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MAGNETIC PROPERTIES OF Fe–Bi FILM STRUCTURES

G.S. Patrin[1,2], V.Yu. Yakovchuk[2], S.A. Yarikov[1,2], Ya.G. Shiyan[1,2], V.P. Furdyk[1]

[1]Siberian Federal University, Krasnoyarsk, Russia.
[2]L.V. Kirensky Institute of Physics, Federal Research Center, Krasnoyarsk Scientific Center, Siberian Branch of Russian Academy of Sciences, Krasnoyarsk, Russia

Magnetic nanoscale layered structures with a semimetallic layer are poorly studied objects and they are of considerable interest for condensed matter physics. Work continues in this direction, both in terms of the development of technology and in terms of the study of fundamental properties, in particular, the effect of the interface on magnetic and transport properties. Among semiconductor and semimetallic elements, bismuth is distinguished by the fact that it practically does not form chemical compounds with 3d metals .That makes bismuth a convenient material for creating layered structures with a sharp interface. Depending on the technology there are formed either solid state solutions , at high speeds and high temperatures of deposition (film Fe_xBi_{1-x}), or film structure at low rates of deposition (Fe/Bi). In the first case, as a rule, the magnetic state of the "spin glass" type is realized, and in the second case the spectrum of manifestations is much wider.

The films were obtained by thermal evaporation at base vacuum $P \sim 10^{-6}$ Tor. Iron was chosen as a magnetic material due to the fact that in our case it is easy to control the formation of metastable modifications of iron, so as not to obscure the interlayer interaction. Fe/Bi, Bi/Fe, Fe/Bi/Fe and reference Fe film were synthesized. The thickness of the iron layer t_{Bi} was about 10 nm, and the thickness of the bismuth layer was 15 nm. In the case of Fe/Bi/Fe structure, the films had different thicknesses of the bismuth layer.

Layer thicknesses were determined by X-ray spectroscopy. Electron microscopic measurements showed that the layers are solid in area and their composition corresponds to the nominal. No traces of 3d-metal–bismuth compounds were found. The presence of iron oxide is also not detected. The surface structure of the films was studied by the atomic force microscope Veeco Multi Mode (resolution 1 nm). It was found that the surface roughness height does not exceed 2.5 nm. This means that with the used thickness of the non-magnetic layer the contact "short circuits" between adjacent magnetic layers cannot be. Magnetization was measured at the MPMS-XL SQUID magnetometer. The magnetic field was in the film plane.

The dependence of the coercive force on the order of deposition of bismuth and iron layers was found at magnetostatic measurements in bilayer films.The magnetic resonance spectrum also depends on the order of deposition of magnetic and non-magnetic layers and differs from the spectrum for the reference film of nominally pure iron. These results are associated with the appearance of additional magnetic anisotropy at the Fe – Bi interface.

It was established that when a magnetic layer is applied over a non-magnetic bismuth layer, an interface magnetic anisotropy appears. Thus, the upper and lower (M1) magnetic layers become non-equivalent and in the case of Fe/Bi/Fe the upper magnetic layer is divided into two sublayers with magnetizations M2 and M3.

In the case of three-layer Fe/Bi/Fe films, the dependence of the coercive force on the bismuth thickness and the effect of the exchange bias, also depending on the thickness of the nonmagnetic layer are found. Temperature dependences of magnetization measured in different fields also show unusual behavior. When cooling in a weak magnetic field and further measurement in the field there is induced negative magnetization. This effect is due to the formation of a strongly anisotropic sublayer on the interface, antiferromagnetically coupled with the iron layer and separated by the bismuth spacer.

These studies are carried out with the financial support of RFBR (grant No. 18-02-00161-a).