Microsc Microanal 14 (supp 3), 2008
 doi: 10.1017/S1431927608089356

Structural and Microanalytical Studies of CrO_2 Thin Films on c-Sapphire by High Resolution Electron Microscopy Methods

M.I. Ortiz [a], P.M. Sousa [b], C. Ballesteros [a], A.J. Silvestre [c], L.F. Cohen [d] and O. Conde [b,*]

[a] Universidad Carlos III, EPS, Departamento de Física, 28911 Leganés (Madrid), Sp
[b] Universidade de Lisboa, Departamento de Física e ICEMS, 1749-016 Lisboa, PT
[c] Instituto Superior de Engenharia de Lisboa e ICEMS, 1959-007 Lisboa, PT
[d] Imperial College, Department of Physic, Blackett Laboratory, London SW7 2AZ, UK
[*] oconde@fc.ul.pt

Chromium dioxide (CrO_2) has been extensively used in the magnetic recording industry. However, it is its ferromagnetic half-metallic nature that has more recently attracted much attention, primarily for the development of spintronic devices. CrO_2 is the only stoichiometric binary oxide theoretically predicted to be fully spin polarized at the Fermi level. It presents a Curie temperature of ~ 396 K, i.e. well above room temperature, and a magnetic moment of 2 μ_B per formula unit [1-5]. However an antiferromagnetic native insulating layer of Cr_2O_3 is always present on the CrO_2 surface which enhances the CrO_2 magnetoresistance and might be used as a barrier in magnetic tunnel junctions.

Here we report on high resolution electron microscopy structural and analytical studies of CrO_2 films deposited onto Al_2O_3 (0001) by atmospheric pressure CVD from CrO_3 precursor. As reported previously [6] films were grown within a broad range of deposition temperatures from 320 to 410 ºC, and oxygen carrier gas flow rates of 50 – 500 sccm. Herein we will show the results obtained for two films grown at 340 and 360 ºC with 100 sccm oxygen.

Cross-sectional specimens for TEM were prepared by mechanical grinding, dimpling and argon ion-milling of the samples in a liquid-nitrogen-cooled holder with an acceleration voltage of 5 keV and an incidence angle of 8º. Analytical TEM and HREM studies were carried out using a Philips Tecnai 20F FEG microscope operating at 200 keV, equipped with an Energy Dispersive X-Ray (EDX) analysis system and a scanning transmission electron microscopy modulus (STEM) with a high angle annular detector (HAAD) for Z-contrast imaging and composition mapping. Electron diffraction pattern (EDP) and simulations using Fast Fourier transform (FFT) of the HREM images were used to analyze the crystal structure.

Bright field images of the sapphire substrate and of the chromium oxide film deposited at 360 ºC are shown in figure 1. Two different growth areas were identified. At the first stages of deposition a three-dimensional (3D) growth forming pyramidal structures of Cr_2O_3 is observed. Defects and distortions at the substrate-film interface can be seen. The corresponding high resolution image is also shown in figure 1, as well as the simulated patterns using FFT which indicate that both aluminium and chromium oxides show corundum structure with an orientation relationship between the substrate and the 3D layer of the type (0001) Al_2O_3 || (0001) Cr_2O_3. The top part of the layer that appears with a clear contrast is a mixture of Cr_2O_3 and tetragonal rutile CrO_2. The observed contrast in the top layer suggests a columnar growth and the defects observed along the layer indicate epitaxial stress during growth.

When the films are grown at a lower temperature of 340 ºC a different interfacial structure is observed. The substrate/film interface appears sharp and free of defects, as can be seen in the high resolution image of figure 2, no Cr_2O_3 3D interlayer structure is formed, and only a mixture of CrO_2 and Cr_2O_3 crystals could be identified. From the selected area diffraction pattern and FFT simulations, the following orientation relationship between the oxides was determined: [01-10] Al_2O_3 || [01-10] Cr_2O_3 || [001] CrO_2.

In conclusion, the CVD films develop with a different interfacial structure depending on deposition temperature which might be used to build different types of devices.

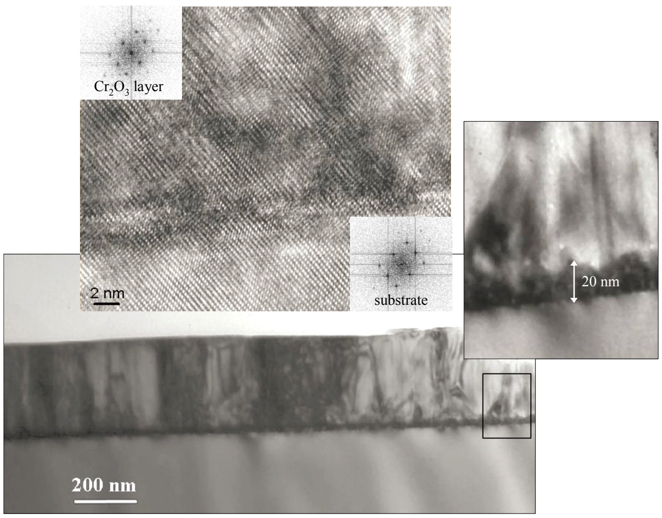

Fig. 1. Bright field and high resolution electron microscopy images and FFT simulations of a film grown at 360 ºC with an oxygen flow rate of 100 sccm.

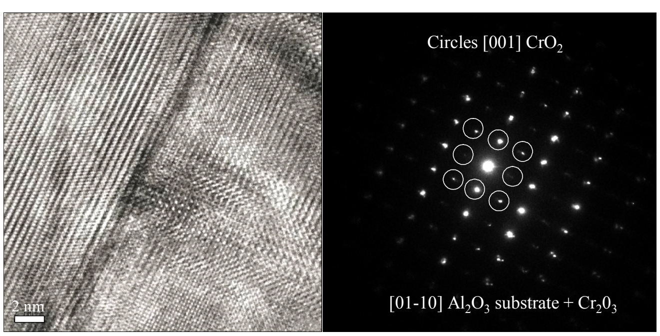

Fig. 2. High resolution electron microscopy image and selected area diffraction pattern of a film grown at 340 ºC with an oxygen flow rate of 100 sccm.

References

[1] K. Schwartz, J. Phys. F: Met. Phys. 16 (1986) L211.
[2] K.P. Kämper et al., Phys. Rev. Lett. 59 (1987) 2788.
[3] R.J. Soulen, et al, Science 282 (1998) 85.
[4] H. Imamura, S. Takahashi, S. Maekawa, Concepts in Spin Electronics, Oxford University Press, Oxford, UK, 2006.
[5] J.M.D. Coey, and M. Venkatesan, J. Appl. Phys., 91 (2002) 8345.
[6] P. M. Sousa et al., Chem. Vapor Deposition, 13 (2007) 537-545.
[7] The authors gratefully acknowledge the financial support of Fundação para a Ciência e Tecnologia (FCT) under contract POCTI/CTM/41413/2001, CRUP/CSIC bilateral contract E-19/06, and CRUP/British council bilateral contract B-7/07. P.M. Sousa also acknowledges FCT for a PhD grant (BD16567/2004).

https://doi.org/10.1017/S1431927608089356 Published online by Cambridge University Press