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1 Original Russian Text © V.A. Ukleev, N.A. Grigorieva, A.A. Vorobiev, S.V. Grigoriev, L.V. Lutsev, E.A. Dyadkina, D. Lott, A.I. Stognii, N.N. Novitsky, 2011, published in Pis'ma v Zhurnal Fizika Elementarnykh Chastits i Atomnogo Yadra, A: Tyazholye Iony (Heavy Ions).

Study of the Au/SiO_2 + Co(65 at %)/GaAs Heterostructure Interfaces By the Polarized Neutron Reflectometry Method

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Abstract—Using the polarized neutron reflectometry method, we studied Au/SiO_2 + Co(60 at %)/GaAs granular films, which display a giant injection magnetoresistance effect in a narrow temperature range close to $T = 300$ K. We revealed the existence of a layer having particular magnetic properties at the boundary of a film with a semiconductor GaAs substrate. Experiments carried out at temperatures $T = 300$ K and $T = 100$ K showed an insignificant difference in the magnetic profile of the heterostructure.

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Magnetic granular films (GF) on gallium arsenide substrates (Au/SiO_2 + Co(65 at %)/GaAs heterostructures) show a giant injection magnetoresistance effect (GIME) at room temperature. At the SiO_2 + Co/GaAs interface, a potential barrier is assumed to be produced from spin-polarized electrons, which prevents the injection of electrons from GF into the GaAs semiconductor with opposite polarization; it is transparent to parallel polarized electrons [1]. The aim of the present work is to determine the magnetic profile of the heterostructure and to study the behavior of its interfaces by using polarized neutron reflectometry.

The experiments were conducted at GKSS Forschungszentrum (Germany) at a polarized neutron reflectometer (PNR) of the FRG research reactor with a neutron wavelength $\lambda = 6.37$ Å ($\Delta\lambda/\lambda = 0.05$) and initial polarization $P_0 = 0.95$ [2]. The reflected beam intensity was recorded by a position-sensitive detector at two different neutron polarizations: parallel $I^+ = I(+P_0)$ and antiparallel $I^- = I(-P_0)$ to a magnetic field ($0 < H < 250$ mT) applied in the film plane.

Neutron reflectometry data were used to define the characteristics of each layer of the heterostructure: thickness, roughness, nuclear (SLD_n), and magnetic (SLD_m) densities of scattering length: SLD_n depends on the chemical composition, while SLD_m is in direct proportion to the layer magnetization. An approximation of the reflectometry data (Fig. 1) showed that there are four layers with different magnetic properties in the heterostructure: Au layer; GF1, supposedly a layer of granular film with oxidized Co nanoparticles; GF2, a layer of granular film with a o nanoparticle concentration of ~65 at %; and GF3, a granular film layer with a Co nanoparticle concentration distinctly smaller than 65 at %, which shows up at $H \neq 0$ because it has magnetic properties significantly different from those of GF2 (Fig. 2).

Measurements taken in magnetic fields ranging from $H = 0$ mT to $H = 240$ mT showed a significant

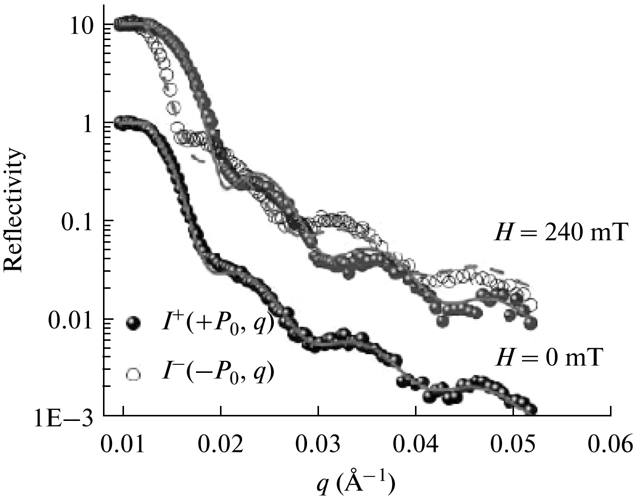

Fig. 1. Reflectivity curve of the heterostructure Au/SiO_2 + Co(65 at %)/GaAs at temperature $T = 300$ K.

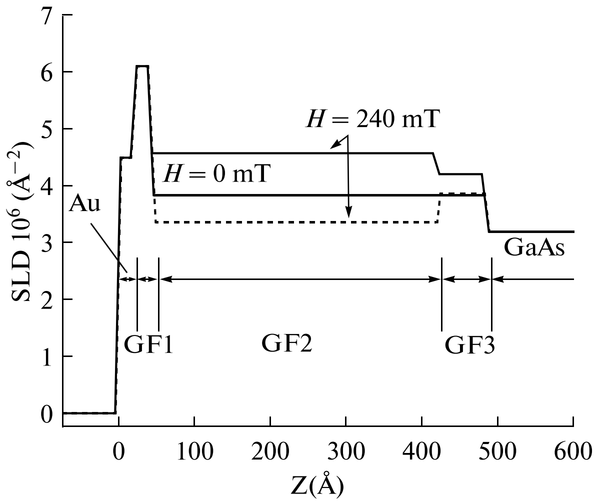

Fig. 2. SLD profile for neutrons with I^+ (solid curve) and I^+ (dashed curve) polarizations at $T = 300$ K.

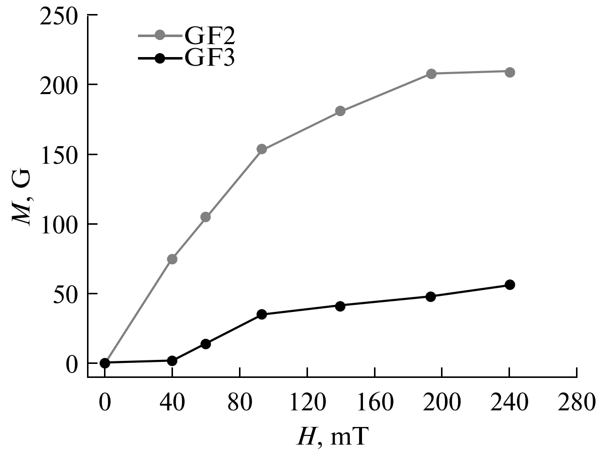

Fig. 3. Magnetization of the GF2 and GF3 layers in relation to the applied magnetic field at $T = 300$ K.

difference in the layer magnetization dynamics (Fig. 3). The diamagnetic upper layer of gold, as well as the GF1 granular film layer with granules of oxidized cobalt, having an antiferromagnetic order at room temperature, does not acquire a macroscopic magnetic moment. The magnetic properties are exhibited only by GF2 and GF3 layers, with the GF2 magnetization surpassing severalfold the magnetization of the interface GF3 layer in an external magnetic field similar in magnitude, suggesting different concentrations of cobalt nanoparticles in the dielectric matrix of these layers.

Thus, we have determined the magnetic profile of the Au/SiO_2 + Co(65 at %)/GaAs heterostructure. We have shown that the heterostructure has an interface layer at the granular film–substrate boundary with lower concentration of cobalt nanoparticles than in the basic thick layer of the film. Further examination and derivation of the theory of magnetic transport properties must take into account the structural peculiarities of this heterostructure.

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REFERENCES

1. L. V. Lutsev, J. Phys.: Condens. Matter. **18**, 1 (2006). 1
2. http://www.gkss.de/

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