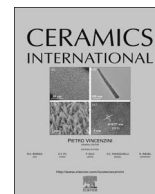




Contents lists available at ScienceDirect

Ceramics International

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

Effect of La-Ni substitution on structural, magnetic and microwave absorption properties of barium ferrite

Pan Shen^a, Juhua Luo^{b,*}, Yue Zuo^b, Zhu Yan^b, Kang Zhang^b

^a School of Material Science and Engineering, Changzhou University, Changzhou 213164, China

^b School of Materials Engineering, Yancheng Institute of Technology, Yancheng 224051, China

ARTICLE INFO

Keywords:

Barium ferrite
Chemical synthesis
Magnetic measurements
Microwave absorption

ABSTRACT

In this paper, La-Ni substituted barium ferrite nanoparticles were prepared by a co-precipitation method. The morphology, structure, magnetic and microwave absorption properties of samples were accomplished by X-ray diffraction (XRD), Fourier transform infrared spectroscopy (FTIR), transmission electron microscope (TEM), vibrating sample magnetometer (VSM) and vector network analysis. From the results evaluation, it can be seen that the magnetoplumbite structure for all of the samples have been formed and the average crystallite sizes of $\text{Ba}_{1-x}\text{La}_x\text{Fe}_{12-x}\text{Ni}_x\text{O}_{19}$ nanoparticles within in the range of 50.9–65.5 nm. $\text{Ba}_{0.9}\text{La}_{0.1}\text{Fe}_{11.9}\text{Ni}_{0.1}\text{O}_{19}$ exhibits a remarkable reflection loss of -13.5 dB at 13.05 GHz with a matching thickness of 1.5 mm. The reflection loss results indicate that $\text{Ba}_{0.9}\text{La}_{0.1}\text{Fe}_{11.9}\text{Ni}_{0.1}\text{O}_{19}$ nanoparticles may be used as a potential for thin microwave absorbers.

1. Introduction

In recent years, the rapidly development of electronics industry coming into microwave frequency range, which has resulted in electromagnetic wave interference (EMI) among devices and electromagnetic compatibility problems in both civil and military application [1–6]. In order to address the problem posed by EMI, thinner microwave absorbing materials can be a good solution [7]. The researchers are interested to consider the ferrites due to their obvious advantages [8]. Among all ferrites, barium ferrite with hexagonal magnetoplumbite structure, has been studied as great electromagnetic wave absorbers due to their high stability, low cost, high electrical resistivity and high microwave magnetic loss [9,10]. It is well known that microwave attenuation is dominated by electric and magnetic dipoles. A favorable electromagnetic match between the relative permittivity and permeability is beneficial to obtain excellent microwave absorption [11].

As is well known, it is an effective way to change the microwave absorption properties of barium ferrite by using other metal ions to replace the barium ions (Ba^{2+}) and ferric ions (Fe^{3+}) [12–15]. Aminreza Baniasadi and his co-workers [3] have studied the substituted M-type Sr-ferrite and minimum reflection loss of -36.13 dB at 13.43 GHz. Reza Shams Alam and his partners have studied the nickel ions (Ni^{2+}) and manganese ions (Mn^{2+}) were employed to partially replace the cobalt ions (Co^{2+}) in $\text{BaCoTiFe}_{10}\text{O}_{19}$, it was found that the

composite ($\text{Ba}(\text{MnNi})_{0.2}\text{Co}_{0.6}\text{TiFe}_{10}\text{O}_{19}$) possessed a minimum reflection loss of -52.8 dB at 13.4 GHz with a matching thickness of 1.8 mm. Moreover, the maximum attenuation could reach -69 dB when its thickness was 1.8 mm, and also the bandwidth less than -20 dB was ranging from 13.2GHz to 18 GHz [16].

In this study, the elements of La^{3+} and Ni^{2+} are chosen to replace Ba^{2+} ions and Fe^{3+} ions, respectively. The structure, ferromagnetism, electromagnetic and microwave absorption properties of La-Ni substituted barium ferrite nanoparticles are discussed. Subsequently, the complex permittivity, permeability and microwave absorbing performance are discussed in detail.

