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Swift heavy ion track - based nanostructures in SiO_2/Si system for spintronic applications

V. V. Malyutina-Bronskaya[1], J. A. Ivanova[2], D. K. Ivanou[2], E. A. Streltsov[2], A. K. Fedotov[2], A. V. Petrov[3], S. E. Demyanov[3] E. Yu. Kaniukov[3] and D. Fink[4]

[1] Institute of Electronics, NAS Belarus, Minsk, Belarus
[2] Belarusian State University, Minsk, Belarus
[3] Joint Institute of Solid State and Semiconductor Physics, NAS Belarus, Minsk, Belarus
[4] Hahn-Meitner-Institute, Berlin, Germany

Abstract. The swift heavy ion track technology is used for creation of new types of magnetic-field-sensitive spintronic structures on the base of SiO_2/Si system. A "TEMPOS" ("Tunable Electronic Material with Pores in Oxide of Semiconductors") concept is used for the preparation of these structures. First samples of the structures with ion tracks (pores) in the SiO_2 layers, filled with metallic nanoparticles were created and their investigations have been started.

Introduction

At present an intensive search for the new technologies, which makes it possible to lower the dimensions of electronic devices down to the nanometric size range, takes place worldwide. On this concern, an interest to the development of non-traditional technologies of formation of nanomaterials, nanostructures and their arrays, increases. In this way, here is used the so called swift heavy ion track technology which is connected with formation of narrow trails of radiation damage ("latent ion tracks") as a result of the high-energy ions impact. Further, by means of the chemical etching of latent tracks, pores of various forms and dimensions (typically 10 to 1000 nm), depending on irradiation parameters, etching conditions and substrate type, are formed. Later on, functional elements for nanoelectronics can be created on the base of these structures [1].

1. Expected properties and preparation of the SiO_2/Si -based nanostructures

New types of spintronic materials and structures, which can be used in magnetoresistive sensors, motion detectors, memory devices, etc., are of a special interest for industry at present. For the creation of such devices, one need to use the structures containing magnetic nanoparticles and their alternating layers, having giant magnetoresistance or tunnel magnetoresistance, and being able to function at high frequencies. The elaboration of the swift heavy ion tracks technology should be quite prospective for this sake. Therefore, goal of the present research is to develop and create the new types of magnetic-field-sensitive spintronic structures on the base of the etched ion tracks in silicon oxide, inside of which homogeneous nanocompositions or multilayered structures with alternating layers of ferromagnetic (Ni, Co, Fe) and non-magnetic (Cu, Ag, Se, $A_{II}B_{VI}$ and $A_{IV}B_{VI}$) nanoparticles. For the creation of these structures, it is planned to use the "TEMPOS" ("Tunable Electronic Material with Pores in Oxide of Semiconductors") concept, which has been developed earlier at the Hahn-Meitner-Institute (Berlin, Germany) and the University of Hagen (Germany). According to this concept [1-3], the structure used in our research consists of the following components: (1) a n- or p-doped silicon wafer, (2) a SiO_2 layer on top of the silicon wafer, (3) very narrow conducting connections traversing the whole dielectric layer, thus connecting top and bottom (etched ion tracks, filled with metallic nanoparticles), and (5) three electrical contacts, two of them being on the top of the sample and one of them being on its back side (Fig.1). The "TEMPOS"-concept is used for the creation of MOS-type structures, having non-linear I/V characteristics, and in this number, with negative differential resistance, which is important for the present research.

Following steps in realization of the described above research concept have been already taken by us. First, the samples of SiO_2/n-Si and SiO_2/p-Si have been prepared by a standard technology of Si thermal oxidation at 1100 ^{0}C during 10 hours, and SiO_2 layer thickness was 0.7 μm. Then, the obtained samples were irradiated with $^{197}Au^{26+}$ having energy 350 MeV and fluence 5×10^8 cm^{-2} at the "Ion Beam Laboratory" Center of the Hahn-Meitner-Institute. During the next stage of the research realization, the latent ion tracks, formed in the SiO_2 layer after irradiation, have been etched with fluoric acid (HF) with concentrations 1.35 wt.% 2.7 wt.% during 40 min. and 20 min. correspondingly. As a result, stochastically placed conical pores, reaching the Si layer, having diameters 250 nm and height 200 nm, have been formed. Further on, the method of underpotential electrochemical deposition, developed at the Chemistry Department of the Belarusian State University, is used for the deposition of metallic nanoparticles [4]. Due to precise measurements of current flowing in an electrochemical cell, this method provides a highly effective control of thickness, stoichiometric composition and grain dimensions of deposited substances, and can also provide a high purity of deposited metals and semiconductors. The electrochemical deposition of metals and semiconductors to form a multicluster/multilayered structure is conducted at relatively low temperatures, which diminishes a possibility of interdiffusion of different components in heterostructures. In this way, the first samples with Cu and Ni nanoparticles deposited in the pores in SiO_2 were prepared (Fig.2), and their microscopic and electrical-physical investigations have been started by our group.

