

# Characteristics of La<sub>0.75</sub>Ca<sub>0.25</sub>MnO<sub>3</sub> Films Grown on Si(100) Substrates

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## ABSTRACT

We grew La<sub>0.75</sub>Ca<sub>0.25</sub>MnO<sub>3</sub> (LCMO) films with different thicknesses on Si(100) substrates using RF magnetron sputtering. We used the X-ray diffractometer and a closed-cycle cryocooler system to measure crystalline structure and resistance of films, respectively. In this work, we study the strain and oxygen-annealing effects on the temperature coefficient resistance (TCR) and metal-insulator transition temperature (T<sub>p</sub>) for films with different thicknesses. We found that the T<sub>p</sub>, maximum TCR value (TCR<sub>max</sub>), and magnetoresistance (MR) are increased for films with thicknesses. We also found that the TCR<sub>max</sub> and MR are decreased for films with oxygen annealing. For the 1200-Å-thick films, the achieved values of T<sub>p</sub>, TCR<sub>max</sub>, and MR are 181 K, 1.93 %K<sup>-1</sup>, and 38 %, respectively. Finally, the relationship between TCR<sub>max</sub> and bipolaron binding energy,  $\epsilon_1$  is deduced by the current-carrier-density-collapse model. It is observed that the TCR<sub>max</sub> increases as  $\epsilon_1$  is decreased, being in agreement with the theoretical prediction.

