Electrical transport properties and magnetoresistance of La-based perovskite structure

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Abstract **—The physical properties of the $La_{x-0.55}Y_xBi_{0.15}Ca_{0.3}MnO_3$ compound have been investigated, focusing on the magnetoresistance phenomenon (MR) studied by electrical transport measurements. These materials find extensive technological applications in magnetic sensors, photonic and optoelectronic devices , computer hard drive reader, logic devices. X-ray diffraction and scanning electron microscopy (SEM) analysis of ceramic samples prepared by solid state reaction revealed that specimens are single phase and reveals that the doping by Y causes a significant change in the microstructure of the sample. The temperature of magneto-resistivity curves are registered from room temperature under a magnetic field up to 5 Tesla and showed that the undoped sample present a metal-insulator transition (I-M) at a temperature $T_P \approx 135,83$ K . Some physical parameters are extracted and their evolution with magnetic field are presented and discussed. The highest obtained MR value is about 91.81% at 5 Tesla.**

Keywords-component; manganite; colossal magnetoresisstance; doping; resistivity.

I. INTRODUCTION

The perovskite manganites $R_{1-x}A_xMnO_3$ (R = trivalent rare earth ions and A = divalent alkaline earth ions) have attracted immense attention after the discovery of the colossal magneto resistance (CMR)[1]. These CMR materials are at the focus of scientific research due to their potential technological applications as magnetic sensors, magnetoelectronic, infrared detector, as well as spintronic technology. Insulator-to-metal transition in manganites makes these materials attractive from the point of view of creating photonic and optoelectronic devices [2,3].

The origin of CMR behavior is explained initially by double exchange (DE) and Jahn–Teller effect and is subsequently extended to include spontaneous electronic phase separation, but still remains controversial [4]. In these manganites, a cascade of magnetic, structural, metal–insulator and charge-ordering phase transitions have been observed by change of doped level, temperature, pressure and applied magnetic field [5].

In the aim to test the effect of doping by Y in this phase, ceramic samples of nominal composition of $La_{0.55-x}Y_xBi_{0.15}Ca_{0.3}MnO_3$ (x= 0 and 0.2) are elaborated and characterized. We will show, that only the undoped sample present a insulator-metal transition, the doped sample has an insulating behavior throughout temperature range. And is revealed an increase in the values of resistivity of all the compounds when doping by Y in La site. CMR effect is present in all the samples. A strong magnetoresistance is obtained for $La_{0.55}Bi_{0.15}Ca_{0.3}MnO_3$ compound (91.81%) at 5T ,which is promising as regards the potential application of CMR.

II. EXPERIMENTAL DETAIL

Polycrystalline samples $La_{0.55-x}Y_xBi_{0.15}Ca_{0.3}MnO_3$ (x= 0 and 0.2) are prepared by the solid state reaction method from dried high purity La_2O_3, Bi_2O_3, Y_2O_3, $CaCO_3$ and MnO_2 powders. The starting materials are intimately mixed in a agate mortar to obtain a homogeneous mixture. These mixtures are calcined in air at 800C° for 20h, pressed into pellets (of about 2 to 2,5 mm of thickness) and sintered at1000C°/20h, 1080C°/20h and 1180C°/20h respectively. Finally obtained samples were annealed at 800C° for 10h.
Samples $La_{0.55}Bi_{0.15}Ca_{0.3}MnO_3$ and $La_{0.35}Y_{0.2}Bi_{0.15}Ca_{0.3}MnO_3$ will be noted LBCM and $LY_{0.2}BCM$, respectively.

Room-temperature powder X-ray diffraction (XRD) measurements are carried out on a Siemens D8-advance diffractometer in the Bragg–Brentano geometry using CuK_α radiation. The microstructural study of the samples done on a JEOL JSM-6390 LV scanning electron microscope .The resistivity of the samples in 0, 0.5, 1 and 5 T magnetic field was measured by the standard four-probe method on a cryodine CTI-Cryogenics closed cycle cryostat.

Magnetoresistance (MR) refers to the relative change in the electrical resistivity by the application of an external magnetic field. It is given by :

$$MR\% = \left(\frac{\rho_0 - \rho_H}{\rho_0}\right) \times 100 \qquad (1)$$

Where ρ_0 and ρ_H represent the resistivities under zero and magnetic field H, respectively.

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III. RESULTS AND DISCUSSION

A. structural aspect

Fig.1 shows the X-ray diffraction patterns of the elaborated samples. These patterns reveals that all samples are single phase when compared to previously published results. The XRD data are refined using Jana 2006 software [6]. and it is displayed that the structure of all samples is orthorhombic , space group Pnma (N°62). No trace of impurity phases were detected in the XRD data. The refined cell parameters are given in Table1. This result suggests that doping by Y on the La site causes a slight decrease of the values of lattice parameters and volume in agreement with previously reported values[7].

