Spin-Valve Film Structures with Nanoparticles Layers

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Ordered arrays of nanoparticles (NP) can be used for creating film device structures of the spin-valve type with higher performance and stability. Moreover, in the classical scheme of forming a sequence of layers of spin-valve structures for magnetic/nonmagnetic/pinned magnetic layer, the magnetic array NP can be used to create tough magnetic lower working layer with high values of coercive power (H_c), and soft magnetic sparkling the upper working layer with low values H_c. Therefore, attention in the study of magneto-optical and magnetoresistive properties of arrays NP primarily aimed at establishing the dependence of H_c on the size of the particles, since the maximum value of H_c determines the physical limit their practical use. Experimental dates [1] which is confirmed in the framework of the cluster approach to the theoretical study of magnetization processes [2] showing that NP can have a larger atoms magnetic moment than the atoms of bulk material even at room temperature. In addition, according to [3], the magnetic moment of the NP at $T \to 0$ K more than the bulk metal, and at $T > 0$ K magnetization NPs shows a strong dependence on temperature.

In [4] ordered arrays of Fe_3O_4 NP on the SiO_2 substrate and embedded in a conductive matrix Cu or Au are considered as fragments of a film of spin-valve structures. It was shown that the ordered structure of one or more layers of NPs is lower H_c than those that include arrays of NPs in a conductive matrix. And when termovar in vacuum this system up to T = 900 K, the value of H_c is increased from 60 to 480 mT (for comparison: the authors [5] have reported the achievement of high values of H_c = 100 mT for the Fe NP with a diameter of 25 nm). By the authors of [4] the growth of the H_c explain the increase in the size of bass from 10 to 20 nm. It is also noted the formation under the influence of high temperature islet structure of the Au film with the inclusion of NP, which confirms the view that the size effects in the magnetic properties of NP to a large extent are determined by the properties of the environment in which they are placed. Uniaxial anisotropic character of H_c Fe_3O_4 NP in the matrix Cu or Au noticeable at all stages of the heat treatment of the samples.

For some cases the sensory instrumentation the upper working magnetic layer of the spin-valve must have a minimum residual magnetization at high values of H_c. In this case, you can use arrays of magnetic NPs in a single domain state, which is achieved by reducing the volume of the NPs to a certain critical value. For Fe_3O_4 NP as 3d-metals the transition to a single-domain state at room temperature is observed when the size of 15 - 20 nm. Reducing the size of NP up to 5 - 8 nm and violations of the homogeneity of their crystal structure leads to a significant reduction of the effective magnetic moment and the disappearance of the ferromagnetic properties of the entire array NP. However, it should be noted that, according to [2] in some cases, even with an average size smaller than 5 nm NPs can have high values of H_c. So the magnetic moment of Co atoms in the 20 atoms cluster bigger than the magnetic moment of atoms in the bulk layer. This can be explained by the high structural stability of such nanoclusters with a minimum number of defects on the surface.

Magnetic layers spin-valve structures based on nanoparticles of different degree of dispersion can be formed in the process of getting film samples with sequential layer-by-layer condensation of magnetic and non-magnetic component with subsequent annealing in vacuum. For example, in [6] studied the magnetic properties of Co NP arrays at different stages of the formation of granular alloys based on Cu and Co. It is shown that the concentration and size of the formed nanoparticles depend on the thickness of the Co layers in Co film system. Formed thereby Co NP in a range of sizes 10 - 40 nm had little coercive, indicating that the super paramagnetic state obtained NP. By increasing the size of 30 - 120 nm in film samples based on Co NP observed isotropy process magnetization values of H_c = 30 mT.

This work was done in state project №52.20.01-01.15/17 ЗФ of the Applied Physic Department of Sumy State University.

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