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Magnetic properties of Fe implanted $SrTiO_3$ perovskite crystal

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ABSTRACT

The results of investigations of magnetic properties of $SrTiO_3$ perovskite crystal implanted with 40 keV Fe ions at the fluencies between 0.5×10^{17} and 1.5×10^{17} ion/cm^2 are presented. It has been revealed that high-fluency implantation with Fe ions results in the formation of a granular metal particulate composite in the irradiated near-surface layer of $SrTiO_3$ substrate, which exhibits remarkable ferromagnetic behavior. The measurements of the temperature dependence of the magnetic moment showed that the samples exhibit blocking temperature at about 350 K, above which a superparamagnetic behavior has been observed. Ferromagnetic ordering and magnetic hysteresis loops were observed in Fe implanted $SrTiO_3$ at the temperatures lower than 350 K. It has been shown that the magnetization of the ferromagnetic state depends on the fluency of implantation.

1. Introduction

In recent years there has been a great interest in the study of magnetic properties of the composite materials representing dispersed magnetic nanoparticles embedded in non-magnetic medium due to their wide application potential in the fields of magnetoelectronics and spintronics, which includes magnetic recording, magneto sensor electronics, magneto optical devices and others [1]. Additionally, these materials provide a good model system for studying experimentally fundamental phenomena in nanomagnetism [2,3], especially due to their exhibiting interesting phenomena when the nanoparticles are coupled by magnetic interactions [4–7].

Among the host non-magnetic media, strontium titanate $SrTiO_3$ (STO) is a very attractive and prospective material which possesses a unique set of physical characteristics. It is a diamagnetic wide-gap semiconductor (3.25 eV) with excellent optical properties: high refractive index ($n \sim 2.5$), transparency in visible and infrared (up to wavelength $\sim$5 μm) spectral range [8]. Besides, STO and STO-based materials have mixed electronic-ion-vacancies conduction mechanism that has been successfully used in oxygen sensing applications [9]. Generally, in combination with their high thermal and chemical stability, STO is being a very attractive material for microelectronic, magneto-optic, superconducting electronics, microwave, electrochemical, energy conversion applications and gas sensing.

The results of first investigations of magnetic resonance and magnetization of Fe implanted strontium titanate ($SrTiO_3$) single crystal were presented in [10]. It was shown that the electron paramagnetic resonance spectrum of Fe implanted $SrTiO_3$ possesses resonance lines due to the paramagnetic (Fe^{3+}-V_o) site with axially disturbed ligand field, and due to S-state Fe^{3+} ions ($S = 5/2$ and $L = 0$) substituted into titanium site coordinated by six oxygen atom in Ti^{4+} centered unit cell. It has been revealed that the implantation of Fe ions into $SrTiO_3$ produces a remarkable ferromagnetic behavior. The ferromagnetic resonance (FMR) and magnetization measurements revealed an out-of-plane uniaxial magnetic anisotropy in Fe-implanted $SrTiO_3$. Then, later these composite structures were investigated using depth-selective conversion electron Mössbauer spectroscopy [11], which revealed that the origin of magnetism is α-Fe metallic nanoparticles with estimated average particle size of 5 nm, formed as a result of iron implantation. Additionally, surface magneto-optical Kerr effect (SMOKE) observed in these samples, confirmed the presence of superparamagnetism at room temperature, as well as ferromagnetism at low temperatures.

In this paper the results of detailed investigation of magnetization of $SrTiO_3$ perovskite crystals implanted by Fe ion with various implantation fluencies are presented. These results show the promise of magnetic nanocomposites based on metal nanoparticles embedded on a dielectric host for potential magnetoelectronic applications as well as the flexibility of ion implantation as a

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