References

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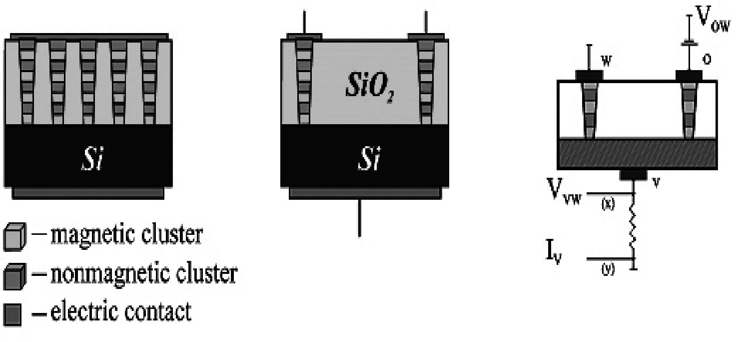

Fig. 1. A sketch of the preparation and measurement of "TEMPOS"-type structures on the base of SiO_2/Si system with etched swift heavy ion tracks.

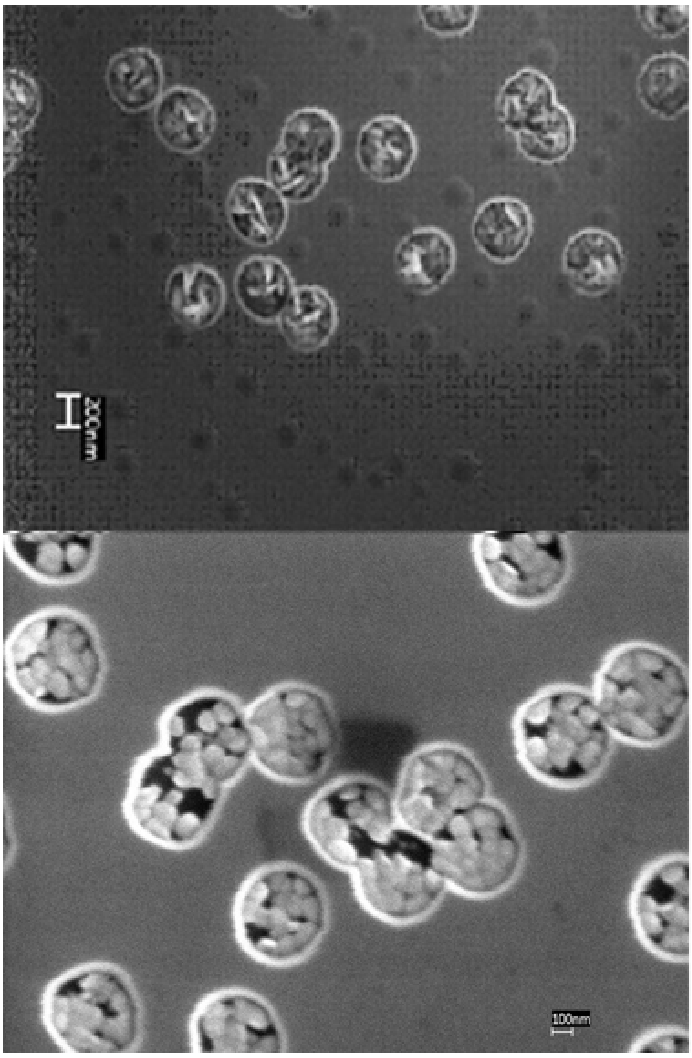

Fig. 2. SiO_2/Si structures with Cu (upper part of the figure) and Ni (lower part of the figure) nanoparticles in the etched swift heavy ion tracks in SiO_2 layer.