Dislocations in charge-ordered $Pr_{0.5}Ca_{0.5}MnO_3$ epitaxial thin films prepared by two-step growth technique

Y. L. Zhu, X. Wang, M. J. Zhuo, and X. L. Ma

Shenyang National Laboratory for Materials Science, Institute of Metal Research, Chinese Academy of Sciences, 72 Wenhua Road, 110016 Shenyang, China

ylzhu@imr.ac.cn
Keywords: Manganite, charge ordering, dislocations, two-step growth, TEM

$Pr_{0.5}Ca_{0.5}MnO_3$ (PCMO) is a typical perovskite type compound showing charge ordering (CO). The insulating CO state can be totally suppressed by the application of an external magnetic field, though the magnetic field is usually quite high in the bulk materials. For example, a 25T magnetic field is required to melt the CO state in the bulk PCMO [1]. In comparison, much lower magnetic fields (below 10T) were employed to destroy the CO state in thin films of PCMO, which ascribes either to the effects of lattice strains due to the substrate [1] or the effects of disorder induced by strain relaxation in the PCMO films prepared by two-step growth technique [2].The latter is closely related to the defects in the films during the film growth.

Two-step growth technique was recently introduced to accelerate strain relaxation of epitaxial perovskite-based oxide films [2], which is proved to be an effective way to separate the influences of lattice and thermal mismatches on misfit strain. In consequence, dislocations and other associated defects in the as-received thin films may display different configurations compared with those in the films grown by normal deposition process.

PCMO thin films were grown on STO substrates by sputtering in pure oxygen atmosphere of 300 Pa with substrate-source on-axis geometry. 80 nm thick films were prepared by two-step growth technique: a thin layer of 10 nm was first grown at 120ºC; after deposition of this layer, the substrate temperature was raised to 840ºC and kept constant for 30min, i.e., annealing; then, the second layer of 70nm was grown at this temperature. Plan view specimens were prepared for TEM observation. A Tecnai G2 F30 transmission electron microscope, equipped with a high angle angular dark field (HAADF) detector and working at 300kV, was used for lattice imaging and contrast analysis.

Tilting experiments in conventional TEM revealed some characteristics of the misfit dislocations. The plan-view images of Fig.1 (a) to (c) were taken under **g**=(110), **g**=(200) and **g**=(020) two-beam conditions, respectively, with an incident beam direction close to [001] of the substrate. Two arrays of dislocation lines along the [100] and [010] directions of the substrate are evident in Fig.1 (a) with nearly equal spacings, forming a square grid of misfit dislocations. The regular distribution of misfit dislocations indicates that the strains on the growth surface is nearly uniform.When the image was taken under **g** = (100) two beam direction as shown in Fig.1 (b), an array of parallel dislocation lines along the (010) direction appears. When the image was taken under **g** = (010) two beam condition, another array of dislocation lines is observed, while those observed under the **g**=(100) condition disappears. According to the extinction criterion **g•b**, the line direction and the Burgers vector are perpendicular to each other for each misfit dislocation, indicating the present of pure edge dislocations.

Threading dislocations (TDs) and other defects were also investigated in plan view specimens. Figure 2 show two plan view bright field images taken from the areas including

DOI: 10.3217/978-3-85125-062-6-598 , © Verlag der TU Graz 2009

both the films and the films on the thin compliant substrates. The **g** vectors used for the images in Fig.2 (a) -2(b) are $(\bar{1}10)$ and (110), of the substrate, respectively. Because the images were recorded including part of substrate, it is reasonable to say that these micrographs reveal the information from the first layer of PCMO film, in which many small segments of dislocations can be observed. They can be divided into two types. One is the threading dislocations denoted by A. The other is the dislocations denoted by B, exhibiting an oscillatory contrast, implying that they are actually inclined with respect to the film surface. The characters of those dislocations type B were also determined by the extinction criterion of **g • b** = 0.From Fig.2 (a) and 2(b), it can be learnt that most these dislocations are those with their line directions parallel to ***b***, which means that these dislocations are screw type. This kind of screw dislocations has not been reported so far in perovskite oxide films.

