Kinetics of Fe Island Films degradation in Air

K.A. Korotkov[1], A.M. Kasumov[1], A.I. Dmiriev[1], V.M. Karavaeva[1], A.I. Ievtushenko[1]

[1] *I.M. Frantsevich Institute for Problems of Material Science, National Academy of Sciences of Ukraine, 3 Krzhizhanovskogo Str.,Kyiv, 03142, Ukraine*
kasumov@ipms.kiev.ua

Iron island films are a promising material for nanotechnologies and spintronic. However, due to their high reactivity, they quickly oxidize in air and can only be used under conditions of ultrahigh ($< 10^{-9}$ Torr) vacuum. The aim of this work is to study the degradation kinetics of Fe island films in air and the effect of this process on such properties as resistivity ρ, optical transmission T, and thickness.

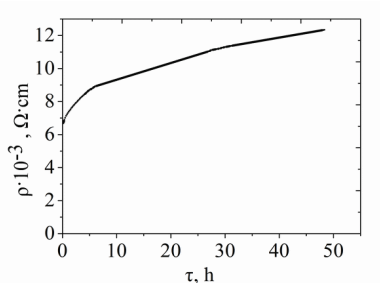

Figure 1.

Figure 1 shows the growth kinetics ρ of the Fe film depending on the time τ of its exposure to air. The initial film thickness is 20 nm, which, according to [1], corresponds to island morphology and the tunneling mechanism of charge transfer between islands. It can be seen from this figure that due to air oxidation, the resistance ρ of the Fe island film rapidly increases in a power-law dependence on the exposure time: $\rho = a\tau^{\kappa}$, where $a = 7.5\ 10^{-3}$ Ω/h, $\kappa = 0.08$. The growth constant κ of the oxide layer is much less than the value of 0.5 observed during reaction diffusion in continuous films [2]. This may be due to the specific morphology of the island film, in which the empty spaces between the islands do not take part in the oxidation process. In addition, at room temperature of the experiment, the low-temperature Mott oxidation mechanism should also take place under the influence of electric field that arises in interface by sorbet oxygen atoms and Fe atoms. This mechanism has a lower rate of oxidation.

After 14 hours of exposure, ρ of the Fe film begins to correspond to Fe_3O_4. And then it increases at a slower rate, approaching Fe_2O_3.

Figure 2 shows the spectral dependence of the optical transmission T(λ) of the Fe island film before (1) and after (2) exposure to air for 48 hours.

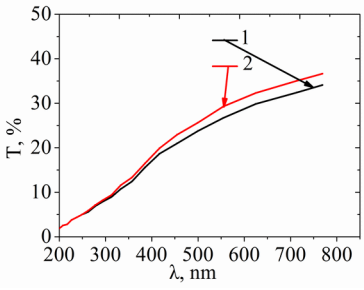

Figure 2

As can be seen from this figure, the process of Fe oxidation is accompanied by film bleaching, which manifests itself to the greatest extent in the long-wavelength region of the spectrum. It is obvious that the transparency of the film is associated with a decrease in its reflection coefficient as the composition changes from metal (Fe) to semimetal (Fe_3O_4) and then to semiconductor (Fe_2O_3).

The thickness of the Fe film in the process of oxidation increases from 20 nm to 40 nm in 48 hours of exposure to air. The increase in thickness caused by the incorporation of oxygen atoms should change the configuration of the islands and additionally affect the change in ρ and T shown in Figures 1 and 2.

[1] K.A. Korotkov, A.M. Kasumov, et all, *Int. Conf. CICS-2022,* 96 (Ukraine, Kyiv, 2022).
[2] B.I. Boltaks, *Diffusion in semiconductors* (Academic Press, 1 January 1963)