EFFECTS IN Gd_2O_3 AND GLASS SUBSTRATES ON THE RESISTANCE OF Fe NANOSCALE FILMS TO DIRECT CURRENT (DC) VOLTAGE

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Thin films of ferromagnetic metal Fe are promising for applications in nanotechnology due to their unique galvanomagnetic, magneto-optical, magneto-conductive and other properties. Understanding the characteristics of film properties under different operating conditions expands the range of practical applications.

Keywords: f-d excange evaporation DC cutrrent voltage, Fe nanoscale films, Gd_2O_3

The influence in Gd_2O_3 and the silicate glass substrates on the kinetic properties of the Fe nanoscale films is shown. Electron beam evaporation of chemically pure iron and Gd_2O_3 targets was used to deposit Fe and Gd_2O_3 films. Electron microscopy and electron phase analysis showed that Fe films are polycrystalline and Gd_2O_3 films are amorphous. Fe films less than 35 nm thick have an island morphology, and those thicker than 40 nm have a continuous morphology. After sputtering, the iron films were exposed to air for 3 days to cover their surface with a thin layer of Fe_3O_4 oxide to prevent further oxidation and stabilize the resistance, which was favorable for the resistance measurements of Fe (R_{Fe}) films.

As can be seen in Fig. 1, the islands are asymmetrically shaped, which appears to result from oxidation in air. Average size of islands is (20…100) nm. The surface of the islands is inhomogeneous and clustered. The image was taken with a Tescan Mira SLMU scanning electron microscope.

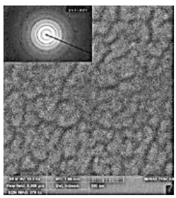

Fig. 1. Electron microscope image of Fe (30 nm) film on Gd_2O_3 (45 nm) layer and its electronograms.

Figure 2 shows the R_{Fe} resistance of Fe films as a function of thickness when measured at DC voltage. Curve 1 corresponds to Fe films on silicate glass, curve 2 to Gd_2O_3.

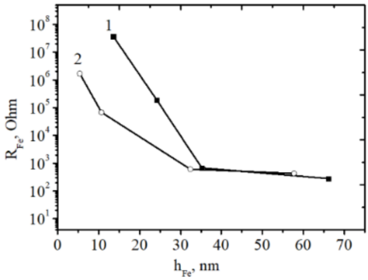

Fig.2. Dependence of the resistance on the thickness of Fe films when they are on glass (1) and on Gd_2O_3 (2). Frequency f = 0.

Fig. 2 shows that the RFe of Fe island films less than 35 nm thick deposited on glass is several orders of magnitude larger than that of films of the same thickness deposited on Gd_2O_3. There are two reasons for this difference.

Firstly, the matrix of the SiO_2 silicate glass contains a large number of ions of Al, Na, Ca, Mg, S, which are technological additives to control its properties. Ions can be traps for electrons tunneling between the islands. The lifetime of the trapped charges on the traps is not 0, so the current resistance in the island films on glass will be greater than on the Gd_2O_3 substrate, where the traps (interatomic Gd^{3+} ions and oxygen vacancies) are much smaller. In continuous Fe films, the influence of traps covered by the iron layer does not appear, and the R_{Fe} resistivity on glass and Gd_2O_3 becomes close.

The second reason for the difference in R_{Fe} for Fe island films on glass and Gd_2O_3 may be the influence of the exchange f-d interaction established between Fe and Gd_2O_3. This interaction leads to the appearance of additional magnetization $M_{f\text{-}d}$ and its corresponding effective magnetic field $H_{f\text{-}d}$ [1]. If the direction of the vector $\vec{H}_{f\text{-}d}$ is opposite to the direction of the spontaneous magnetization field of the ferromagnetic film Fe, then the Lorentz force acting on the current flowing along the film should decrease and the R_{Fe} resistance should decrease. This can be seen in Fig. 2.

Thus, as a result of these studies, it is shown that the properties in substrates of the different nature are manifested mainly in Fe island films having tunnel conduction mechanism, where electron motion is possible both by the influence of numerous traps (glass) and exchange f-d interaction (Gd_2O_3).

1. *Kasumov A.M., Dmitriev A.I., Radchenko M.V., Baybara A.E., Bykov O.I., Korotkov K.A., Karavaeva V.M., Vyshnevska K.O., Olifan O.I. and Ievtushenko A.I.* Anomalous Hall effect in a double-layer Ni/Gd_2O_3 nanosized films // Him. Fiz. Tehnol. Poverhni. – 2022. – 13, № 1. – P. 105–110.