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Magnetic resonance and magnetization in Fe implanted $BaTiO_3$ crystal

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ABSTRACT

The results of investigations of the magnetic properties of Fe implanted barium titanate ($BaTiO_3$) perovskite crystal are presented. It has been revealed that the implantation with Fe^+ ions at a fluence of 0.75×10^{17} ions/cm^2 results in the formation of iron nanoparticles with mean size of 5 nm in the implanted surface layer of $BaTiO_3$ substrate. Room temperature magnetic resonance measurements have shown Electron Paramagnetic Resonance (EPR) spectra originated from Fe^{3+} ions in the $BaTiO_3$ substrate, as well as ferromagnetic resonance (FMR) spectrum from the Fe-implanted surface layer, exhibiting the out-of-plane uniaxial magnetic anisotropy. On the other hand, Vibrating Sample Magnetometer (VSM) measurements of the static magnetization have shown that the composite Fe: $BaTiO_3$ system displays superparamagnetic response at room temperature, and evident ferromagnetic behavior with an easy-plane magnetic anisotropy at temperature below 100 K. The observed magnetic anisotropy is discussed on a model of strong magnetic dipolar interaction between superparamagnetic nanoparticles of iron within the granular composite film formed in a result of the high-fluence implantation.

1. Introduction

Multiferroic materials, made by combining ferroelectric and ferromagnetic substances, have been under significant interest in recent years due to their attractive physical properties and multifunctionality, which provide opportunities for potential applications in information technologies, radioelectronics, optoelectronics, and microwave electronics [1]. In these materials, the coupling interaction between ferroelectric and ferromagnetic constituents may produce a magnetoelectric effect [2] in which change in magnetization is induced by an electric field, and change in electric polarization is induced by an applied magnetic field. However, very few natural multiferroics that are both ferromagnetic and ferroelectric in the same structural phase [3]. This is because off-center distortions responsible for the electric polar behavior are usually incompatible with the partially filled *d*-levels, which required for a magnetic ground state [4]. As known from the literature, strong magnetoelectric effect, which exceeds intrinsic effects by orders of magnitude, could be realized in composites consisting of magnetostrictive and piezoelectric components [5]. In particular, multiferroic composites based on dispersion of ferromagnetic nanoparticles in ferroelectric and/or piezoelectric matrices typically reveal a giant magnetoelectric effect that makes them suitable for technical applications [1].

Hence, the synthesis and characterization of new multiferroic nanocomposite materials, especially magnetic nanoparticles embedded into a crystalline matrix of ferroelectric perovskite oxides, are of great interest. The magnetic properties of such composites can be controlled on a large scale by varying the average nanoparticle size, distribution, packing factor, and composition of the magnetic inclusions and surrounding ferroelectric medium. Actually, there is a number of different techniques for fabrication of composite materials with controlled structural and magnetic characteristics. Among these techniques, ion implantation has a number of advantages: easy control of the metal distribution and concentration; the availability of almost arbitrary metal-dielectric compositions; the ability to surpass the solubility limits constrained by the chemical and thermodynamic equilibrium of the host matrix and metal impurities [6]. Besides, the ion implantation technique is ideally suited for fabrication of thin-film magnetic media and planar devices for magneto-sensor electronics.

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