Keywords : strain effect ; RF sputtering ; temperature coefficient of resistance

## Table of Contents

封面內頁 簽名頁 授權書 . . . . .	iii	中文摘要 . . . . .	iii
. . . . .	iv	英文摘要 . . . . .	v
. . . . .	vi	目錄 . . . . .	vii
. . . . .	x	表目錄 . . . . .	xiii
第一章 緒論 1.1 超巨磁阻材料 . . . . .	1	1.2 CMR材料成長於不同基座與薄膜厚度之介紹 . . . . .	3
1.2.1 CMR薄膜通氧退火之介紹 . . . . .	6	1.3 研究目的 . . . . .	9
第二章 理論基礎 2.1 磁性物質的發展 . . . . .	11	2.1.1 磁性理論 . . . . .	11
現象 . . . . .	14	2.1.2 磁阻 . . . . .	11
2.1.3 超巨磁阻(CMR) . . . . .	15	2.2 CMR材料之電阻傳輸機制 . . . . .	17
2.2.1 極化子之傳輸機制 . . . . .	17	2.2.2 載子崩潰模型 . . . . .	17
2.2.2 載子崩潰模型 . . . . .	17	2.3 La <sub>1-x</sub> A MnO <sub>3</sub> (A=Ca, Sr) 之物理特性 . . . . .	20
2.3 La <sub>1-x</sub> A MnO <sub>3</sub> (A=Ca, Sr) 之物理特性 . . . . .	20	2.4 應力效應 . . . . .	21
2.4.1 應力種類 . . . . .	21	2.4.2 應力效應(strain effect) . . . . .	22
2.4.2 應力效應(strain effect) . . . . .	22	2.5 TCR與雜訊對熱輻射偵測器靈敏度之影響 . . . . .	24
2.5 TCR與雜訊對熱輻射偵測器靈敏度之影響 . . . . .	24	第三章 實驗方法與儀器設備 3.1 實驗流程 . . . . .	25
3.1 實驗流程 . . . . .	25	3.2 樣品製作與樣品量測 . . . . .	26
3.2 樣品製作與樣品量測 . . . . .	26	3.2.1 樣品製作：薄膜製程 . . . . .	27
3.2.1 樣品製作：薄膜製程 . . . . .	27	3.3 實驗儀器 . . . . .	30
3.3 實驗儀器 . . . . .	30	3.3.1 薄膜濺鍍系統 . . . . .	30
3.3.1 薄膜濺鍍系統 . . . . .	30	3.3.2 薄膜厚度量測 . . . . .	30
3.3.2 薄膜厚度量測 . . . . .	30	3.3.3 高溫爐管 . . . . .	34
3.3.3 高溫爐管 . . . . .	34	3.3.4 X-ray繞射分析儀 . . . . .	36
3.3.4 X-ray繞射分析儀 . . . . .	36	3.3.5 磁化強度之量測 . . . . .	38
3.3.5 磁化強度之量測 . . . . .	38	3.3.6 電阻率量測 . . . . .	38
3.3.6 電阻率量測 . . . . .	38	3.3.7 電阻率-溫度之微分與TCR之計算 . . . . .	41
3.3.7 電阻率-溫度之微分與TCR之計算 . . . . .	41	第四章 結果與討論 4.1 不同厚度之LCMO薄膜特性分析 . . . . .	42
4.1 不同厚度之LCMO薄膜特性分析 . . . . .	42	4.1.1 X-ray繞射與應力分析 . . . . .	42
4.1.1 X-ray繞射與應力分析 . . . . .	42	4.1.2 電阻的溫度係數(TCR)分析 . . . . .	46
4.1.2 電阻的溫度係數(TCR)分析 . . . . .	46	4.1.3 應力(σ)對T <sub>p</sub> 值與TCR值影響之討論 . . . . .	49
4.1.3 應力(σ)對T <sub>p</sub> 值與TCR值影響之討論 . . . . .	49	4.1.4 磁阻分析 . . . . .	50
4.1.4 磁阻分析 . . . . .	50	4.2 退火後效應 . . . . .	51
4.2 退火後效應 . . . . .	51	4.2.1 X-ray繞射與應力分析 . . . . .	51
4.2.1 X-ray繞射與應力分析 . . . . .	51	4.2.2 電阻的溫度係數退火與無退火比較分析 . . . . .	54
4.2.2 電阻的溫度係數退火與無退火比較分析 . . . . .	54	4.2.3 通氧退火後其磁性分析 . . . . .	56
4.2.3 通氧退火後其磁性分析 . . . . .	56	4.2.4 通氧退火後其磁阻分析 . . . . .	58
4.2.4 通氧退火後其磁阻分析 . . . . .	58	4.3 雙極化子結合能(ε <sub>1</sub> )、熱激活能(E <sub>a</sub> )對TCR與T <sub>p</sub> 影響之討論 . . . . .	59
4.3 雙極化子結合能(ε <sub>1</sub> )、熱激活能(E <sub>a</sub> )對TCR與T <sub>p</sub> 影響之討論 . . . . .	59	4.3.1 雙極化子結合能(ε <sub>1</sub> )對TCR與T <sub>p</sub> 之影響 . . . . .	59
4.3.1 雙極化子結合能(ε <sub>1</sub> )對TCR與T <sub>p</sub> 之影響 . . . . .	59	4.3.2 熱激活能(E <sub>a</sub> )對TCR與T <sub>p</sub> 之影響 . . . . .	61
4.3.2 熱激活能(E <sub>a</sub> )對TCR與T <sub>p</sub> 之影響 . . . . .	61	第五章 結論 . . . . .	64
5.1 結論 . . . . .	64	參考文獻 . . . . .	65

## REFERENCES

- [1] S. Jin, T. H. Tiefel, M. McCormack, R. A. Fastnacht, R. Ramesh, and L. H. Chen, Science 264, 413 (1994).
- [2] K. Chahara, T. Ohno, M. Kasai, and Y. Kozono, Appl. Phys. Lett. 63, 1990 (1993)
- [3] R. von Helmlot, J. Weckerg, B. Holzapfel, L. Schultz, and K. Samwer, Phys. Rev. Lett. 71, 2331 (1993).
- [4] L. M. Wang, H. C. Yang, and H. E. Horng, " Electrical transport and carrier density collapse in doped manganite thin films " , Physical

Review B 64, 224423 (2001) [5] Alvydas Lissauskas, S. I. Khartsev, and Alex Grishin, Appl. Phys. Lett. 77, 756 (2000) [6] G. A. Prinz, Phys. Today 48, 58 (1995); Science 282, 1660 (1998).

