Physica B 477 (2015) 105–112

Contents lists available at ScienceDirect

Physica B

journal homepage: www.elsevier.com/locate/physb

Effect of Ni-doping on critical behavior of $La_{0.6}Pr_{0.1}Ba_{0.3}Mn_{1-x}Ni_xO_3$ nanocrystalline manganites

Elaa Oumezzine [a], Sobhi Hcini [a,*], E.K. Hlil [b], Essebti Dhahri [c], Mohamed Oumezzine [a]

[a] Laboratoire de Physico-chimie des Matériaux, Faculté des Sciences de Monastir, Département de Physique, Université de Monastir, 5019 Monastir, Tunisie
[b] Institut Néel, CNRS et Université Joseph Fourier, BP 166, 38042 Gronoble, France
[c] Laboratoire de Physique Appliquée, Faculté des Sciences de Sfax, Université de Sfax, B.P. 1171, 3000 Sfax, Tunisie

ARTICLE INFO

Article history:
Received 21 February 2015
Received in revised form
10 June 2015
Accepted 18 August 2015
Available online 20 August 2015

Keywords:
Nanocrystalline manganites
Second order phase transition
Critical behavior

ABSTRACT

We used Banerjee's criteria, modified Arrott plots and the scaling hypothesis to analyze magnetic-field dependences of magnetization near the ferromagnetic–paramagnetic (FM–PM) phase-transition temperature (T_C) of $La_{0.6}Pr_{0.1}Ba_{0.3}Mn_{1-x}Ni_xO_3$ ($0 \le x \le 0.3$) nanocrystalline manganites. Experimental results reveal that all samples undergo a second-order phase transition. The estimated critical exponents obtained for $x=0$ sample are close to the mean-field model ($\beta=0.503 \pm 0.004$, $\gamma= 1.024 \pm 0.068$ and $\delta=2.821$ at $T_C=215$ K). Whereas for a high amount of Ni, these exponents belong to a different universality class ($\beta=0.599 \pm 0.014$, $\gamma=0.897 \pm 0.013$ and $\delta=2.570$ at $T_C=162$ K for $x=0.1$ sample) and ($\beta=0.733 \pm 0.012$, $\gamma=0.753 \pm 0.014$ and $\delta=2.320$ at $T_C=131$ K for $x=0.3$ sample). This is due to the fact that the substitution of Ni ions into the Mn-site leads to the formation of a larger proportion of Mn^{4+} with respect to Mn^{3+} which reduces the ferromagnetic double exchange interaction of Mn^{3+}–Mn^{4+} couples. These exponents indicate that the exchange interaction $J(r)$ decreases with distance r slower than $r^{-4.5}$ for $x=0$ sample, however it ranges from r^{-5} and $r^{-4.5}$ for $x=0.1$ and 0.3 samples.

1. Introduction

Colossal magnetoresistance (CMR) and magnetocaloric (MCE) effects discovered in perovskite ABO_3-type manganites $(R^{3+}_{1-x}A^{2+}_x)(Mn^{3+}_{1-x}Mn^{4+}_x)O^{2-}_3$ (R= La, Pr, Nd…, A= Ca, Sr, Ba…) around the paramagnetic (PM)–ferromagnetic (FM) phase transition temperature (T_C, the Curie temperature) has attracted much interest because of their potential applications [1,2]. These CMR and MCE effects can be tuned by doping of some chemical elements into the R and/or A sites and Mn, and are usually explained by the double exchange (DE) mechanism, trivalent (Mn^{3+}) and tetravalent (Mn^{4+}) ions [3].

To better understand the CMR and MCE properties of these manganites, it is essential to fully study the nature of the PM–FM phase transition. One of the effective methods is to study in detail the critical exponents associated with this transition. In fact, the analysis of the critical behavior in the vicinity of the magnetic phase transition is a powerful tool to investigate in details the mechanisms of the magnetic interaction responsible for the transition [4,5]. The study of critical exponents allows determining very accurately the Curie temperature (T_C) and the correlation of these exponents with those of the appropriate model, existing in the literature, allows the determination of the exchange integral in the ferromagnetic state.

Experimental studies of the critical behavior in manganites near the PM–FM phase transition, using a variety of techniques, have yielded a wide range of values for the critical exponent β of the magnetization [6–8]. The values range between 0.25 and 0.5, which includes the mean-field ($\beta=0.5$), the 3D isotropic nearest-neighbor Heisenberg ($\beta=0.365$), the 3D Ising ($\beta=0.325$) and tricritical mean-field ($\beta=0.25$) estimates. In addition to β, static *dc*-magnetization measurements also yield critical exponents γ and δ for the initial susceptibility $\chi(T)$ and the critical isotherm $M(T_C, H)$, respectively [9,10].

