Materials Research Bulletin 46 (2011) 2304–2307

Contents lists available at SciVerse ScienceDirect

Materials Research Bulletin

journal homepage: www.elsevier.com/locate/matresbu

Magnetic phase composition of strontium titanate implanted with iron ions

E.N. Dulov [a,*], N.G. Ivoilov [a], O.A. Strebkov [a], L.R. Tagirov [a,b], V.I. Nuzhdin [b], R.I. Khaibullin [a,b], S. Kazan [c], F.A. Mikailzade [c,d]

[a] Kazan Federal University, 420008 Kazan, Russian Federation
[b] Zavoisky Physico-Technical Institute, Kazan Scientific Center, Russian Academy of Sciences, 420029 Kazan, Russian Federation
[c] Department of Physics, Gebze Institute of Technology, Gebze, 41400 Kocaeli, Turkey
[d] Institute of Physics, Azerbaijan National Academy of Sciences, H. Javid Av. 33, AZ 1143, Baku, Azerbaijan

ARTICLE INFO

Article history:
Received 24 December 2010
Accepted 25 August 2011
Available online 3 September 2011

PACS:
76.80.+y
75.75.Cd
68.55.Ln

Keywords:
A. Nanostructures
B. Magnetic properties
C. Mössbauer spectroscopy

ABSTRACT

Thin magnetic films were synthesized by means of implantation of iron ions into single-crystalline (1 0 0) substrates of strontium titanate. Depth-selective conversion electron Mössbauer spectroscopy (DCEMS) indicates that origin of the samples magnetism is α-Fe nanoparticles. Iron-substituted strontium titanate was also identified but with paramagnetic behaviour at room temperature. Surface magneto-optical Kerr effect (SMOKE) confirms that the films reveal superparamagnetism (the low-fluence sample) or ferromagnetism (the high-fluence sample), and demonstrate absence of magnetic in-plane anisotropy. These findings highlight iron implanted strontium titanate as a promising candidate for composite multiferroic material and also for gas sensing applications.

1. Introduction

Strontium titanate $SrTiO_3$ (STO) itself comprises a unique set of physical characteristics. First, it is diamagnetic wide-gap semiconductor (3.25 eV, insulator for most of practical applications) with excellent optical properties: high refractive index ($n = 2.5$), transparency in visible and infrared (up to wavelength ~5 μm) spectral range [1]. Second, perfect STO is a quantum ferroelectric, however, ^{18}O-enriched material exhibits paraelectric to ferroelectric phase transition when cooling below 25 K [2]. It can be affected by mechanical strain or impurities. For example, biaxial strains in epitaxially grown thin STO film can increase the transition temperature so that the room temperature ferroelectricity is observed [3]. Third, STO and STO-based materials have mixed electronic-ion-vacancies conduction mechanism that has been successfully used in oxygen sensing applications [4], and it is closely related to the high photocatalytic activity of STO [5]. In combination with their high thermal and chemical stability, and parent crystalline structure for most of high-temperature superconductors, STO is being a very attractive material for microelectronic, magneto-optic, superconducting electronic, microwave, electrochemical, energy conversion applications and gas sensing.

Doping of STO by impurities is considered as a way to tune known characteristics of the base material or to obtain new functional properties. In the light of present microelectronic and spintronic demands, the most interesting kind of dopant is a transition metal atom. It was recently shown that thin (500 nm) film of STO, epitaxially grown by pulsed laser deposition on lanthanum aluminate and heavily doped by iron, can exhibit diluted ferromagnetism at room temperature [1]. Taking into account ferroelectric properties of STO it should be expected multiferroicity appearing in ferromagnetic iron-doped STO, at least for low temperatures. An argument to expect the multiferroicity in ion-implanted STO at room temperature is that pure STO has estimated pressure of about 6 GPa needed to initiate cubic-to-tetragonal transition at 300 K [6]. This may be a value of the same order as induced by the implanted ions strains [7,8]. Besides, formation of nanoclusters induced by ion implantation in STO [9–11] may lead to the composite multiferroicity.

In this work, we report on magnetic phase composition of strontium titanate heavily implanted with iron ions as studied by the depth-selective conversion electron Mössbauer spectroscopy and surface magneto-optical Kerr effect.

2. Experimental

The samples were prepared irradiating (1 0 0)-oriented single-crystalline plates of STO with 40 keV iron ions representing a 1:3

* Corresponding author. Tel.: +7 917 9114637; fax: +7 843 2925824.
E-mail addresses: evgeny.dulov@ksu.ru, fe57@rambler.ru (E.N. Dulov).

0025-5408/$ – see front matter © 2011 Elsevier Ltd. All rights reserved.
doi:10.1016/j.materresbull.2011.08.057