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Development of improved ion-beam technologies for preparation of nanocomposite heterostructures with tunable electric and magnetic properties

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This work is devoted to the results of the study of metal-semiconductor-insulator (MSI) nanostructures, produced by ion-beam technologies, which can be used for production of sensors, memory media and micro- and nanosized electric engineering componentry.

MSI film nanocomposites deposited by ion-beam sputtering of compound targets FeCo-insulator (silica, alumina, fluoride, PZT) in vacuum chamber with argon or argon-oxygen gas atmosphere. As a rule, such nanocomposites contain FeCo-based nanoparticles embedded into insulating matrixes and possess “core-shell” structures. When “shells” around metallic “core” are composed of semiconducting FeCo-based oxides, MSI film nanocomposites show 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 capacitive one. The domination of inductive-like contribution (approached the values of 10-20 $\mu H/\mu m^3$) 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 replacing the gyrators and Archimedian spirals in hybrid ICs.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 found out perpendicular magnetic anisotropy that can be used for the formation of magnetic memory media.

Ni/SiO2/Si composite nanostructures containing array of Ni nanorods, distributed in pores of SiO2 layer, on Si substarte. These structures were sintered by template-assisted deposition using porous SiO_2/Si templates with SiO_2 layer irradiated 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 top and backside probes) $Ni/SiO_2/Si$ nanostructure display 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.