Recently, we have investigated in our previous work [11] the effect of Ni doping on structural, magnetic and magnetocaloric properties of $La_{0.6}Pr_{0.1}Ba_{0.3}Mn_{1-x}Ni_xO_3$ ($0 \le x \le 0.3$) nanocrystalline manganites synthesized by the Pechini sol–gel method. We have shown that our samples crystallize in the orthorhombic structure with *Pnma* space group with a decrease of the unit cell volume and the average grain size when Ni content increases. Magnetic measurements show that all compounds present a second order PM–FM phase transition with a decrease in both magnetization magnitude and in Curie temperature T_C. The magnetocaloric effect has also been assessed by means of magnetic entropy change ΔS_M which is basically determined from magnetic field

* Corresponding author.
E-mail address: hcini_sobhi@yahoo.fr (S. Hcini).

http://dx.doi.org/10.1016/j.physb.2015.08.028
0921-4526/

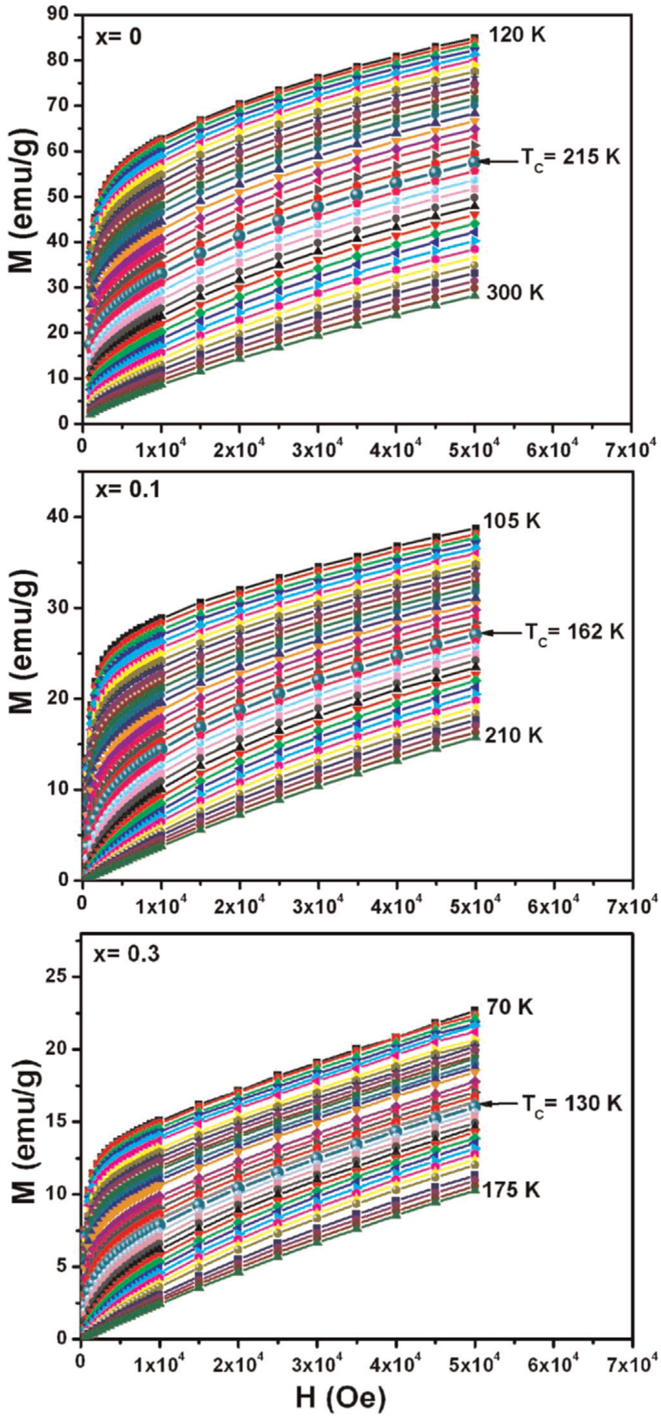

Fig. 1. $M(H, T)$ curves near T_C for $La_{0.6}Pr_{0.1}Ba_{0.3}Mn_{1-x}Ni_xO_3$ $(0 \leq x \leq 0.3)$ nanocrystalline samples.