Representative SEM micrographs for $La_{0.55}Bi_{0.15}Ca_{0.3}MnO_3$ and $La_{0.35}Y_{0.2}Bi_{0.15}Ca_{0.3}MnO_3$ are shown in Fig.2. The scanning electronic microscopy reveals that the doping by Y causes a significant change in the microstructure of the samples.

TABLE I. THE REFIND CELL PARAMETERS OF COMPOUNDS LBCM AND $LY_{0.2}BCM$.

Samples	LBCM	$LY_{0.2}BCM$
a(Å)	5.4587(5)	5.4323(3)
b(Å)	5.4445(5)	5.4374(4)
c(Å)	7.7289(5)	7.[illegible]644(2)
V($Å^3$)	229.7(3)	22[illegible].4(7)
R_P(%)	17.89	7.34
R_{WP}(%)	28.62	11.30
Gof	2.02	0.80

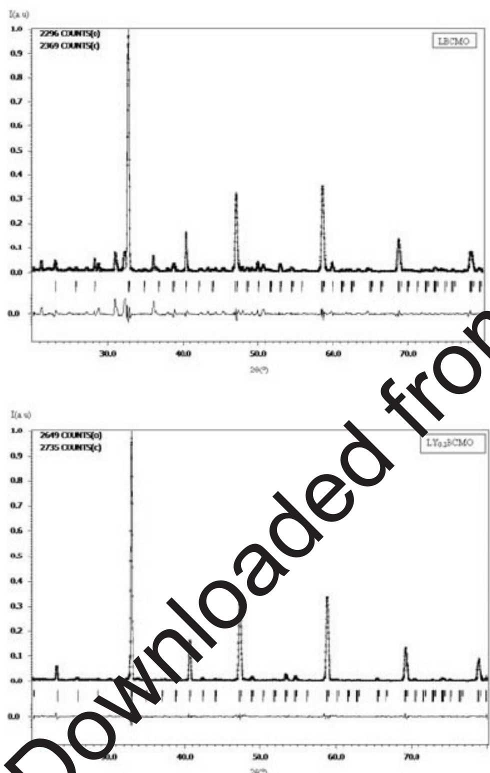

Figure 1. The superposition of the observed (dots) and the calculated (line) patterns of of LBCM and $LY_{0.2}BCM$.

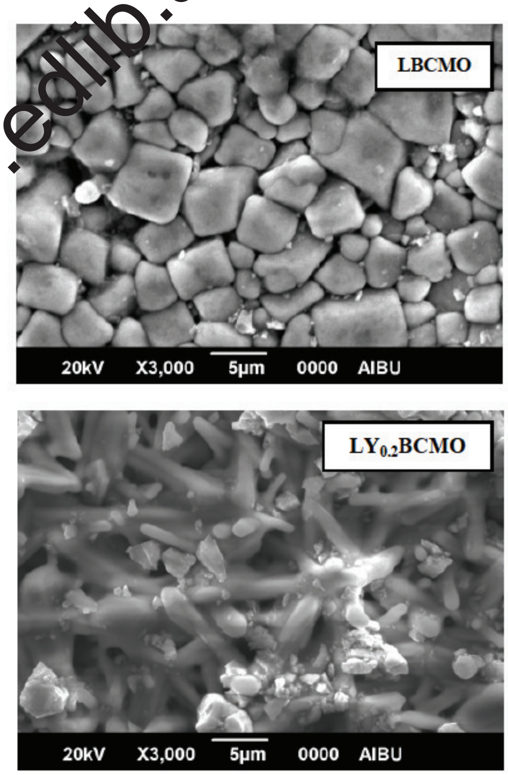

Figure 2. SEM image of LBCM and LY0.2BCM

B. Electrical behavior and magntoresistance

The evolution of the resistivity with temperature under a magnetic field up to 5 Tesla for samples LBCM and $LY_{0.2}BCM$ is plotted in fig.3. It is clear that only the undoped sample has an insulator-metal transition at a temperature T_P. The doping by Y causes a great increase of resistivity and lowers the temperature of the insulator-metal transition (T_p). The transition from the metallic to insulating state disappears by this doping. Indeed, it is clear from the curves of resistivity that compound $LY_{0.2}BCM$ has an insulating behavior throughout temperature range. The disappearance of the transition I-M may be caused by the decrease in the probability of charge transferred due to the deformation of the octahedra MnO_6 [8].

We note that the application of a stronger magnetic field (5T) introduce a metallic state in the compound $La_{0.35}Y_{0.2}Bi_{0.15}Ca_{0.3}MnO_3$. This results are in strong correlation with resulted obtained by other authors [9].

