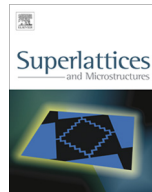




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Superlattices and Microstructures

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Fascinating properties of multifunctional nanocomposites manganite/magnetite



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ARTICLE INFO

Article history:

Received 25 August 2013

Received in revised form 4 April 2014

Accepted 6 June 2014

Available online 26 June 2014

Keywords:

Manganite/magnetite

Nanocomposite

XRD

HRTEM

Hysteresis

ABSTRACT

Multifunctional nanocomposites $\text{La}_{0.6}\text{Sr}_{0.4}\text{MnO}_3/\text{Fe}_3\text{O}_4$ (LSMO/ Fe_3O_4) were prepared with different weight ratios and characterized using X-ray diffraction (XRD), high resolution transmission microscope (HRTEM) and vibrating sample magnetometer (VSM). The parent nanomaterials (LSMO and Fe_3O_4) were prepared by citrate–nitrate auto combustion method and coprecipitation method respectively. Thermal dc magnetization curves were measured from room temperature up to 800 K for the nanocomposites. Vibrating sample magnetometer measurements reveal the enhancement of ferromagnetic properties with increasing magnetite ratio. Dielectric properties were reported and discussed for all investigated nanocomposites. The results recommend the use of such nanocomposites in memory devices and spintronics applications.

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1. Introduction

Nanocomposites have found much interest by many researchers [1–5] because they can retain the physical characteristics of their ingredients and their physicochemical interactions. By changing molar or weight ratios of the parent constituents, one can easily tailor the composition of nanocomposite with a consequent change in their physical [6,7] properties. Accordingly, nanocomposites represent a very important class of materials that show physically tunable characters to be used in different applications such as sensors, waveguides, switches, phase invertors, transducers, modulators, and in

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magnetic storage systems. Magnetic nanocomposites attract attention according to the synergetic combination of the properties of their components and to the possibility of controlling of these properties by varying the component composition ratio. The physical properties (magnetic, electrical and optical) of nanoparticles are controlled by their chemical composition and crystal structure and to a great extent small size effect [8]. Magnetite Fe_3O_4 is a semiconductor having high saturation magnetization along a wide range of temperature [9]. The addition of Fe_3O_4 nanoparticle into a nanocomposite leads to induce strong local magnetic fields near the nanoparticles of other components in the nanocomposite. This effect is rather strong, since magnetite nanoparticles are in single domain state due to their small size (14–33 nm) with high stray field [10].

$\text{La}_{0.6}\text{Sr}_{0.4}\text{MnO}_3$ Manganite (LSMO) belongs to a series of $\text{A}_{1-x}\text{R}_x\text{MnO}_3$ substituted manganites where $\text{A} = \text{La}, \text{Pr}, \text{Nd}$ is a rare earth element and $\text{R} = \text{Sr}, \text{Ca}, \text{Ba}$ is an alkaline earth element. The uniqueness of these materials is due to their specific crystal structure and the electronic shell structure of manganese and manifests itself in the fact that the electrical properties of the substituted manganites was strongly correlated to their magnetic properties [11]. Triki et al. [2] studied the magnetocaloric effect in composite structures based on ferromagnetic–ferroelectric $\text{Pr}_{0.6}\text{Sr}_{0.4}\text{MnO}_3/\text{BaTiO}_3$ perovskites and they found that the presence of BTO has no great effect on the physical properties of PSMO compound. The Curie temperature remains unchanged ($T_c \approx 273 \text{ K}$). The maximum magnetic entropy $|\Delta S_M \text{ max}|$ and relative cooling power (RCP) values are not very affected for the low content of BTO and decreased for $x > 0.1$. Pud et al. [3] studied the enhancement of the magnetoresistive effect in nanocomposites based on manganite $\text{La}_{0.67}\text{Sr}_{0.33}\text{MnO}_3$ and magnetite Fe_3O_4 , and they found that the addition of magnetite Fe_3O_4 nanoparticles to an LSMO nanopowder was shown to substantially increase the low field MRE that increases more than twofold in a field of 10 kOe at a concentration ratio of Fe_3O_4 –LSMO of 1:1 and 1:1.4 in the nanocomposite. Wenjia et al. [4] studied the broad temperature range of resistance and magnetoresistance of multi-phase nanocomposites $\text{La}_{1-x}\text{Sr}_x\text{MnO}_3$ and they found that both a flat magnetoresistance of about 3% and a smooth resistance temperature relationship around room temperature were obtained, which could be useful for applications. Huang et al. [5] studied the enhanced magnetoresistance in $\text{La}_{0.7}\text{Sr}_{0.3}\text{MnO}_3/\text{Nd}_{0.7}\text{Sr}_{0.3}\text{MnO}_3$ nanocomposites. Magnetic measurement shows that the combination of LSMO with NSMO would lead to a structural disorder and hence an enhanced spin disorder at interfaces and grain boundaries. This can well interpret the variation of magnetoresistance effect in the composites on the basis of the tunneling transport model.

Merging together the high and low temperature ranges of ferromagnetic properties of both the spinel magnetite (Fe_3O_4) and the manganite ($\text{La}_{0.6}\text{Sr}_{0.4}\text{MnO}_3$) respectively extends the magnetic temperature application range. Moreover, below T_c of the manganite the composite is both ferromagnetic and electrically conducting exhibiting colossal magnetoresistance (CMR) behavior. On the other hand, above T_c , the composite is electrically insulating but still ferromagnetic due to the existence of magnetite phase [12]. Due to these unique properties, one decided to prepare magnetoelectric nanocomposites with different ratios between $\text{La}_{0.6}\text{Sr}_{0.4}\text{MnO}_3$ and Fe_3O_4 nanoparticles, to extend the ferromagnetic temperature region of LSMO and to optimize its magnetic properties.

The aim of the present work is to study the effect of the weight ratios forming the manganite/magnetite nanocomposite $\text{La}_{0.6}\text{Sr}_{0.4}\text{MnO}_3/\text{Fe}_3\text{O}_4$ on its structural, magnetic and transport properties. Another goal of our work is also to choose the optimum ratio at which the properties were improved to open a new era of technological applications. The selected ratios cover a wide range of compositional variation that can match different possibilities of applications.

2. Experimental techniques

Parent compounds of the nanocomposites namely manganite (LSMO) and magnetite (Fe_3O_4) were prepared by citrate–nitrate auto combustion method [13,14] and coprecipitation method [15] respectively. Fe_3O_4 was prepared by the coprecipitation method [15] using high-purity FeCl_3 and FeCl_2 in molar ratio 2:1 respectively and dissolved in triply distilled water in presence of N_2 gas. Droplets of ammonia were added to the solution to adjust the pH value till precipitation that occurred in the presence of N_2 gas flow as well. This precipitate was carefully washed using double distilled water for several times to remove excess ammonia and then dried at 60°C .

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