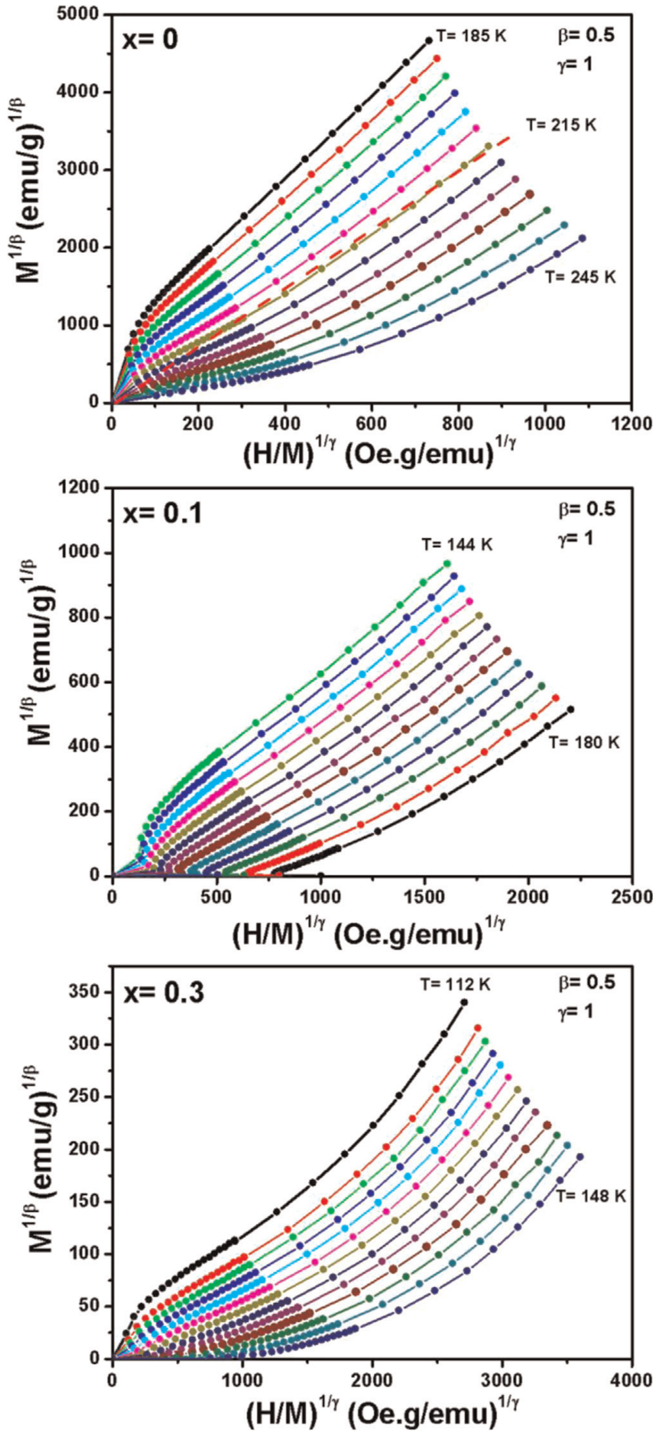

Fig. 2. Arrott plots around T_C for $La_{0.6}Pr_{0.1}Ba_{0.3}Mn_{1-x}Ni_xO_3$ $(0 \leq x \leq 0.3)$ nanocrystalline samples. According to the mean field model (values of critical exponents $\beta=0.5$ and $\gamma=1$ should generate the regular Arrott plots, M^2 vs. H/M).

dependences of magnetization at different temperatures $M(H, T)$ near T_C. We have shown that the doping of a high amount of Ni reduced the maximum magnetic entropy $|\Delta S_M^{max}|$ and the relative cooling power (RCP), respectively.

Based on the $M(H, T)$ curves presented by us elsewhere in Ref. [11], we detailed in the present work the critical behavior in the vicinity of the PM–FM phase transition for $La_{0.6}Pr_{0.1}Ba_{0.3}Mn_{1-x}Ni_xO_3$ $(0 \leq x \leq 0.3)$ nanocrystalline manganites by analyzing the critical exponents through various techniques, such as the modified Arrott plot (MAP) and the Kouvel–Fisher (KF) methods.

2. Results and discussion

Fig. 1 shows the representative isothermal magnetization $M(H, T)$ curves recorded at temperatures around the Curie temperature T_C (indicated by arrow in Fig. 1) for $La_{0.6}Pr_{0.1}Ba_{0.3}Mn_{1-x}Ni_xO_3$ $(0 \leq x \leq 0.3)$ nanocrystalline manganites in the applied field range of $H=0$–50 kOe. Below T_C, $M(H, T)$ curves show a non linear behavior with a sharp increase for low field values and a tendency to saturation as field increases reflecting a ferromagnetic behavior.