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Electrical and Magnetic properties Comparison between LCMO and LSMO system

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Abstract

Electrical and magnetic properties of $La_{0.67}Ca_{0.33}MnO_3$ and $La_{0.67}Sr_{0.33}MnO_3$ systems were studied via solid-state reaction method. The studies have been carried out by powder X-ray diffraction analysis (XRD), resistance techniques by using D.C four point probe and magnetic susceptibility by using A.C susceptometer. These materials are extensively studied also by the substitution of rare-earth compound to understand the nature of transport phenomena in each system. From X-ray diffraction (XRD) patterns, the samples of LCMO and LSMO systems show single phase perovskite structure and our powder samples crystallize in a orthorhombic and rhombohedral structures respectively. The electrical transport studies exhibit metal to insulator transition (MIT) at low temperature, AC susceptibility studies exhibit ferromagnetic to paramagnetic transition with an antiferromagnetic ordering at low temperature.

مقارنة الخصائص الكهربية والمغناطيسية بين أنظمة LSMO و LCMO

في الآونة الأخيرة ظهر اهتمام كبير في دراسة نظام ($La_{1-x}A_xMnO_3$) (Sr, Ca) =A في
محاولات لتطوير وتحسين خواص هذه المواد لما لها من خواص تطبيقية وعلمية هامة في مختلف نواحي الحياة. لذا

فقد وقع الاختيار على (LSMO, LCMO) للدراسة في محاولة لتقديم مواد ذات تطبيقات كهربية عالية الكفاءة وذلك بهدف دراسة خواصها الكهربية والمغناطيسية لإمكانية استخدامها في تطبيقات تكنولوجية كثيرة كأجهزة الاحساس والاستشعار وزيادة حساسية تخزين البيانات.

ففي هذا العمل تمت دراسة بعض الخصائص الكهرومغناطيسية والتركيبية لأنظمة ($La_{0.67}Ca_{0.33}MnO_3$) و ($La_{0.67}Sr_{0.33}MnO_3$) بطريقة تفاعل الحالة الصلبة عند درجات حرارية مختلفة وباستخدام طريقتي التلدين والتلبيد .وقد فحصت العينات باستخدام حيود الأشعة السينية (XRD) ، كما اشتملت على فحوصات كهربائية لقياس المقاومية الكهربائية باستخدام تقنيات تحقيق الأربع نقاط وفحوصات مغناطيسية لإيجاد ودراسة خصائص التأثيرية المغناطيسية وكذلك قياس الانفاذية المغناطيسية باستخدام (A.C susceptometer) (وايضا يتم دراسة هذه المواد على نطاق واسع بالاستعاضة عن مجموعة المركبات الأرضية النادرة وذلك لفهم طبيعة الخواص في كل نظام). ومن خلال أنماط حيود الأشعة السينية (XRD)، اظهرت عينات LCMO و LSMOتكونها في الصورة البلورية الأحادية الطور ذو الشكل معيني قائم (الاورثورومبيك) ومنشور سداسي منتظم (روهومبوهيدرا) على التوالي وانها تعتمد في الحقيقة عل درجة الحرارة والتركيز في هذا الجانب. اما الخواص الكهربائية فأظهرت الانتقال من المعدنية الى العازل (MIT) عند درجة الحرارة المنخفضة، ودلت دراسة قابلية التأثير المغناطيسي (A.C) بالانتقال من الفيرومغناطيسية الى البارا مغناطيسية مع ظهور ضدية الفيرومغناطيسية في درجة الحرارة المنخفضة. كما أوضحت هذه الدراسات ان درجة الحرارة الحرجة في هذه المركبات تكون حساسة جدا تبعا لظروف تحضير العينة ونقاوتها.

هذه الخصائص، جنبا إلى جنب مع الاستقطاب الدوراني 100%، يجعل LSMO مادة مثيرة للاهتمام لتطبيقها في الأجهزة من النوع الإلكتروني الدوراني. ومن الأمثلة على ذلك نفق التقاطعات المغناطيسية والأجهزة الكهربائية والمغناطيسية وعلاوة على ذلك، يتم استخدامه كالموصلات الفائقة لتحقيق الاستقطاب الدوراني .بينما الاهتمام التقني ل LCMO للتطبيقات المحتملة على سبيل المثال , المحسسات المغناطيسية, قراءة رؤوس مولدات المقاومة المغناطيسية للذاكرة العشوائية وكذلك تخزين البيانات.

