Development of Physical/Technological Fundamentals or Production of Composite Metal-Semiconductor-Insulator Nanostructures with Tunable Electric and Magnetic Properties

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This work is devoted to the results of the study of two types composite metal-semiconductor-insulator (MSI) nanostructures, which can be used for production of sensors, transducers, microminiature electric engineering componentry and memory media.

1. MSI film nanocomposites containing metallic FeCo-based nanoparticles with "core – shell" structures embedded into insulating matrixes (alumina, fluoride, PZT, etc.). Semiconducting "shells" around metallic "core" are composed of FeCo-based oxides which are formed when deposition of the films in argon – oxygen atmosphere in vacuum chamber using ion-beam sputtering of compound targets. The presence of semiconducting FeCo-based oxide "shells" around FeCo-based nanoparticles results in the appearance of inductive-like contribution into reactive part of impedance in form of the so called negative capacitance effect. We analyze the conditions (concentration of FeCo-base phase, type and state – amorphous or crystalline - of insulating matrix, composition of "core-shell" structure, temperature, frequency range, annealing, etc.) when inductive-like contribution prevails over capacitance. The domination of inductive-like contribution (approached the values of 10-20 pH/pm^3) in some of composite MSI nanostructures allows to use them in future as miniature planar (non-coil-like) inductive elements with the tunable parameters in hybrid ICs or other electric engineering applications. We offer to use this principle to develop planar mocroinductors using technology compatible with planar silicon IC-technology.

Some of the composites studied possessed temperature dependences of resistance which are linearized in log-log, Arrheniuse or Mott scales allowing to use them as a low-cost temperature sensors in the wide range of temperatures (2 – 400 K). Nanocompostes FeCoZr-fluorite have find out perpendicular magnetic anisotropy that can be used for the formation of magnetic memory media.

2. $Ni/SiO_2/Si$ composite nanostructures containing array of Ni nanorods, distributed in pores of SiO_2 layer, on Si substarte. These structures were sintered by template-assisted deposition. Porous SiO_2/Si template can be manufactured by two ways. The first way, which was used in our work, includes the irradiation of SiO_2 layer by swift heavy ions with energies of about 50-400 MeV and the following selective etching of template for the formation of vertical cone-like pores. Using under-potential electrochemical deposition, these pores were filled with Ni nanoparticles forming the array of Ni nanorod-like Schottky barriers on Si substrate. After preparation of $Ni/SiO_2/Si$ nanostructure, three electrodes, two of which were situated on the top side of nanostructure and the third - on the back side of Si substrate. It was shown that, at the determined combination of operating current between two top probes and also sign and value of transversal biase voltage (applied between one top and backside probes) $Ni/SiO_2/Si$ nanostructure have found out the huge magnetoresistive effect (tuned by both longitudinal and transversal electric fields) in the temperature range 20 – 30 K (approaching the values up to 35 000 % at H = 8 T) and in the range 200-320 K (up to 500 %).

We offer to fabricate such $Ni/SiO_2/Si$ nanostructures in the ordered pores created using micron or submicron lithography and other methods of planar Si technology to form electric probes to every Ni rod. This will allow to manufacture magnetosensitive matrixes with Ni rod arrays permitting to estimate distribution (visualization) of magnetic fields in space in different magnetic systems like superconducting solenoids, transformers and other magnetic systems.