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Anisotropic ferromagnetism in Co-implanted TiO_2 rutile

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Abstract

We have studied the magnetic properties of the Co-implanted TiO_2 thin films by magneto-optical Kerr effect (MOKE) and superconducting quantum interference device (SQUID) techniques. The single-crystalline (1 0 0), (0 0 1) and (1 1 0) TiO_2 substrates of rutile structure have been heavily irradiated by Co^+ ions with an energy of 40 keV to a dose of 1.5×10^{17} ion/cm^2. Both techniques revealed strong room-temperature ferromagnetism, with magnetic parameters depending on the crystallographic orientation of the substrate. It has been observed by MOKE that the angular dependencies of the magnetic remanence and of the coercive field indicate a two-fold in-plane anisotropy for the (1 0 0) and (1 1 0) substrate and a four-fold in-plane anisotropy for the (0 0 1) substrate samples. SQUID measurements at room and low temperatures confirm the MOKE results. We also discuss the origin of the ferromagnetism emerging in dielectric and diamagnetic single-crystalline TiO_2 substrates after Co-ion implantation.

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Keywords: Room-temperature ferromagnetism; Titanium dioxide; Ion implantation; Ferromagnetic semiconductors

1. Introduction

The discovery of ferromagnetism in magnetic ion-doped diluted magnetic semiconductors (DMSs) has inspired a growing interests because of their potential applications in spintronics [1]. The key requirement in the realization of such devices is that the candidate material must be ferromagnetic above room temperature. Since the observation of room-temperature ferromagnetism in Co-doped anatase TiO_2 [2], considerable attention has been paid to the Co:TiO_2 system [3–7]. Recently, we have observed that Co-implanted single-crystalline TiO_2 rutile shows very high Curie-temperature ferromagnetism [8]. We have also shown that the crystallographic orientation of the substrate has a strong influence on the magnetic anisotropy of single-crystalline TiO_2 rutile after heavy implantation by Co ions with a dose of 2×10^{17} ion/cm^2 [9].

In this article, we report on magnetic properties of the single crystalline TiO_2 substrates of rutile structure implanted with Co to a dose of 1.5×10^{17} ion/cm^2. The influence of implantation dose on magnetic properties and on the in-plane anisotropies of the (1 0 0), (1 1 0) and (0 0 1) substrates have been studied by magneto-optical Kerr effect (MOKE) and superconducting quantum interference device (SQUID) techniques.

2. Experiment

The (1 0 0), (1 1 0) and (0 0 1) face single-crystalline rutile plates were implanted in *ILU*-3 ion accelerator (KPTI of RAS) with 40 keV Co^+ ions to a dose of 1.5×10^{17} ion/cm^2, at an ion current density of 8–9 μA/cm^2. Room temperature hysteresis loops were measured using a high-resolution MOKE set-up in the longitudinal configuration with s-polarized light (see details in Ref. [10]). MOKE measurements were performed for various in-plane orientations of

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