Keyword: Electrical , magnetic and colossal magnetoresistance

Introduction

The interest in perovskite manganites with the form , $La_{1-x}A_xMnO_3$ (A = divalent alkaline earth metal, i.e. Ca^{+2}, Sr^{+2}, B^{+2} and Pb^{+2}) in recent years was due to their observed colossal magnetoresistance (CMR) effects near the ferromagnetic-paramagnetic transition temperature T_C in this material and the potential applications in magnetoresistive transduser and magnetic sensors [1]. These systems have technological importance such as in sensor application and increasing data storage by increasing in sensitivity of hard disk drive read heads [2]. The phenomenon of CMR effects, explained by Zener through the double exchange mechanism, occurs in the phase transition from a paramagnetic insulator at high temperature to the ferromagnetic metal at low temperature T_p [3]. Above the metal-insulator transition temperature $T_{p,}$ the sample shows activated behavior ($d\rho/dT<o$) or behave like a semiconductor material. The $LaMnO_3$ is a perovskite-type oxide and it's antiferromagnetic insulator due to the superexchange antiferromagnetic coupling interaction between the Mn^{3+} and Mn^{4+} ions.LSMO is metallic ferromagnetic manganite with Curi temperature of ≈ 360 K [4,5]. $La_{1-x}Sr_xMnO_3$ is considered as an alloy of $LaMnO_3$ with a(La) atom substituted by a(Sr) atom. It shows colossal MR and exhibits half-metallic properties for x=0.3 [6]. At x= 0.3, it has been shown that its spin polarization is 95% at 4K and ~ 90% at 100K [7,8]. As early ,provided evidence $La_{1-x}Ca_xMnO_3$ is an HM [9]. The manganites doped with calcium and strontium [10-13] received much attention due to the high Tc and small variance of the B site ionic radii. Recent studies on these materials revealed that CMR phenomenon is attributed not only to the double exchange (DE) mechanism but also to the interactions such as electron-phonon coupling, electronmagnon interaction, and the complicated band structure . In the present paper, we have studied the electrical and magnetic properties of

probe and to compare between $La_{0.67}Ca_{0.33}MnO_3$ and $La_{0.67}Sr_{0.33}MnO_3$ systems.

Experiment

The manganites samples of $La_{0.67}Ca_{0.33}MnO_3$ and $La_{0.67}Sr_{0.33}MnO_3$were prepared via the conventional solid-state reaction method. A well-mixed stoichiometric mixture of La_2O_3 , $CaCO_3$, $MnCO_3$ and La_2O_3, $SrCO_3$, MnO_2 with purities higher than 99.9% were mixed with acetone, ball milled for 6 h and oven dried at 110 °C overnight. The dried powder was heated at 900 °C in air for 12 h with rate $3^oC/min$ to produce a highly reactive powder. After calcination, the black powdery mixture was grounded and sieved in order to ensure good homogeneity, then pressed into pellets using 1.2g powder by hydraulic press at ($3Tcm^{-2}$) and sintered at 1300 ^oC for 24 hours with rate $2^oC/min$, followed by furnace cooling at room temperature.

Characterization of the samples were done by Philip x-ray diffractometer (XRD) with a rotating anode at room temperature with Cu$K\alpha$ radiation using Phillips (PW1830) in order to see the structure of the samples with λ=1.54056 ˚A. The resistance was measured by the conventional four-probe technique in the temperature range of 20 to 300 K. Ac magnetic susceptibility χ measurements for two systems as a function of temperature in a magnetic field of H=10 Oe were measured by a Lakeshore AC(Model 7000) susceptometer with temperature range of 30-300 K and a frequency of 125 Hz.

Results and Discussion

1- Structure properties:

X-ray diffraction spectrum (XRD) 2Θ pattern ranged from 20^o to 80^o is obtained with the scattering vector perpendicular to the plane of the samples are asshown in Figure1.The Miller indexed XRD peaks correspond to an orthorhombic structure for $La_{0.67}Ca_{0.33}MnO_3$ [14] and to rhombohedral structure for $La_{0.67}Sr_{0.33}MnO_3$. No clear evidence of reflection peaks is observed in the XRD spectrum. Lattice parameters and unit cell volume for two systems were calculated and listed in table 1. The unit cell volume for LCMO sample is bigger than that of LSMO.

