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Study of morphology, magnetic properties, and visible magnetic circular dichroism of Ni nanoparticles synthesized in SiO2 by ion implantation

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Abstract

A systematic study of ensembles of nickel nanoparticles fabricated by Ni+-ion implantation at a dose of (0.5-1.0)×1017 ions/cm2 in a thin near-surface layer of an amorphous SiO2 matrix by means of transmission electron microscopy (TEM), dc magnetic measurements, and magneto-optical technique is presented. TEM characterization of Ni nanoparticles proves the formation of isolated spherical nickel nanoparticles with diameters from 2 to 16 nm. The crystal structure and lattice constant of the nanoparticles correspond to face-centered-cubic Ni. The larger size nanoparticles are shown to have core-shell structure, which is unusual for the implantation conditions used. The shell of these nanoparticles consists of Ni, while the core has supposedly the composition coinciding with the matrix, i.e., SiO2. The core-shell nanoparticles in the investigated sample coexist with ordinary pure Ni nanoparticles, which strongly affects the magnetic and especially magneto-optic properties of the samples. For all three doses, the nanoparticles are in the superparamagnetic state at room temperature passing to the "frozen" state at lower temperatures. However, only the sample implanted with the lowest dose demonstrates the classic superparamagnetic behavior according to the shape of the experimental magnetization temperature dependencies for the zero-field-cooled (ZFC) and field-cooled regimes. This shape deviation from that characteristic of the pure superparamagnetic ensembles is ascribed mainly to the particle core-shell structure. The Ni nanoparticles' anisotropy constant estimated with the help of ZFC curves appears to exceed the bulk Ni anisotropy second constant approximately by two orders of magnitude. Magnetic circular dichroism (MCD) is characterized by spectral dependence modified strongly as compared to the MCD spectra of a continuous Ni film. In the spectral range 1.1-4.2 eV, the MCD spectrum consists of two broad maxima of opposite sign with the characteristics depending on the implantation dose and the measurement temperature. The MCD spectra analysis allows one to show that the higher-energy maximum (at 3.34-3.48 eV depending on the dose) is related to the surface plasmon resonance (SPR) excitation in pure Ni nanoparticles, while the lower-energy maximum (at 2.19-2.73 eV depending on the dose) should be associated with the SPR excitation in core-shell nanoparticles. © 2013 American Physical Society.

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