2. Experimental

$\text{Ba}_{1-x}\text{La}_x\text{Fe}_{12-x}\text{Ni}_x\text{O}_{19}$ hexaferrite ($x=0, 0.05, 0.1, 0.15, 0.2$) were synthesized by the chemical co-precipitation method. The stoichiometric amount of chloride compounds of Ba, Fe, La and Ni with chemical compositions of $\text{Ba}(\text{NO}_3)_2$, $\text{Fe}(\text{NO}_3)_3$, $\text{La}(\text{NO}_3)_3$ and $\text{Ni}(\text{NO}_3)_2$ were dissolved in deionized water at 60 °C to form a homogeneous solution. The mixed solution was added dropwise to the aqueous solution of NaOH and Na_2CO_3 using vigorous stirring to obtain the precipitate. Then the pH of the solution was adjusted slowly to 10 by adding drop wise NaOH solution (1 mol/L) to form a brownish yellow suspension of the hybrid complex. After precipitation, the precipitate was obtained by filtrating and washed with distilled water and ethanol.

* Corresponding author.

E-mail address: luojuhua@163.com (J. Luo).

<http://dx.doi.org/10.1016/j.ceramint.2016.12.107>

Received 21 October 2016; Received in revised form 1 December 2016; Accepted 20 December 2016
0272-8842/ © 2016 Elsevier Ltd and Techna Group S.r.l. All rights reserved.

Then the precipitate was dried at 60 °C in vacuum for 24 h to obtain the precursor. The precursor was calcined at 900 °C for 2 h to obtain the $\text{Ba}_{1-x}\text{La}_x\text{Fe}_{12-x}\text{Ni}_x\text{O}_{19}$.

3. Characterization

The resulting powder was characterized by X-ray powder diffraction (XRD) using a diffractometer (RIGAKU, model D/max) with $\text{CuK}\alpha$ radiation of wavelength $\lambda=1.5418 \text{ \AA}$. Its morphology was studied with a field emission scanning electron microscope (JEOL, model JSM-7001F) and a transmission electron microscope (JEOL, model JEM 2001). Fourier transform infrared spectroscopy (FTIR) for the prepared samples were carried out using the infrared spectrophotometer (NICOLET, model NEXUS 670) in the range from 4000 to 400 cm^{-1} . Magnetization measurements were taken at room temperature (293 K) using a vibrating sample magnetometer (LDJ, model 9600-1). The measured samples were dispersed in paraffin homogeneously with a sample-to-paraffin weight ratio of 1:2, then the mixtures were pressed into cylindrical-shaped specimens ($\Phi_{\text{out}}=7.00 \text{ mm}$ and $\Phi_{\text{in}}=3.04 \text{ mm}$) and thickness of about 2 mm. The complex permittivity and permeability of the samples were measured by a microwave vector network analyzer (AGILENT, model N5244A) in the frequency range 2–18 GHz by using coaxial reflection/transmission technique.

4. Results and discussion

The XRD patterns of all the samples recorded at room temperature are presented in Fig. 1. The obtained peaks in XRD patterns were matched with the standard pattern of the Barium hexaferrite (PDF Card #33-1340). XRD patterns (up to $x=0.15$) confirm the formation of single phase hexagonal ferrites. On the contrary, when x reaches 0.2, the peaks of $\alpha\text{-Fe}_2\text{O}_3$ are also observed.

The lattice parameters (a and c) and unit cell volume of the prepared samples are calculated from the following equations [17].

$$d = \left(\frac{4}{3} \cdot \frac{h^2 + hk + k^2}{a^2} + \frac{l^2}{c^2} \right)^{-1/2} \quad (1)$$

$$V = 0.8666a^2c \quad (2)$$

where d is the D -spacing of the line in XRD patterns and h, k, l are the Miller indices.

The average crystallite size (D) of the prepared samples was calculated using Debye-Scherrer equation.

$$D = \frac{k\lambda}{\beta \cos \theta} \quad (3)$$

where D is the average crystallite size, k is a dimensionless shape

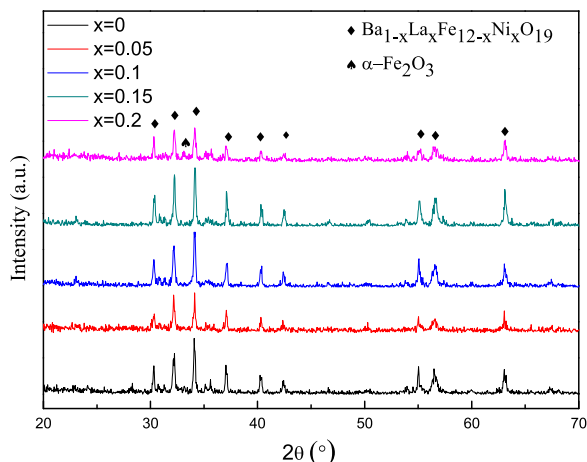


Fig. 1. XRD patterns of $\text{Ba}_{1-x}\text{La}_x\text{Fe}_{12-x}\text{Ni}_x\text{O}_{19}$ at various amounts of substitution.

