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Fabrication and Magnetic Properties of Co-doped $La_{0.5}Sr_{0.5}TiO_3$ Nanofibers

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Abstract

$La_{0.5}Sr_{0.5}Ti_{0.95}Co_{0.05}O_3$/PVP composite nanofibers were fabricated by electrospinning technique. The $La_{0.5}Sr_{0.5}Ti_{0.95}Co_{0.05}O_3$ nanofibers with average diameters of ~ 118 - 155 nm were successfully obtained from calcination of $La_{0.5}Sr_{0.5}Ti_{0.95}Co_{0.05}O_3$/PVP composite nanofibers at 630 – 930 °C in argon for 2 h. The as-spun and $La_{0.5}Sr_{0.5}Ti_{0.95}Co_{0.05}O_3$ nanofibers were characterized by a variety of technique. X-ray diffraction and transmission electron microscopy indicated that the samples of $La_{0.5}Sr_{0.5}Ti_{0.95}Co_{0.05}O_3$ nanofibers had cubic perovskite structure and no secondary magnetic phase in this study. The $La_{0.5}Sr_{0.5}Ti_{0.95}Co_{0.05}O_3$ nanofibers are ferromagnetic having the specific magnetizations of 0.096 – 0.552 emu/g and increase with increasing calcinations temperature. The results from x-ray photoelectron spectroscopy spectra show there are some oxygen vacancies in the nanofibers which may play an important role to induce room temperature ferromagnetism in $La_{0.5}Sr_{0.5}Ti_{0.95}Co_{0.05}O_3$ nanofibers. Our results indicate that the ferromagnetic propertie of $La_{0.5}Sr_{0.5}Ti_{0.95}Co_{0.05}O_3$ system is an intrinsic and interest to the study of diluted magnetic oxide.

1. Introduction

Recently, search for intrinsic high Curie temperature diluted magnetic semiconductors (DMS) has become a interesting effort in the context of the emerging field of spintronics [1-2]. Although ferromagnetic properties have been found in DMS; however, the Curie temperature (T_c) of this class of materials is too low to be used in practical applications.The observed of room temperature ferromagnetism in Co-doped anatase TiO_2 [3] are particularly interesting research on other diluted magnetic oxide (DMO). Diluted magnetic oxide such as ZnO, TiO_2, SnO_2, and In_2O_3 doped with transition metal ions have been investigated intensively [4]. A few years back, above room temperature ferromagnetism (RTFM) has been reported in perovskite of Co-doped (La.Sr)$TiO_{3-\delta}$ thin films. Zhao et al [5] successfully induced ferromagnetism in $La_{1-x}Sr_xTiO_3$ above room temperature by low doping of Co ions. It was noted that the samples, which were heated to high temperatures, changed from a metal to an insulator with resultant loss of ferromagnetism also lost. More recently, Wongsaprom et al [6] reported the existence of ferromagnetism in Co-doped $La_{0.5}Sr_{0.5}TiO_{3-\delta}$ fabricated by a polymerized complex (PC) method. The specific saturation magnetization (M_s) value of 0.038 emu/g was observed for the sample calcined at 800 °C which provides strong indication that Co-doped $La_{0.5}Sr_{0.5}TiO_{3-\delta}$ nanoparticles display RTFM. And the same research group, reported the synthesis of nanoparticles of Fe doped $La_{0.5}Sr_{0.5}TiO_{3-\delta}$ which provided ferromagnetic with high Curie temperature using PC method [7]. Moreover, the ferromagnetism has been found to be an intrinsic in 3d-cations doped $La_{0.5}Sr_{0.5}TiO_3$ nanoparticles [8]. Note that most studies reported on Co-doped $La_{0.5}Sr_{0.5}TiO_{3-\delta}$ has been fabricated in different morphology such as thin films, powder, or nanoparticles which prepared by several method. No studies report on the fabrication, characterization and effect of calcinations temperature on magnetic properties of Co-doped $La_{0.5}Sr_{0.5}TiO_3$ nanofibers. The finding of RTFM in Co-doped $La_{0.5}Sr_{0.5}TiO_3$ nanofibers would allow an enhanced flexibility for several applications.

In this paper, we report the fabrication, characterization and effect of calcinations temperature on magnetic properties and of electrospun $La_{0.5}Sr_{0.5}Ti_{0.95}Co_{0.05}O_3$ nanofibers with average diameters of ~ 118 - 155 nm. The prepared $La_{0.5}Sr_{0.5}Ti_{0.95}Co_{0.05}O_3$ nanofibers were characterized by scanning electron microscopy (SEM), transmission electron microscopy (TEM), X-ray diffraction (XRD), and X-ray photoelectron spectroscopy (XPS). The room temperature magnetic properties of the samples were also investigated by Vibrating sample magnetometry (VSM).

2. Results and Conclusions

The results of TEM, XRD, VSM, and XPS are shown in Figures 1-4. All the information and magnetization taken from XRd and VSM are also summarized in Table 1.It is seen that $La_{0.5}Sr_{0.5}Ti_{0.95}Co_{0.05}O_3$/PVP composite nanofibers have been successfully fabricated using an electrospinning technique. All of TEM bright field images show the nanofibers with diameter of ~ 100 – 150 nm that corresponding to the results of SEM in Figure 1. From the result of selected-area electron diffraction in Figure 1, all of samples show spotty ring pattern including the reflection of (110), (111), (200), (211) and (220) of cubic perovskite structure without any contribution phase. The $La_{0.5}Sr_{0.5}Ti_{0.95}Co_{0.05}O_3$ ceramic nanofibers are single phase of cubic perovskite structure without any impurity phases. Room temperature magnetization results showed ferromagnetic behavior and increase with increasing calcinations temperature, having the specific magnetizations of 0.096, 0.219, 0.284 and 0.552 emu/g at 10 kOe for $La_{0.5}Sr_{0.5}Ti_{0.95}Co_{0.05}O_3$ nanofibers calcined at 730, 830 and 930 °C, respectively. The oxygen vacancies may play an important role to induce room temperature ferromagnetism in $La_{0.5}Sr_{0.5}Ti_{0.95}Co_{0.05}O_3$ nanofibers. This work demon-

strates that a simple method can be used to fabricate the nanofibers of $La_{0.5}Sr_{0.5}Ti_{0.95}Co_{0.05}O_3$, which may potentially be useful for several applications.