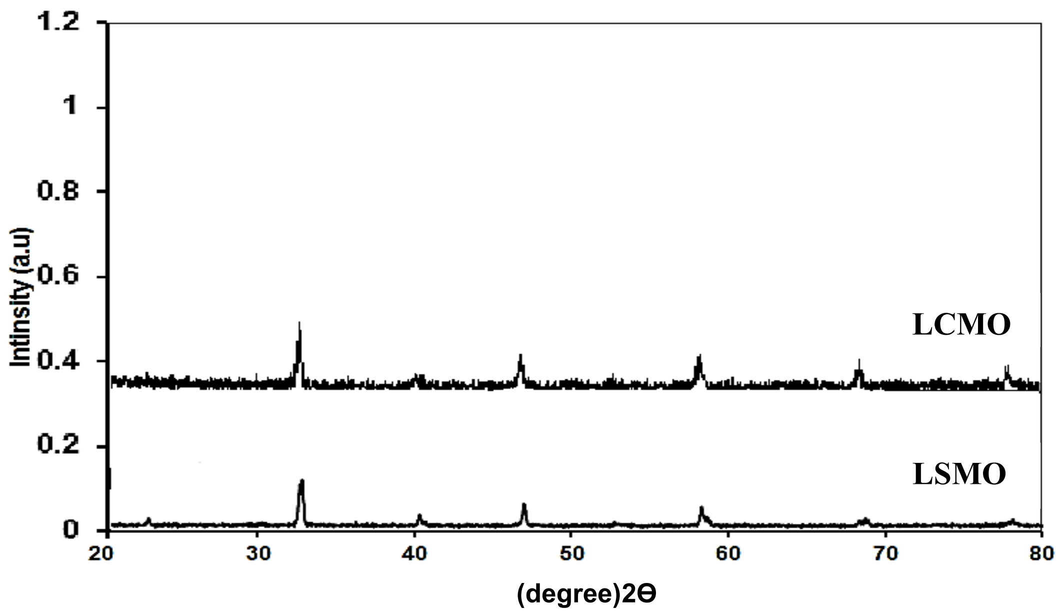

Figure 1: XRD spectrum for LCMO and LSMO sample.

Table 1: Lattice parameters and unit cell volume for LCMO and LSMO sample

System	Lattice parameters (Å)	Volume (Å^3)
$La_{0.67}Ca_{0.33}MnO_3$	a = 5.474 b = 7.702 c = 5.448	229.69
$La_{0.67}Sr_{0.33}MnO_3$	a=b=c=5.471	116.66

2- **Electrical properties**:

Figure 2 shows the temperature dependence of the resistance under zero magnetic field. The measurement was done by using the standard four-probe method with a constant current 1mA.

The insulator-metal transition occurs at (246K) with metallic behavior at lower temperature side for LCMO sample as shown in figure (2a) [14].Whereas the samples of LSMO is metallic throughout the measured temperature region and it's a round 360K (Tc is not indicated because the measuring system is incapable to measure up to 300 K) as shown in figure (2b).

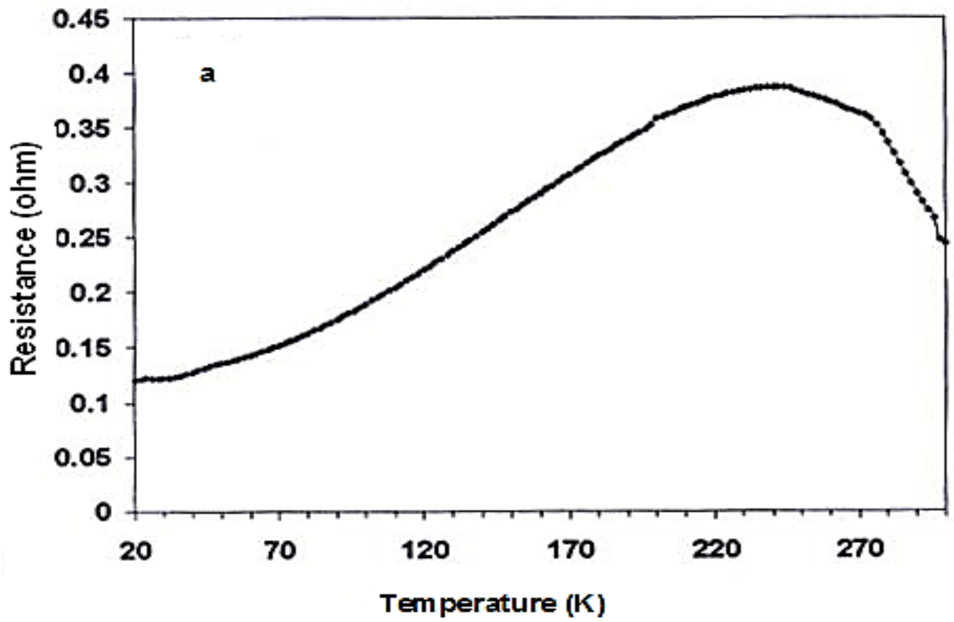

Figure 2a: Temperature dependence of resistance for LCMO sample.