[7] Parkin S. S. P. et al., Science 281, 797(1998) [8] M. Ziese, H. C. Semmelhack, and K. H. Han, Journal Of Applied Physics 91, 9930 (2002) [9] Jong Cheol Lee, Dong Gyun You, Sang Yub Je, Myeon Chang Sung, Ho Shik Song, Hyun Soon Park, Sei Kwon Kang, Sam Hyeon Lee, and Kwangho Jeong, Journal Of Applied Physics 91, 221 (2002) [10] A. Goyal, M. Rajeswari, R. Shreekala, S. E. Lofland, S. M. Bhagat, T. Boettcher, C. Kwon, R. Ramesh, and T. Venkatesan, Appl. Phys. Lett. 71, 27 (1997) [11] Wiley, "Soshin Chikazumi, Physics of Ferromagnetism", 1964, p. 3.

[12] Charles Kittel, "Introduction to Solid State Physics 4th ed.", John Wiley & Sons, New York, 2000, Chap. 14-15, (1996) [13] B.D. Cullity, "Introduction to Magnetic Materials", Addison-Wesley, Massachusetts, 1972, p. 85.

[14] Robert C. O'Handley, Modern Magnetic Materials Principles and Applications (John Wiley & Sons, New York, 2000) [15] J. Baszynski, T. Tolinski, B. Idzikowski, D.M. Tobbens, A. Hoser J. Baszynski et al. / Journal of Alloys and Compounds 345 (2002) 210–213 [16] C. Zener, Phys. Rev. 82 403(1951) [17] A. S. and A. M. Bratkovsky, Phys. Rev. Lett. 82, 141 (1999) [18] Guo-meng Zhao, V. Smolyaninova, W. Prellier, and H. Keller, Phys. Rev. Lett. 84, 6086 (2000) [19] G. J. Snyder, R. Hiskes, S. DiCarolis, M. R. Beasley, and T. H. Ge, Phys. Rev. B 53, 14 434 (1996).

[20] T. Akimoto, Y. Moritomo, and A. Nakamura, Phys. Rev. Lett. 85, 3914 (2000) [21] S. Jin, M. McCormack, T. H. Tiefel, and R. Ramesh, J. Appl. Phys. 76, 6929 (1994).

[22] P. Schiffer, A. P. Ramirez, W. Bao, and S.-W. Cheong, Phys. Rev. Lett. 75, 3336 (1995).

[23] C. Zener, Phys. Rev. 82, 403 (1951).

[24] F. S. Ravavi, G. Gross, H. U. Habermeier, O. Lebedev, S. Amelinckx, G. Van Tendeloo, and A. Vigliante, Appl. Phys. Lett. 76, 155 (2000)

[25] S. I. Khartsev, P. Johnsson, and A. M. Grishin, J. Appl. Phys. 87, 2394 (2000) [26] M. Kanai, H. Tanaka, and T. Kawai, Phys. Rev. B. 70, 125109 (2004) [27] L. Mechin, F. Yang, J.-M. Routoure, and D. Robbes, J. Appl. Phys. Lett. 93, 8062 (2003) [28] Alvydas Lissauskas, S. I. Khartsev, and Alex Grishin, Appl. Phys. Lett. 77, 756(2000) [29] C. Marshall, N. Butler, R. Blackwell, R. Murphy, and T. Breen, Proc. SPIE 2746, 23 (1996) [30] J. Baszynski, T. Tolinski, B. Idzikowski, D.M. Tobbens, A. Hoser J. Baszynski et al. / Journal of Alloys and Compounds 345 210–213 (2002) [31] Guo-Qiang Gong, Chadwick Canedy, and Gang Xiao, Appl. Phys. Lett 67, 1783 (1995) [32] Wei Zhang, W. Boyd and Martin Elliot, Appl. Phys. Lett 69 3929(1996)