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Thermoelectric power factor of LSCoO compounds

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Abstract

Electrical resistivity $\rho(T)$ and Seebeck coefficient $S(T)$ measurements of polycrystalline $La_{0.8}Sr_{0.2}Co_{1-x}$ Mn_xO_3 ($0 \leqslant x \leqslant 0.1$) (LSCoO) samples were carried out in the temperature range between 90 and 290 K. The samples were grown by citrate complex method; Seebeck coefficient and electrical resistivity were measured by differential technique and four-probe method, respectively. Both $S(T)$ and $\rho(T)$ increase monotonically with the Mn content, the electrical resistivity exhibit a metallic-semiconducting temperature behavior, while Seebeck coefficient is positive in whole measured temperature range. From $S(T)$ and $\rho(T)$ data it was possible to calculate the thermoelectric power factor PF, which in the samples with $x = 0.08$, reaches values close to $18\,\mu W/K^2\,cm$; these values for PF are comparable with those of conventional thermoelectric materials, becoming these oxides in promissory thermoelectric materials.

Keywords: Thermoelectricity; LSCoO compounds; Thermoelectric power factor

1. Introduction

The oxides as thermoelectric (TE) compounds have many advantages such as high thermal stability, excellent oxidation resistance, low cost and weak toxicity [1]. The need of finding efficient TE materials that work at room temperature and below it has made the research on these materials shift from conventional TE semiconductors [2].

Important candidates are perovskites-type phases such as $Na_xCo_2O_4$, $La_{1-x}Sr_xCoO_3$, $Ca_3Co_4O_9$, $Bi_2Ca_2Co_2O_x$, $Ca_3Co_2O_6$, etc., which show a wide variety of useful and interesting transport properties [3].

Among these oxides, the $La_{1-x}Sr_xCo_{1-x}$ Mn_xO_3 compounds are good electronic and ionic conductors, their electrical resistivity and Seebeck coefficient can be properly tuned by changing the Sr and Mn content [4].

The performance of a TE material is evaluated in terms of its dimensionless figure of merit ZT, which is a function of its transport properties, given by the expression [2,3] $ZT = S^2T/\rho\kappa$, where S is the Seebeck coefficient, ρ the electrical resistivity, κ the total thermal conductivity and T the absolute temperature of the system.

The challenge of the research on TE materials is to find materials with high ZT values. In this sense, according to the last equation, there are studies focused on the reduction of thermal conductivity and others on the increase in the TE power factor: $PF = S^2/\rho$, which is an important parameter that drives the electrical properties of a TE material, and it depends on both the electron (hole) effective mass and the carrier mobility.

In this work, we study the effect of Co-site substitution on the TE power factor of $La_{0.8}Sr_{0.2}Co_{1-x}Mn_xO_3$ polycrystalline samples as a function of manganese content, in order to consider the possibility of using this kind of perovskite-compound as TE material.

2. Experimental

Polycrystalline samples of $La_{0.8}Sr_{0.2}Co_{1-x}Mn_xO_3$ ($0 \leqslant x \leqslant 0.1$) were prepared by using the citrate complex method, from La_2O_3 (Merck), $Sr(NO_3)_2$ (Merck), $Co(NO_3)_2 \cdot 6H_2O$ (Merck), $Mn(NO_3)_2 \cdot 6H_2O$ (Merck) and citric acid $C_6H_8O_7 \cdot H_2O$ (Merck). Lanthanum nitrate was prepared adding nitric acid solution to lanthanum oxide. Precursor solutions were prepared adding stoichiometric

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amounts of nitrate solutions and citric acid solution. Total concentration of both cations and citric acid were 0.2 M. The obtained solution was heated at 393 K for gelation and drying process. LSCoO-manganese oxides with pure perovskite crystalline phase were achieved by heating these foams at 1100 K, during 36 h under an oxygen gas flow.

The Seebeck coefficient was measured by using the differential method, with an accuracy of 0.5 μV/K. The electrical resistivity data were obtained by the standard four-probe method with an accuracy about 0.1 mΩ cm. Both, Seebeck coefficient and electrical resistivity were measured in the temperature range between 90 and 290 K. Additionally, the structural and morphological properties of the samples were studied by powder X-ray diffraction analysis and scanning electron microscopy (SEM), respectively.

