Available online at www.sciencedirect.com
SCIENCE DIRECT
Journal of Magnetism and Magnetic Materials 304 (2006) e303–e305
Journal of magnetism and magnetic materials
www.elsevier.com/locate/jmmm

Optical and magneto-optical studies of $(La_{0.7}A_{0.3})MnO_3$ (A = Sr, Ca, and Ce) thin films

H.L. Liu[a,*], Kenneth Y.-J. Zhang[a], L.C. Wu[a], L. Uba[b], S. Uba[b], W.J. Chang[c], J.-Y. Lin[c], L.M. Wang[d]

[a]Department of Physics, National Taiwan Normal University, Taipei, Taiwan
[b]Institute of Experimental Physics, University of Bialystok, Bialystok, Poland
[c]Institute of Physics, National Chiao Tung University, Hsinchu, Taiwan
[d]Department of Electrical Engineering, Da-Yeh University, Changhua, Taiwan

Available online 6 March 2006

Abstract

The optical and magneto-optical (MO) properties of $(La_{0.7}A_{0.3})MnO_3$ (A = Sr, Ca, and Ce) thin films have been investigated. It is found that the value shape of spectra is strongly dependent on different cation dopings. The Sr-doped thin film exhibits a strong Drude response and maximum Kerr rotation angle of 0.32° at ~3.4 eV. Interestingly, the replacement of Sr ions with the smaller Ca ions and the tetravalent Ce ions all lead to a remarkable suppression of the carrier density and the MO response. Such differences are interpreted as due to their different electronic band structures.

PACS: 74.25.Gz; 75.47.Gk; 78.20.Ls

Keywords: Colossal magneto-resistance; Optical property; Magneto-optical effect

1. Introduction

The subject of colossal magneto-resistance (CMR) effect in the manganite thin films $R_{1-x}A_xMnO_3$ (R and A being trivalent rare-earth and divalent alkaline-earth ions, respectively) continues to attract much attention [1,2]. Interest in these systems is exemplified by their potential technological applications related to magnetism and spintronics. The films often have different CMR effects and Curie temperatures (T_C) compared to bulk materials due to lattice mismatch between the film and the substrate. In this study, we further show that the optical and magneto-optical (MO) properties of the manganite thin films are critically dependent on different cation dopings such as Sr, Ca, and Ce. To the best of our knowledge, few studies of the MO properties of the manganites have been reported in the past [3–5]. Our investigations are therefore very important to understand the optical and MO Kerr effects of devices based on the manganite thin films.

2. Results and discussion

Thin films of $La_{0.7}Sr_{0.3}MnO_3$ (LSrMO), $La_{0.7}Ca_{0.3}MnO_3$ (LCaMO), and $La_{0.7}Ce_{0.3}MnO_3$ (LCeMO) were grown on (1 0 0) $SrTiO_3$ substrates using the pulsed-laser deposition or the off-axis magneton sputtering technique described previously [6,7]. The thickness of the films is around 300 nm. The strain effect due to lattice mismatch between the film and the substrate is fully relaxed [8]. Characterizations of X-ray diffraction, DC resistivity, and magnetization were also preformed on these samples. Fig. 1 shows the temperature dependence of in-plane magnetization under 100 G for the three films, clearly revealing that they have a ferromagnetic transition. The T_C for LSrMO is ~350 K, whereas that of LCaMO and LCeMO is ~275 K.

The near-normal optical reflectance spectra of the three films were taken over a wide frequency range (50–55000 cm^{-1}) and at temperatures between 20 and

*Corresponding author. Tel.: +886 2 29343163; fax: +886 2 29326408.
E-mail address: hliu@phy.ntnu.edu.tw (H.L. Liu).

0304-8853/$ - see front matter © 2006 Elsevier B.V. All rights reserved.
doi:10.1016/j.jmmm.2006.02.074

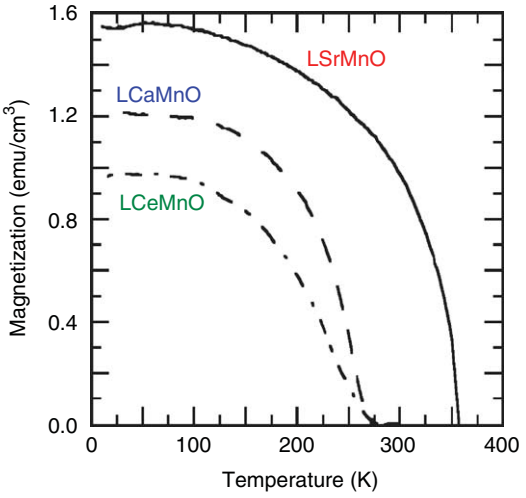

Fig. 1. (Color online) Temperature-dependent field-cooled magnetization of LSrMO (red, solid line), LCaMO (blue, dashed line), and LCeMO (green, dashed–dotted line) thin films measured with a field of 100 G in the plane of the films.