1. W. Prellier, Ch. Simon, B. Mercey, M. Hervieu, A. M. Haghiri-Gosnet, D. Saurel, Ph. Lecoeur, and B. Raveau, J. Appl. Phys. 89 (2001) 6612
2. Y. Q Zhang, Y. L. Zhu, Z. D Zhang, and J. Aarts, J. Appl. Phys. 101 (2007)063919
3. This research was supported by the Chinese Academy of Sciences and the National Natural Science Foundation of China (Grant No. 50871115)

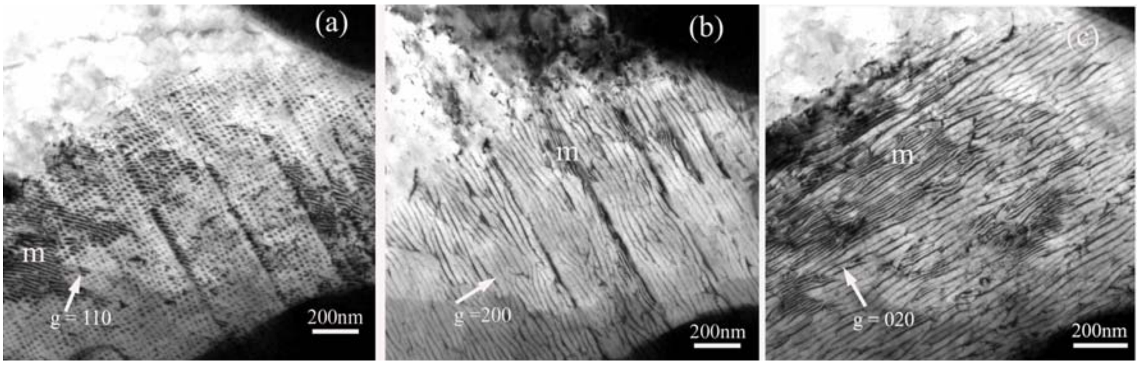

Figure 1. Brighe field images taken from a plan view specimen under the two-beam conditions of **g**= (a) (110); (b) (200); and (c) (020). The misfit dislocations are pure edge type and have Burgers vectors $a\langle 010\rangle$ and line directions of $\langle 100\rangle$. m stands for moiré fringe.

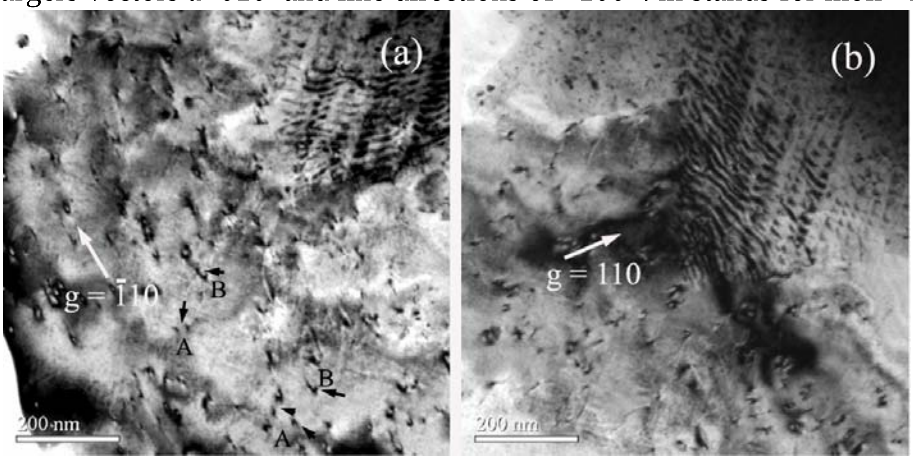

Figure 2. Plan view images taken from the area including the film and the film on the thin compliant substrate under the two-beam conditions of **g**= (a) $(\bar{1}10)$ and (b) (110).Those dislocations denoted by B are screw type with a Burgers vector $a\langle 110\rangle$ and line directions of $\langle 11h\rangle$.

W. Grogger, F. Hofer, P. Pölt (Eds.): MC2009, Vol. 3: Materials Science,
DOI: 10.3217/978-3-85125-062-6-598 , © Verlag der TU Graz 2009