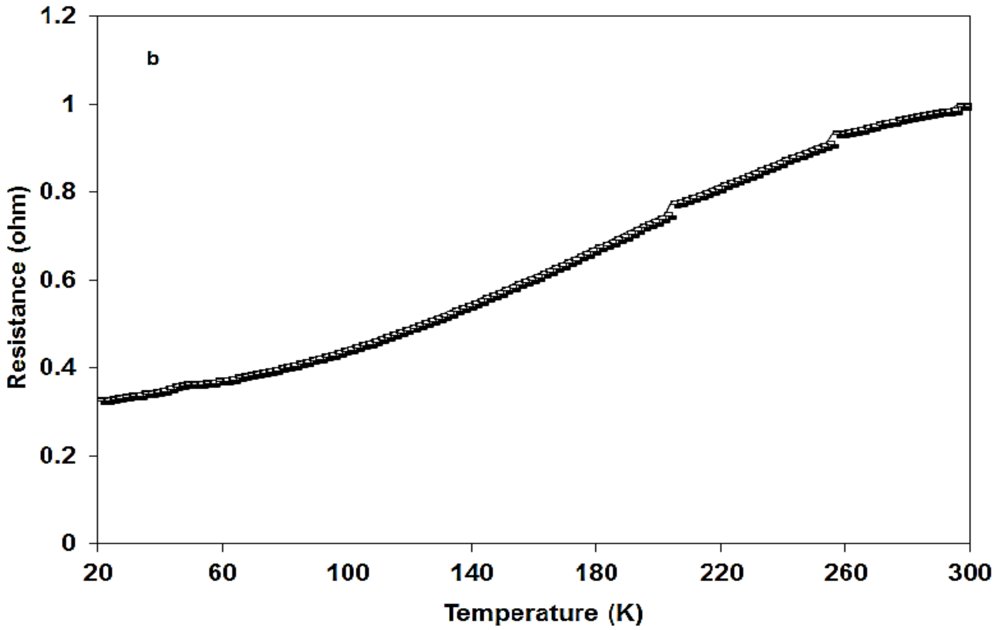

Figure 2b: Temperature dependence of resistance for LSMOsample.

3- **Magnetic properties**:

The temperature dependence of the ac magnetic susceptibility, χ' at the magnetic field of 10 Oe of the samples are as shown in Figure 3. Both samples display classical phase transition from paramagnetic to ferromagnetic state at Cuire temperature, Tc. The LCMO sample display lower Tc at around 245K as shown infigure (3c) [14]. Whereas, The sample of LSMO exhibits the high Tc at 365 K, but here Tc is not indicated because the measuring system is incapable to measure up to 300 K only as shown in figure (3d). As the magnetic field increases from 0.1 Oe to 10 Oe the LSMO sample shows increase of Ac susceptibility value. However, as the temperature increases the Ac susceptibility increases.

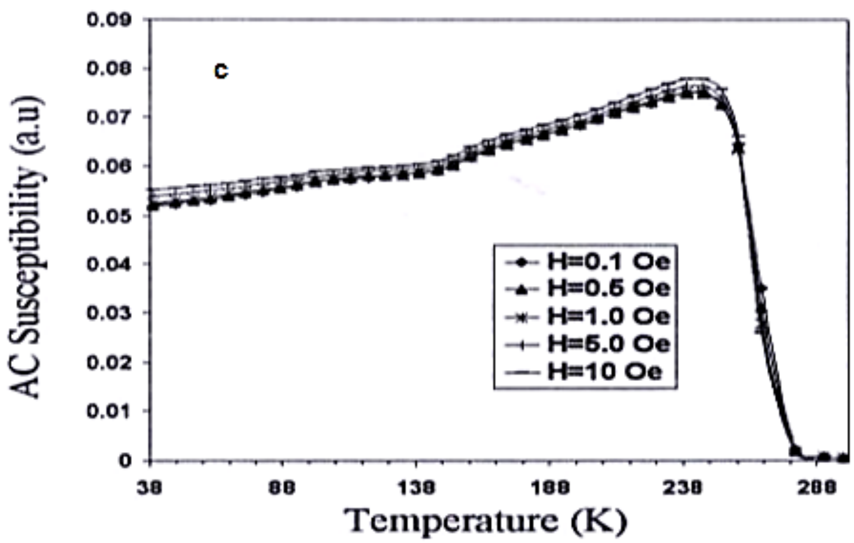

Figure 3c: Temperature dependence of ac-Susceptibility forLCMO sample.

