Synthesis, Characterization, and Microwave Absorption Properties of $Bi_{1-x}Zn_xFeO_3$ Nanoparticles

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Abstract

$BiFeO_3$ multiferroic materials have been widely applied into microwave absorbing area due to its coexistence ferroelectric and ferromagnetic property. In the present work, the sol-gel method were conducted to prepare the $Bi_{1-x}Zn_xFeO_3$ (x=0, 0.1, 0.15 and 0.2) nanoparticles. Moreover, the X-ray diffraction (XRD), scanning electron microscope (SEM), vector network analysis (VNA) were conducted to characterize the as-prepared samples. Consequently, testing results indicate that the $Bi_{1-x}Zn_xFeO_3$ nanoparticles were successfully obtained. And the electromagnetic performance of the $Bi_{1-x}Zn_xFeO_3$ were adjusted by changing the doping ratio. Moreover, when the proportion is 15%, the as-prepared samples possess best microwave absorption ability.

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Introduction

Multiferroic materials have attracted tremendous attention in recent years due to their potential applications in microelectronic devices, quantum electromagnets and energy storage, and significant efforts have been drawn on understanding their intrinsic properties, mechanical response and failure mechanisms. Furthermore, the BiFeO3 have turned out to be the most widely used multiferroic materials. In this work, we utilized the sol-gel method to prepare the Bi1-xZnxFeO3 (x=0.1, 0.15, 0.2) samples, and the dielectric properties of the as-prepared samples are discussed.

Results and discussion

The XRD patterns of the Zn-substituted BFO are presented in figure 1. The structure and morphology of the samples were investigated by X-ray diffraction (XRD, Rigaku Ultima IV, Cu-Ka) in the range of 15°~90° with a scan speed of 3 s and a step size of 0.02° in 2θ. The results indicate that the Zn^{2+} have replaced the Bi^{3+}.

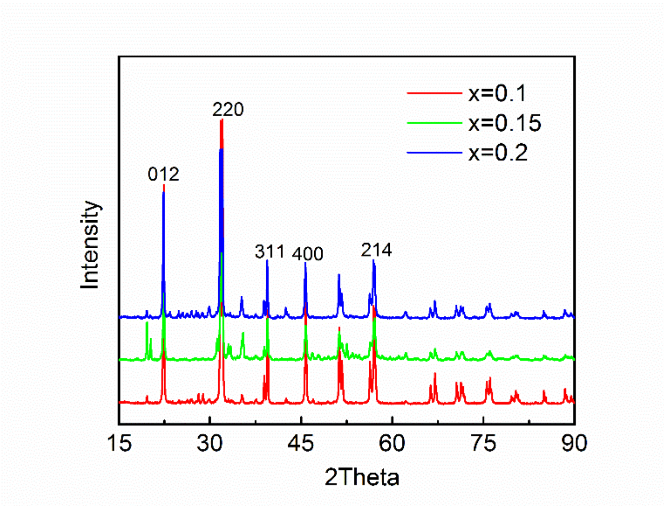

Figure 1 XRD patterns of the $Bi_{1-x}Zn_xFeO_3$ (x=0.1, 0.15 and 0.2) nanoparticles

FESEM images of the $Bi_{1-x}Zn_xFeO_3$ (x=0.1, 0.15 and 0.2) nanoparticles are demonstrated in Fig. 2. It is obvious that the $Bi_{1-x}Zn_xFeO_3$ samples all well-crystallized and have uniform particle size distribution. The average particle sizes are roughly 130, 110 and 100 nm for the $Bi_{0.9}Zn_{0.1}FeO_3$, $Bi_{0.85}Zn_{0.15}FeO_3$ and $Bi_{0.8}Zn_{0.2}FeO_3$ samples, respectively. Therefore, it can be gained that the particle sizes does not have a significant impact on the electromagnetic performance of the samples.