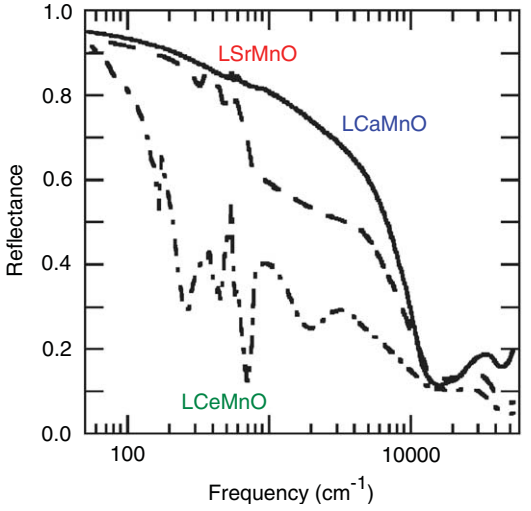

Fig. 2. (Color online) The reflectance spectra of LSrMO (red, solid line), LCaMO (blue, dashed line), and LCeMO (green, dashed–dotted line) thin films at 20 K.

340 K [9]. The polar Kerr rotation θ_k and ellipticity η_k spectra were measured at room temperature with an MO spectrometer based on the polarization modulation technique [10] over the photon energy range of 0.74–5.8 eV.

Fig. 2 shows the measured optical reflectance of LSrMO, LCaMO, and LCeMO thin films over the entire spectral range at 20 K. Note the logarithmic scale. There are several important features to these spectra. First, the far-infrared reflectance in LSrMO displays a metallic character, with a line shape in accord with a Drude theory. As the frequency increases, the reflectance drops steadily throughout the infrared, with a sort of plasmon minimum around 15,000 cm^{-1}. Several electronic features are observed for frequencies above 20,000 cm^{-1}. Second, for the LCaMO sample with a reduction in T_C, the reflectance in the whole infrared region is decreased, indicating the decreased carrier concentrations. Third, although both LCaMO and LCeMO thin films have approximately the same T_C, the far-infrared spectrum of LCeMO can be described by a very weak, overdamped Drude contribution typical of a poor conductor. As a consequence, the effect of multiple reflection of light in the film on the substrate is clearly seen in the mid-infrared frequency region. Finally, the Drude–Lorentz fits [9] to the reflectance yield an estimation of the Drude plasma frequency values ω_{pD}: LSrMO (~5600 cm^{-1}) > LCaMO (~4800 cm^{-1}) > LCeMO (~2500 cm^{-1}), and the Drude scattering rate $1/\tau_D$: LSrMO (~120 cm^{-1}) < LCaMO (~270 cm^{-1}) < LCeMO (~870 cm^{-1}). These are consistent with the results by the transport measurements [6], suggesting the replacement of Sr ions with the smaller Ca ions and the tetravalent Ce ions all modify the electronic structure near the Fermi level in the manganite thin films [6].

The room-temperature polar Kerr rotation θ_k and ellipticity η_k spectra of the three films measured under saturation conditions are shown in Figs. 3(a) and (b),