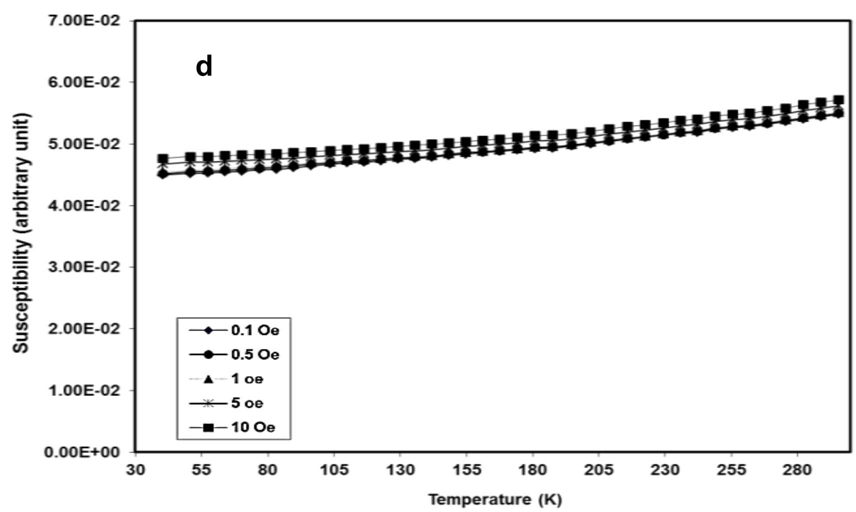

Figure 3d: Temperature dependence of ac-Susceptibility for LSMO sample.

Conclusion

The electrical and magnetic properties of LCMO and LSMO samples were investigated. Both the metal insulator and ferromagnetic transition temperatures were found. An insulator-metal (I-M) transition is observed at 246K for the LCMO sample, while a broad MIT is observed for LSMO sample and it shows a high phase transition temperature at around 360 K.Parent compound (LCMO) shows a paramagnetic (PM) to ferromagnetic (FM) transition with Curie temperature ($T_C \approx 245K$) near to that peak in electrical resistivity (≈246 K), and the Curie temperature T_C for LSMO sample is ≈ 365 K. The perovskite structure manganites, specifically LCMO and LSMO exhibits colossal magnetoresistance behavior which is of interest to magnetic information storage applications and LSMO has received much attention due to its largest single electron bandwidth and the highest Curie temperature. These properties, together with the 100% spin polarization, make LSMO an interesting material for application in spintronic devices. Examples are magnetic tunnel junctions and magnetoelectric devices .Furthermore, LSMO is also used to investigate other materials, e.g. by spin-injection into cuprite superconductors to probe spin polarization. While, the CMR effect for LCMO is of great technological interest. Potential applications are for instance magnetic sensors, magnetoresistive read heads, random access memory and data storage.

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List of Abbreviations and Symbols

(الرموز والمصطلحات)

Symbol/Term	**Designation/Explanation**
Sr	Strontium
Ca	Calcium
Mn	Magnesium
La	Latium
O	Oxygen
C	Carbon
MR	Magnetoresistance
Cukα	The wavelength of the Kα1 line of copper
CMR	Colossal magnetoresistance
Oe	Oersted
MIT	Metal to insulator transition
HM	Half Metal
K	Kelvin
Tp	Phase transition temperature

Tc	Curie temperature
R	Resistance
AC	Alternating Current
XRD	X-ray diffractometer
ρ	Resistivity
a.u	Arbitrary unit
DC	Direct current
χ	Susceptibility
ºC	Degree Celsius
h	Hour
Å	Angstrom
Hz	Frequency unit
FM	Ferromagnetic
PM	Paramagnetic
C	Curie constant for material
λ	Wavelength
θ	Angle of diffraction
a, b, c	Lattice parameters