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Effect of a magnetic field on the dielectric properties of PLT–BNCFO composites

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The main goal of this study is to analyze the magnetic, dielectric and magneto-dielectric characteristics of $Pb_{1-x}La_xTi_{1-x}O_3$ (PLT)–$(Ba_{1-3x}Nd_{2x})_4Co_2Fe_{36}O_{60}$ (BNCFO) (where $x = 0.25$) composite materials T1–T3 sintered at various temperatures (1100, 1200 and 1300°C, respectively). An X-ray diffraction investigation was performed in order to pinpoint the creation of a U-type hexaferrite phase. Scanning electron microscopy micrographs reveal that sample T2 reached the maximum value of grain size and the largest experimental density value of 6.14 g/cm^3 due to the intensified grain growth of the composite material. The magnetic investigations further indicate that sample T2 achieved the highest remnant magnetization, measuring 1.550 emu/g, revealing the suitability of the sintering temperature. The magneto-dielectric investigations demonstrate the presence of multiferroicity in all samples and show that sample T2 exhibits the highest magneto-dielectric response of 41.99 at 1.2 T and a magneto-dielectric coefficient (γ) of around 0.7609 g^2/emu^2. Numerous metrics, including Nyquist plots, impedance, electrical modulus, dielectric constant and conductivity, were carefully examined in order to determine the electrical properties of the proposed sample. It was found that sample T2 produced enhanced results and had the right temperature for the substance to develop.

Keywords: ceramics/composite materials/impedance spectroscopy/magnetic properties/magneto-dielectric coefficient/magneto-dielectric properties/multifunctional

Notation

A	temperature-dependent constant that gives the strength of polarization
f	frequency
H_c	coercive electric field
K_B	Boltzmann constant
M	magnetization
M^*	complex modulus
M'	real part of the electrical modulus
M''	imaginary part of the electrical modulus
$M''_{(max)}$	peak value of M'
M_∞	limiting real part of permittivity
M_r	remnant magnetization
n	amount of interaction between mobile ions and the lattice
P	polarization
T_c	ferroelectric transition temperature
Z'	real part of the impedance
Z''	imaginary part of the impedance
$\alpha, \alpha', \beta, \beta'$	coefficients of magnetoelectric coupling
γ	magneto-dielectric coefficient
ε'	real part of dielectric constant
$\varepsilon'(0)$	dielectric constant in the absence of a magnetic field
$\varepsilon'(H)$	dielectric constant in the presence of a magnetic field
ε''	imaginary part of dielectric constant
ε_∞	highest frequency
ε_s	lowest frequency
σ_{ac}	alternating current conductivity
σ_{dc}	direct current conductivity
τ	relaxation time
$\phi(t)$	Kohlrausch–Williams–Watts relaxation function
ω	frequency
$\omega_{(max)}$	maximum value of the frequency at a particular peak

1. Introduction

Due to their unique qualities, multifunctional materials are receiving a lot of attention. Multiferroic materials have a significant deal of potential for usage in a variety of applications, including sensors, spintronics, transducers and information storage, because of the coexistence of ferromagnetic and ferroelectric properties.[1–7] This interaction of the magnetic and