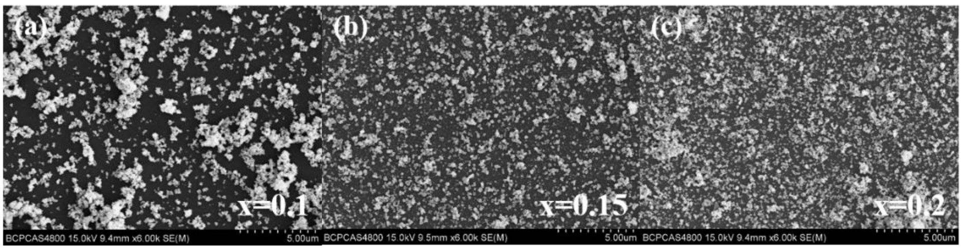

Figure 2 SEM images of the $Bi_{1-x}Zn_xFeO_3$ (x=0.1, 0.15 and 0.2) nanoparticles

The frequency-dependent complex permittivity (ε) and permeability (μ) of the samples are exhibited on figure 3. It obvious that with the increase of frequency, the permittivity of the samples all have a slight decline trend. The real permittivity of the $Bi_{0.9}Zn_{0.1}FeO_3$, $Bi_{0.85}Zn_{0.15}FeO_3$ and $Bi_{0.8}Zn_{0.2}FeO_3$ is roughly up to 10.3, 13.2 and 8.6, respectively.

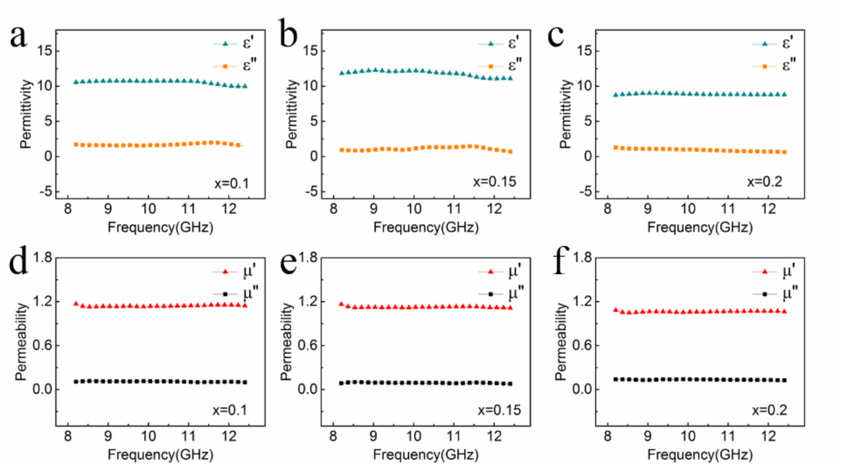

Figure 3 Frequency-dependent permittivity and permeability of the $Bi_{1-x}Zn_xFeO_3$

The reflection loss (R_L), which could be a direct reflection of the ability of the microwave absorption performance of the absorber, is achieved by the relation

$$R_L = 20\log(|Z_{in}-1|/|Z_{in}+1|). \quad (1)$$

Here the Z_{in} refers to the input impedance of the absorption layer, which could be achieved by

$$Z_{in} = (\mu_r/\varepsilon_r)^{1/2}\tanh[j2\pi fd(\mu_r\varepsilon_r)^{1/2}/c]. \quad (2)$$

where, μ_r and ε_r is the complex permittivity and permeability of the samples, respectively. f is frequency. d is thickness of the absorber, and c is the light velocity.

Figure 4 show the microwave absorption performance of the as-prepared samples at different thickness. It is obvious that the composites possess best microwave absorption performance when the Zn doped ratio is 15%.

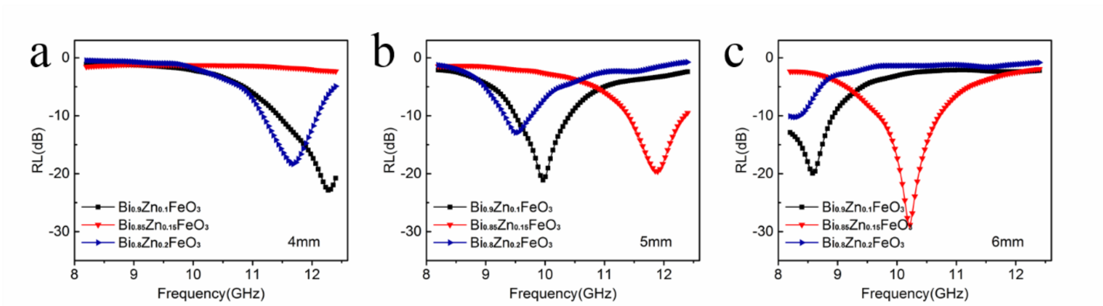

Figure 4 Microwave absorption performance of the as-prepared samples at different thickness