Available online at www.sciencedirect.com
SCIENCE DIRECT
ELSEVIER
Journal of Magnetism and Magnetic Materials 300 (2006) e526–e529
Journal of magnetism and magnetic materials
www.elsevier.com/locate/jmmm

Strain-induced magnetic anisotropies in epitaxial CrO_2 thin films probed by FMR technique

B.Z. Rameev[a,b,*], A. Gupta[c], F. Yıldız[a], L.R. Tagirov[a,d], B. Aktaş[a]

[a]Department of Physics, Gebze Institute of Technology, 41400 Gebze-Kocaeli, Turkey
[b]Kazan Physical-Technical Institute of RAS, 420029 Kazan, Russian Federation
[c]University of Alabama, Tuscaloosa, Al 35487, USA
[d]Kazan State University, Kazan 420008, Russian Federation

Available online 16 November 2005

Abstract

Epitaxial CrO_2 thin films were grown onto TiO_2 (1 0 0) single-crystalline substrates by chemical vapour deposition (CVD) process with use of the solid precursor CrO_3. The CrO_2 films with thickness of 27 and 65 nm were deposited onto TiO_2 substrates pre-etched in the diluted HF. The magnetic properties of the epitaxial chromium-dioxide films have been probed by the ferromagnetic resonance (FMR) technique. Analysis of the FMR spectra shows that the magnetic behaviour of the CrO_2 films results from a competition between magnetocrystalline and strain anisotropies. The thin films are heavily strained due to lattice mismatch of CrO_2 epitaxial film with the TiO_2 single-crystalline substrate. For the thinnest film (27 nm) the stress anisotropy dominates, and the magnetic easy axis switches from the ***c*** direction to the ***b*** direction of the rutile structure. Unusual angular dependence of the resonance signal and multiple FMR modes are observed for the film with the thickness of 65 nm, where a partial strain relaxation results in appearance of two magnetic phases with mutually perpendicular easy axes along the ***c*** and ***b*** directions.

PACS: 75.70.Ak; 75.50.Cc; 75.30.Gw; 76.50. + g

Keywords: Thin films; Half-metallic materials; Magnetic anisotropy; Ferromagnetic resonance

1. Introduction

Further development of electronics towards higher miniaturization, operation speed, energy efficiency, and enhanced functionality has provided the opportunity of *magnetoelectronic* devices that exploit not only the electrical charge but also the spin of the conducting electrons. Recent progress in magnetoelectronics has been breathtaking and has already resulted in some commercial products [1]. The most critical parameter for the performance of magnetoelectronic devices is the spin polarization of the conduction band of a ferromagnetic component. In this respect, the extremely high polarization (almost 100%) of the conduction band of chromium dioxide (CrO_2) [2–6] has attracted much attention to this material.

For the practical applications of CrO_2 in magnetoelectronic devices, it is very important to understand the magnetic anisotropies of thin films of CrO_2, and explore possible approaches to control these properties and to tailor them appropriately. High-quality single-crystalline CrO_2 films grown on TiO_2 substrates have been synthesized recently by chemical vapour deposition (CVD) [7], and quite a few papers on their electric and magnetic properties have been published [4–13]. We have demonstrated previously [7,14,15] that the effect of strain anisotropies can become dominant in the ultrathin ($\leqslant$60 nm) CrO_2 films deposited on (1 0 0) TiO_2 substrates. Besides, it is possible to grow strain-free films by skipping the cleaning procedure of the substrate in HF acid [7]. Furthermore, it has been shown that the magnetic anisotropies of the CrO_2 films, depending on specific features of the CVD process, show a very slight or even opposite thickness behaviour [12,13]. Apparently, the morphology of a very thin CrO_2 sub-layer

*Corresponding author. Tel.: +90 262 6051314; fax: +90 262 6538490.
E-mail address: rameev@gyte.edu.tr (B.Z. Rameev).

0304-8853/$ - see front matter
doi:10.1016/j.jmmm.2005.10.207