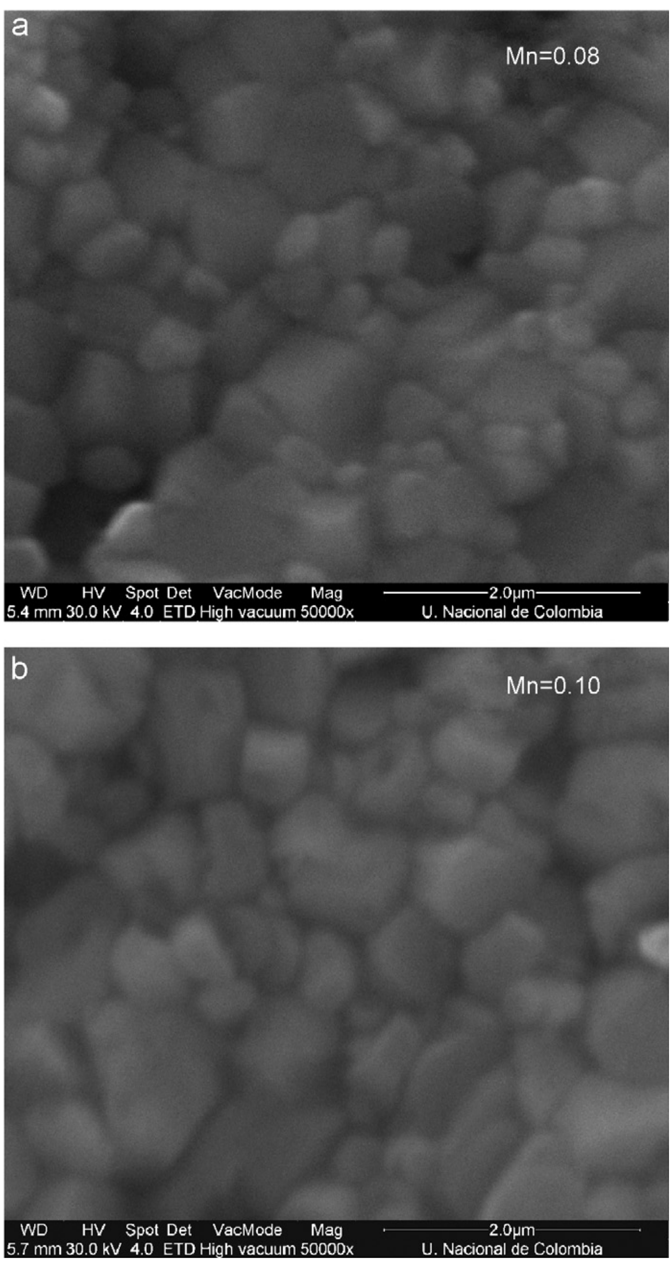

Fig. 1. SEM micrographs pictures of powders synthesized by the citrate complex method.

3. Results and discussion

The powder X-ray diffraction analysis showed that LSCoO phase is predominant in the samples with small quantities of impurities. All the samples exhibited the typical K_2NiF_4 structure, which is a body centered tetragonal structure.

Fig. 1 shows the microstructure of LSCoO-Mn compounds, the particle size and the crystallinity increase with the manganese content. The grain size takes values between 300 and 600 nm.

The Seebeck coefficient (see Fig. 2a) is positive in the measured temperature range, indicating *p*-type conduction. It takes values from 30 μV/K for the samples with low manganese content to 400 μV/K for the samples with Mn = 0.1.

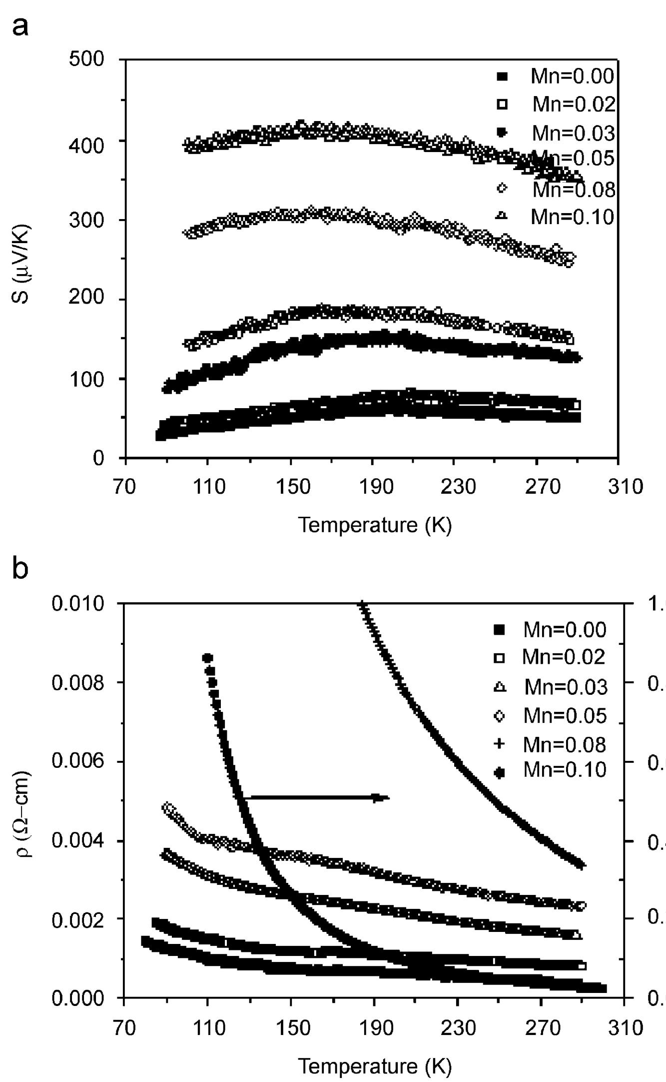

Fig. 2. Behavior of Seebeck coefficient (a) and electrical resistivity (b), as a function of temperature and the manganese content.