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Electrophysical Properties of Granular Film Alloys Based on Fe and Ag or Au

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The experimental results of electrophysical properties of granular film alloys based on Fe and Ag or Au are presented. It is established that the value of the temperature coefficient of resistance depends on the total thickness of the samples and the concentration of magnetic component. The components concentration in the system is shown to affect the formation of the solid solution and the granular film alloy. The optimal concentration value of Fe, in which the thermally stable solid solution forms, is 45 at. %.

Keywords: Granular film alloy, Solid solution, Temperature coefficient of resistance, Strain coefficient.

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1. INTRODUCTION

The search of film materials with improved properties is caused by their high functionality, extensive use for creating thermistors, strain gauges, sensors of magnetic characteristics and etc. [1, 2]. The film materials should have the thermal stability of the crystal structure, the phase state and stable parameters in the operating range of the temperature, the deformation and the magnetic field. The needs of electronics and spintronics determine the search of new materials with stable electrophysical and magnetoresistive properties. Solid solutions (s.s.) and granular film alloys based on noble and magnetic metals could be a such type of systems [3].

The electrical properties of such systems in contrast to the magnetoresistive properties are required the further study. Therefore, this work is devoted to study thermal and tensoresistive properties of the granular film alloys based on Fe and Ag or Au.

2. EXPERIMENT

The two- and three-layer film systems based on Fe and Ag or Au have been deposited by alternative thermal evaporation on steel substrates in dimensions 20 ×2 mm covered with polyimide at room temperature and base pressure 10^{-4} Pa. The thickness of each layer was measured by the quartz resonator method, accurate within ± 10 %. The total system thicknesses are 15-45 nm. of According to our previsions work [4-6], the granular alloy are formed in such type of structures after heat treatment up to 700 K, so the films were annealed to 700, 800 and 900 K in vacuum of 10^{-4} Pa. Thus, a series of granular thin film alloys based on Fe and Ag of Au were prepared. The chemical composition of the film systems controlled by an energy-dispersive X-ray spectroscopy (EDA) using scanning electron microscope-mass-analyzer JSM-6610LV. The concentration of magnetic component is 18-80 at. %. Fig. 1 shows an example of the EDA spectrum for film systems based on Fe and Au after heat treatment to 800 K. The phase state and crystalline structure of the samples were investigated by transmission electron microscopy (TEM-125K).

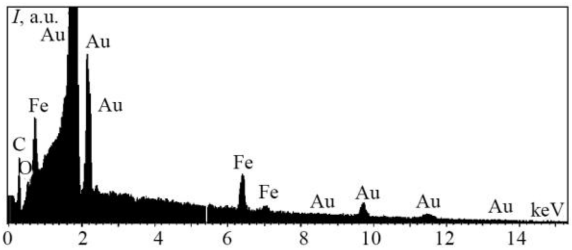

Fig. 1 – Energy-dispersive spectrum of Fe(5)/Au(25)/Fe(5)/S film sample annealed to 800 K

3. RESULTS

3.1 Phase State

Consider the phase formation process and crystal structure features of film systems based on Fe and Ag or Au on Fe(5)/Au(25)/Fe(5)/S (Fig. 2) and Fe(10)/Ag(15)/Fe(10)/S (Fig. 3) examples after condensation and annealing to 700, 800 and 900 K.

The diffraction rings for sample Fe(5)/Au(25)/Fe(5)/S after condensation (Fig. 2a) correspond to fcc-Au and

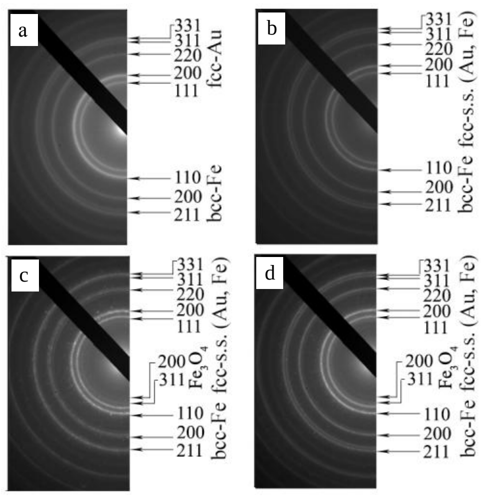

Fig. 2 – Diffraction patterns of Fe(5)/Au(25)/Fe(5)/S film sample after condensation (a) and annealing to 700 (b), 800 (c) and 900 (d). S-substrate, the value of thickness is in nm

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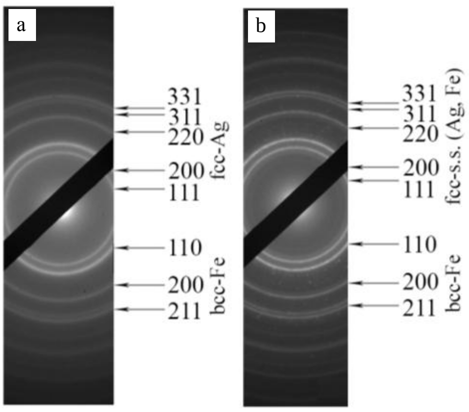

Fig. 3 – Diffraction patterns of Fe(10)/Ag(15)/Fe(10)/S film sample after condensation (a) and annealing to 800 K (b)

bcc-Fe with lattice parameters 0.408 and 0.287 nm respectively. The annealing to 700 K leads to the formation of fcc solid solution on the base of Au and Fe with lattice parameter 0.407 nm that corresponds to the literature data [7, 8]. In addition the diffraction rigs of bcc-Fe are fixed too (Fig. 2b-d) in consequence of Fe atoms excesses in the sample. Heat treatment to 800 and 900 K leads to stabilization of limited solid solution and to the Fe_3O_4 iron oxide formation (Fig. 2c, d).

