

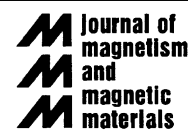


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Strain-induced magnetic anisotropies in epitaxial CrO₂ thin films probed by FMR technique

B.Z. Rameev^{a,b,*}, A. Gupta^c, F. Yıldız^a, L.R. Tagirov^{a,d}, B. Aktaş^a^aDepartment of Physics, Gebze Institute of Technology, 41400 Gebze-Kocaeli, Turkey^bKazan Physical-Technical Institute of RAS, 420029 Kazan, Russian Federation^cUniversity of Alabama, Tuscaloosa, AL 35487, USA^dKazan State University, Kazan 420008, Russian Federation

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Abstract

Epitaxial CrO₂ thin films were grown onto TiO₂ (1 0 0) single-crystalline substrates by chemical vapour deposition (CVD) process with use of the solid precursor CrO₃. The CrO₂ films with thickness of 27 and 65 nm were deposited onto TiO₂ 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 CrO₂ films results from a competition between magnetocrystalline and strain anisotropies. The thin films are heavily strained due to lattice mismatch of CrO₂ epitaxial film with the TiO₂ 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.

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1. Introduction

Further development of electronics towards higher miniaturization, operation speed, energy efficiency, and enhanced functionality has provided the opportunity of *magneto-electronic* devices that exploit not only the electrical charge but also the spin of the conducting electrons. Recent progress in magneto-electronics has been breathtaking and has already resulted in some commercial products [1]. The most critical parameter for the performance of magneto-electronic 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 (CrO₂) [2–6] has attracted much attention to this material.

For the practical applications of CrO₂ in magneto-electronic devices, it is very important to understand the magnetic anisotropies of thin films of CrO₂, and explore possible approaches to control these properties and to tailor them appropriately. High-quality single-crystalline CrO₂ films grown on TiO₂ 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 (≤ 60 nm) CrO₂ films deposited on (1 0 0) TiO₂ 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 CrO₂ 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 CrO₂ sub-layer

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