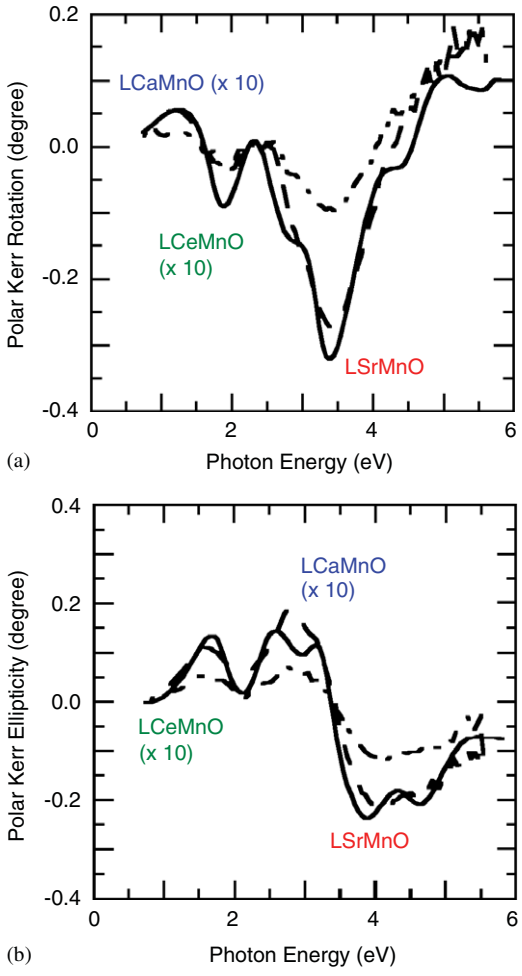

Fig. 3. (Color online) Experimental polar Kerr (a) rotation and (b) ellipticity of LSrMO (red, solid line), LCaMO (blue, dashed line), and LCeMO (green, dashed–dotted line) thin films at 300 K.

respectively. One first observes that the Kramers–Kronig relation seems to be fulfilled between θ_k and η_k, which were independently deduced. Second, the Kerr spectra of the three films exhibit similar overall structure, but the magnitude of LCaMO and LCeMO is smaller than that of LSrMO by a factor of 10. This difference can be due to different magnetization related with a reduction of the ferromagnetic ordering temperature. Third, it was found that the maximum values of θ_k and η_k for the LSrMO thin film are 0.32° at $\sim$3.4 eV and 0.24° at $\sim$3.4 eV, respectively. The characteristic behavior in our LSrMO spectra is qualitatively similar with two earlier studies [3,5], but appears to disagree with those reported on corresponding single crystals [4].

3. Summary

In summary, we report the optical and MO properties of the LSrMO, LCaMO, and LCeMO thin films. The value shape of the measured spectra is strongly dependent on different cation dopings. Such differences are interpreted as due to their different electronic band structures. Our results are important to those attempting to understand the material properties and improve device qualities based on the manganite thin films.

Acknowledgments

This work was supported by the National Science Council of Republic of China under Grant no. NSC94-2112-M-003-002, 94-2120-M-007-013, and the National Taiwan Normal University under Grant no. ORD93-B.

References

[1] R. von Helmholt, J. Wecker, B. Holzapfel, L. Schultz, K. Samwer, Phys. Rev. Lett. 71 (1993) 2331.
[2] S. Jin, T.H. Tiedel, M. McCormack, R.A. Fastnacht, R. Ramesh, L.H. Chen, Science 264 (1994) 413.
[3] P. Fumagalli, C. Spaeth, G. Guntherodt, IEEE Trans. Magn. 31 (1995) 3277.
[4] S. Yamaguchi, Y. Okimoto, K. Ishibashi, Y. Tokura, Phys. Rev. B 58 (1998) 6862.
[5] M. Koubaa, A.M. Haghiri-Gosnet, J.P. Renard, M. Veis, V. Kolinsky, S. Visnovsky, Ph. Lecoeur, W. Prellier, B. Mercey, J. Magn. Magn. Mater. 272–276 (2004) 1812.
[6] W.J. Chang, J.Y. Tsai, H.-T. Jeng, J.-Y. Lin, Kenneth, Y.-J. Zhang, H.L. Liu, J.M. Lee, J.M. Chen, K.H. Wu, T.M. Wen, Y.S. Gou, J.Y. Juang, Phys. Rev. B 72 (2005) 132410.
[7] L.M. Wang, J.-Y. Lee, H.C. Yang, J.C. Chen, H.L. Liu, K.-S. Lu, L. Horng, H.E. Horng, J. Magn. Magn. Mater. 298 (2006) 48.
[8] H.L. Liu, M.X. Kuo, J.L. Her, K.S. Lu, S.M. Weng, L.M. Wang, S.L. Cheng, J.G. Lin, J. Appl. Phys. 97 (2005) 113528.
[9] F. Wooten, Optical Properties of Solids, Academic Press, New York, 1972.
[10] K. Sato, Jpn. J. Appl. Phys. Part 1 20 (1981) 2403.