The application of magnetic field causes a reduction of the resistivity of all the samples , therefore CMR effect appears but it is much more significant in the case of $LY_{0.2}BCM$ because the resistivity decreases little in this compound .

The reduction of the resistivity by the application of magnetic field which makes the a ferromagnetic state on the same temperature range more ordered, then the scattering function on carriers weakens. Also, the magnetic field can restrain thermal fluctuation and cause paramagnetic(PM) – ferromagnetic (FM) transition to occur at higher temperature , the temperature of I-M transition shift to higher temperature[10].

The temperature dependence of magnetoresistance (MR) at different magnetic field for all samples are shown in fig 4. The highest obtained MR values is about 91.81% and 48.28 % at 5T for the $La_{0.55}Bi_{0.15}Ca_{0.3}MnO_3$ and $La_{0.35}Y_{0.2}Bi_{0.15}Ca_{0.3}MnO_3$ samples, respectively. For the undoped phase $La_{0.7}Ca_{0.3}MnO_3$ and even for a higher magnetic field of 7 Tesla, the MR value does not exceed 44% [11].

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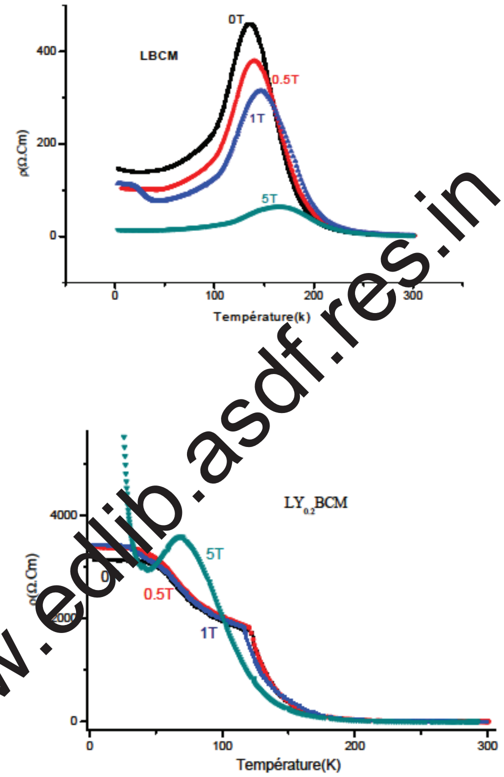

Figure 3. Temperature dependance of resistivity under 0,0 5,1,5T of LBCM and $LY_{0.2}BCM$

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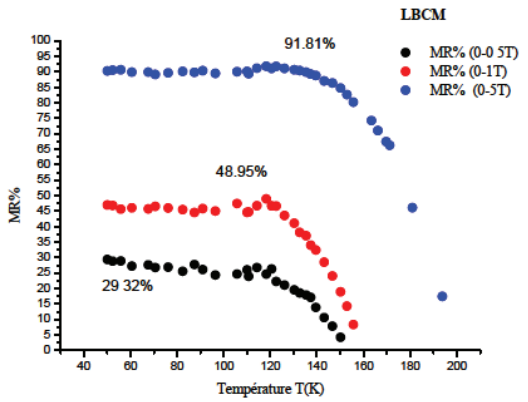

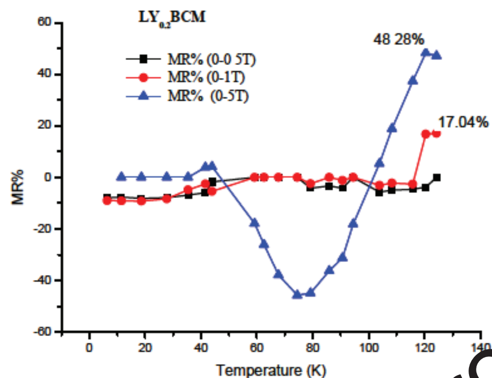

Figure 4. MR%. vs. temperature plots of LBCM and $LY_{0.2}BCM$ under 0 5,1,5T.

IV. CONCLUSION

In summary, we have investigated the transport properties of doping by Y in La site for a compound $La_{0.55-x}Y_xBi_{0.15}Ca_{0.3}MnO_3$ (x=0, 0.2). All the samples are good single phases with perovskite orthorhombic structures (Pnma space group). Measurements of resistivity as a function of temperature show that only the undoped sample present a insulator-metal transition. The resistivity of the Y doped sample is higher than that the undoped sample , contrary to the M-I transition temperature which is greater by this latter. CMR effect is present in all the samples. A strong magnetoresistance is obtained for $La_{0.55}Bi_{0.15}Ca_{0.3}MnO_3$ compound (91.81%).

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