production cost [3–5]. The particle size, morphology and magnetic properties of barium hexaferrite are strongly dependent on the preparation conditions and nature of applied precursors. In fact, several methods such as co-precipitation, sol–gel combustion and micro-emulsion have been employed to process ultrafine barium hexaferrite particles [6–8].

The properties of hexaferrites obtained by high-energy ball milling result from the large specific area of grain boundaries and the high volume fraction of atoms located at these boundaries [9]. The repeated fracturing and welding of powder particles during milling increases the contact between fresh surfaces. Increments of these contacts, reduction of particle size and storage of strain energy in particles are the most important reasons for increasing the kinetics of reactions and lowering the reaction temperature [9]. By controlling the milling power (MP) and milling time (MT), allied to the sintering temperature, high-energy ball milling processing is also a promising technique for producing a wide range of nanostructures and magnetic nanocomposites [10–14].

The magnetic properties of barium hexaferrite depend on the structure of its magnetic domains. To reach magnetic

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saturation, the magnetization within each domain must be aligned with the direction of the applied field. A high degree of reversibility of the movement of the domain walls is closely tied to low coercivity, hysteresis loss and significant low-field permeability [15–16].

The dielectric properties of hexaferrites depend on factors such as the method of preparation, sintering temperature and chemical composition. The dielectric constant decreases when the frequency increases; which occurs very rapidly at low frequencies and slowly at high frequencies [17]. In ceramic materials, the loss tangent is related to the inertia of the movement of electric charge, which causes a time delay in the current that follows the applied field and depends on the ability of the charges to follow an applied external field.

In this study, we prepared barium hexaferrite (BHF) samples by high energy ball milling using different milling powers (MP) and milling times (MT). Further, we compared the dielectric and magnetic properties of these BHF samples.

2. Materials and methods

Barium hexaferrite ($BaFe_{12}O_{19}$) powders were obtained by mixing barium carbonate (99.37% purity) and iron oxide (98.1% purity). The starting materials were mixed in stoichiometric

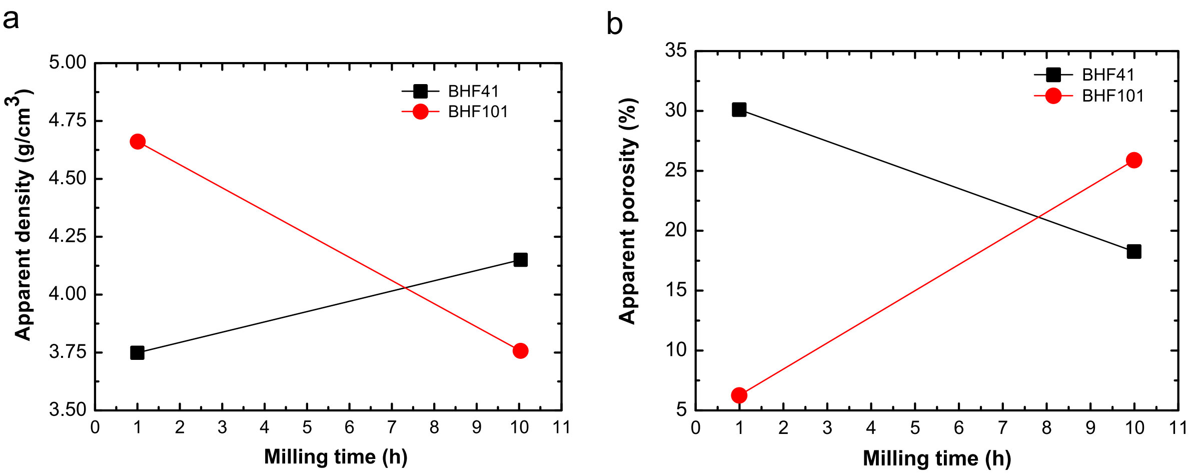

Fig. 1. (a) Density; and (b) porosity of BHF samples sintered at 1200 °C as a function of milling time.

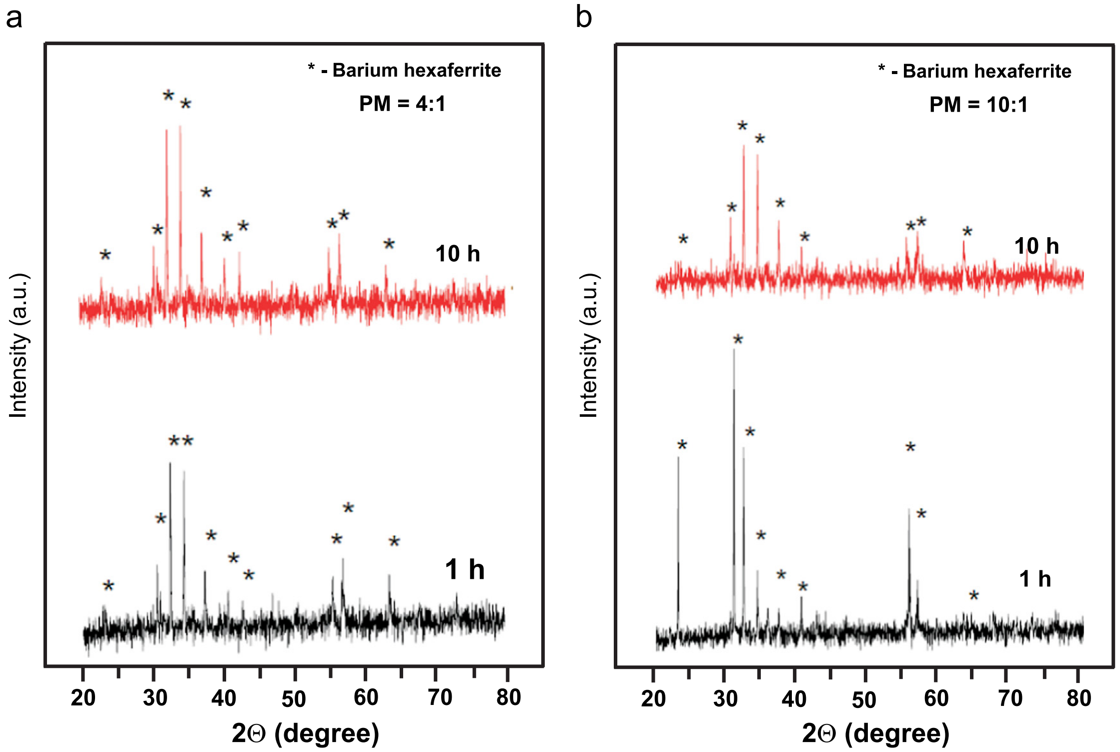

Fig. 2. XRD diffractograms of the following BHF samples after sintering at 1200 °C (a) BHF411 and BHF4110; (b) BHF101 and BHF1010.