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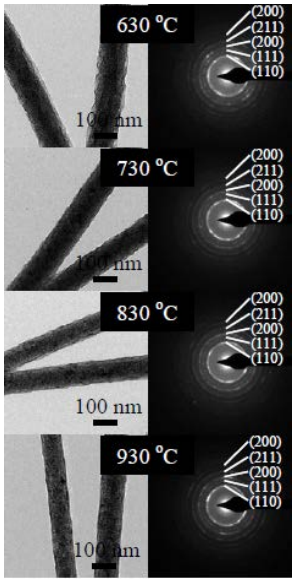

Figure 1. TEM bright-field images with corresponding selected-area electron diffraction (SAED) of $La_{0.5}Sr_{0.5}Ti_{0.95}Co_{0.05}O_3$ nanofibers calcined in argon for 2 h at different temperature.

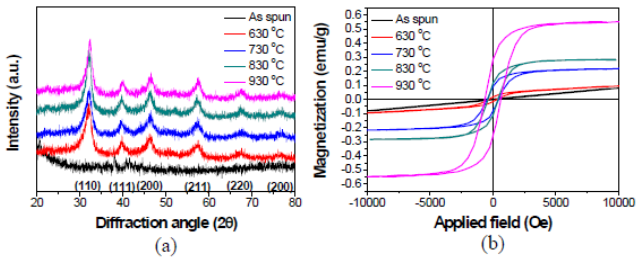

Figure 2. (a) XRD patterns and (b) Magnetization at room temperature measured by VSM of as-spun and $La_{0.5}Sr_{0.5}Ti_{0.95}Co_{0.05}O_3$ nanofibers after calcined in argon for 2 h at different temperature.

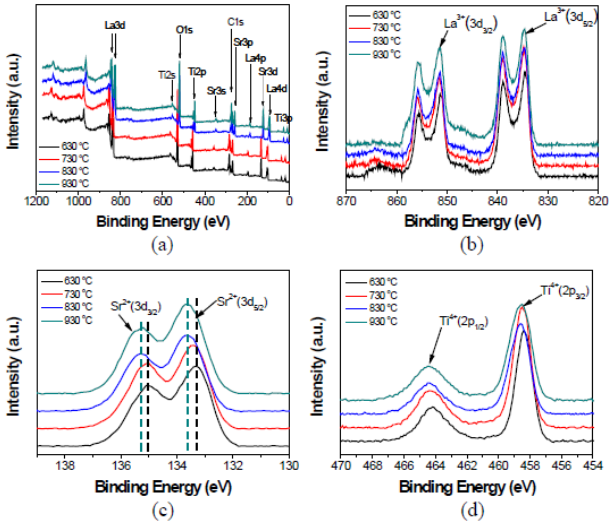

Figure 3. X-ray photoelectron spectra of (a) Survey scans, (b) La 3d, (c) Sr 3d and (d) Ti 2p at different calcinations temperature.

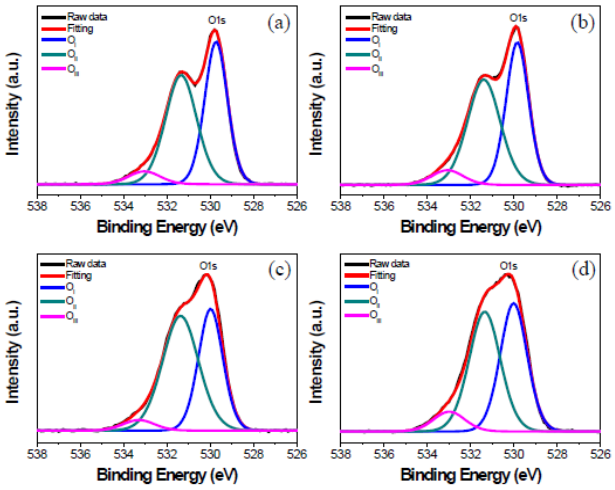

Figure 4. XPS profiles of O1s for different calcinations temperature: (a) 630 ˚C, (b) 730 ˚C, (c) 830 ˚C and (d) 930 ˚C.

Table 1. Average crystal sizes from XRD line broadening, lattice parameter *a*, average fibers diameter from SEM of $La_{0.5}Sr_{0.5}Ti_{0.95}Co_{0.05}O_3$/PVP composite nanofibers before (as spun) and after calcined in argon for 2 h at 630, 730, 830 and 930 ˚C.

Sample	Average crystal size from XRD (nm)	Lattice parameters *a*, (nm)	Fiber diameter (nm)	M_s at 10 kOe (emu/g)
As spun	-	-	187 ± 24	0.081
630 ˚C	8.4 ± 2.2	0.3926 ± 0.0003	155 ± 25	0.096
730 ˚C	8.3 ± 2.8	0.3932 ± 0.0001	134 ± 16	0.219
830 ˚C	8.7 ± 1.5	0.3943 ± 0.0002	118 ± 17	0.284
930 ˚C	8.8 ± 1.8	0.3944 ± 0.0006	151 ± 25	0.552