Table 1
Lattice constants (a, c), ratio (c/a), cell volume and crystallite size of $\text{Ba}_{1-x}\text{La}_x\text{Fe}_{12-x}\text{Ni}_x\text{O}_{19}$ ($x=0, 0.05, 0.1, 0.15, 0.2$).

$\text{Ba}_{1-x}\text{La}_x\text{Fe}_{12-x}\text{Ni}_x\text{O}_{19}$	a (Å)	c (Å)	Ratio		Crystallite size (nm)
			c/a	Unit cell volume V (Å ³)	
$x=0$	5.9025	23.2818	3.944	702.9	65.5
$x=0.05$	5.8922	23.2282	3.942	698.9	62.0
$x=0.1$	5.8906	23.2081	3.940	697.9	60.5
$x=0.15$	5.8891	23.1955	3.939	697.1	57.3
$x=0.2$	5.8874	23.1719	3.936	696.0	50.9

factor, λ is the wavelength of the X-ray radiation (1.5406 Å), β is the peak width of the diffraction peaks profile at half of maximum height and θ is the diffraction angle.

Table 1 shows the lattice parameter (a and c), ratio (c/a), unit cell volume and the average crystallite size of all samples. It can be seen from Table 1, the value of lattice constant a is basically unchanged, while the lattice constant c , unit cell volume and the average crystallite size of all samples decreases decreased with the increase in substitution of La^{3+} and Ni^{2+} . The observed decreasing trend in the lattice constant c , unit cell volume and the average crystallite size can be ascribed to the smaller ionic radius of metal ions as well as the amount of substituted La-Ni ions in the structure. Although the radius of Ni^{2+} (0.69 Å) is slightly larger than Fe^{3+} (0.65 Å), but the radius of La^{3+} (1.06 Å) is smaller than Ba^{2+} (1.35 Å). Therefore, the lattice constant c and unit cell volume gradually decrease with increase in La-Ni contents. Doped La^{3+} and Ni^{2+} into the crystal lattice of barium ferrite will produce lattice distortion. The internal stress produced by lattice distortion will prevent the growth of the crystal lattice and the grain size becomes smaller. Moreover, $\alpha\text{-Fe}_2\text{O}_3$ phase state appeared when $x=0.2$, it will restrain the growth of crystallite size. The lattice constant ratio c/a may be used to quantify the structure type and M-type hexaferrite structure might be assumed if the lattice constant ratio is observed to be lower than 3.98. From Table 1, the lattice constant ratio c/a is in range from 3.944 to 3.936 and confirmed the formation M-type hexaferrite structure. It is consistent with the standard pattern for hexagonal barium ferrite.

Fig. 2 shows the FTIR spectra of barium hexaferrite with various quantities of the dopant. The strong absorption peaks at 436 cm^{-1} and 590 cm^{-1} are attributed to Fe-O stretching vibration band in octahedral and tetrahedral clusters [3,18]. The absorption peak at about 547 cm^{-1} is distinguishable associated with Ba-O stretching vibration band [19]. The peaks appearing around 1635 cm^{-1} are due to asymmetric stretching of carbonyl groups ($\text{C}=\text{O}$). The peaks in the range of 1100–1500 cm^{-1} related to M-O-M bands (Metal-Oxygen-Metal) such as Ni-O-Ni and Fe-O-Fe bands [20]. The relatively broad peaks at about

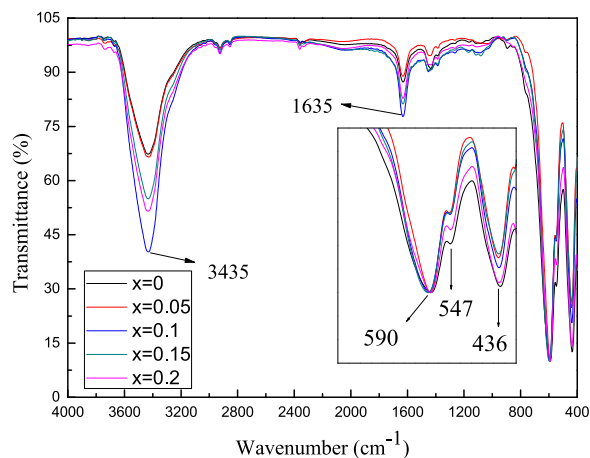


Fig. 2. FTIR spectra of barium hexaferrite with various quantities of the dopant.

Download English Version:

<https://daneshyari.com/en/article/5438611>

Download Persian Version:

<https://daneshyari.com/article/5438611>

[Daneshyari.com](https://daneshyari.com)