The changing of layers thickness don't change the phase state of the thin film systems. The samples both after condensation and after annealing have two phase state: fcc-Au + bcc-Fe and fcc s.s-(Au, Fe) + bcc-Fe.

The similar result has been received in the case of film systems based on Ag and Fe (Fig. 3). Systems have two phase sate after condensation, which correspond to fcc-Ag and bcc-Fe with lattice parameters 0.407 and 0.287 nm respectively. The phase state of the systems after annealing to 800 K corresponds to fcc-s.s (Ag, Fe) + bcc-Fe with lattice parameter 0.406 nm and 0.287 nm respectively.

3.2 Electrophysical Properties of Granular Film Alloy

The film samples with different concentration of the magnetic component were prepared for the study of the electrophysical properties. The decrease of resistivity (ρ) is observed with the temperature (T) increase at the first thermostabilization cycle for all dependences $\rho(T)$. It's explained by the defects healing of crystalline structure in the recent-condensed samples. The resistivity (ρ) and the temperature coefficient of resistance (β) depend on the total thickness (d) and the concentration of magnetic component at the second thermostabilization cycle of «heating ↔ cooling».

The concentration dependences of β for Fe/Au/Fe/S three-layers film samples at 300 K (the thicknesses interval is 15-25 nm) are shown in Fig. 4.

Some growth of β from $1.15 \cdot 10^{-3}$ to $1.45 \cdot 10^{-3}$ K^{-1} is observed with the increasing of magnetic content concentration, that can be explained by blurring of the interface and the s.s. formation with elements of iron granular state.

The tensoresistive properties of as-deposited and annealed to 800 K thin film systems based on Fe and

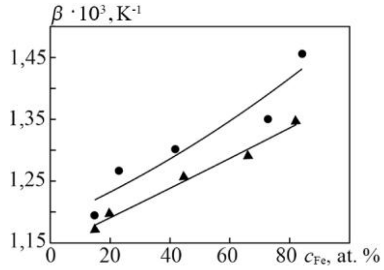

Fig. 4 – The concentration dependence of β (T_a = 300 K) for Fe/Au/Fe/S three-layers film samples with a total thicknesses d = 15 (•) and 25 nm (▲)

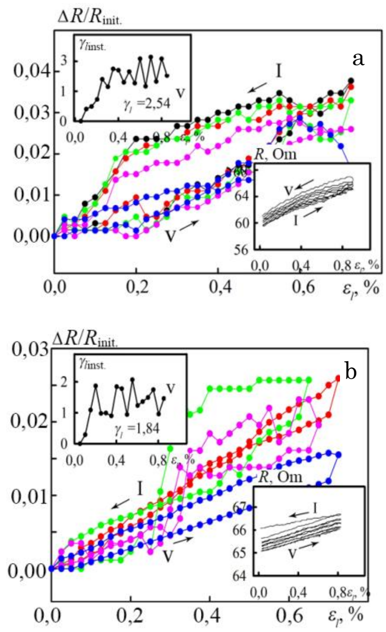

Fig. 5 – Deformation dependences ($\Delta R/R_n$) for Ag(10)/Fe(10)/S samples as-deposited (a) and after annealing to T_a = 800 K (b). $R_{init.}$ is the resistance at ε_l = 0 %

Ag or Au have been investigated too. The samples with the magnetic component concentration c =48-60 at.% and the total thickness, which changed from 10 to 30 nm were prepared. Dependence of the relative change of the resistance versus the strain is shown in Fig. 5. Dependences of the resistance (R) and the instantaneous strain coefficient ($\gamma_{inst.} = d\ln R_i/d\varepsilon_l$, where i is the number of the measurement interval of $\gamma_{inst.}$) versus longitudinal strain (ε_l) are presented at inserts of Fig. 5.

The maximum value of the average strain coefficient coefficient ($\bar{\gamma}_l$) have been observed in Au(25)/Fe(20)/S systemfor the V-th cycle of the strain (ε_l = 0,8 %). There are 2.05 and 1.97 for as-deposited and annealed to 800 K samples, respectively. The larger values of γ_l for the as-deposited samples can be explained by the presence of the interfaces. Besides, the increase of the γ_l value of three-layer systems in relation to the of single-layer films of Co, Ag and Au is observed too. This fact can also indicate the s.s. formation with elements of granular state.

4. CONCLUSION

In the paper the experimental dependences of ρ and β vs. the temperature and the concentration of magnetic components, the instant strain coefficient vs. the strain for film alloys and granular s.s. based on Fe and Ag or Au were analyzed. The connection between phase state and electrophysical properties was established.

The concentration of components is main factor which mainly affects to the s.s. and granular film alloy formation. Studies have shown that the optimal value of magnetic component concentration at which the thermally stable s.s. formed is 45 at. %.

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REFERENCES

1. Mitra Djamal, Ramli, *Procedia Eng.* **32**, 60 (2012).
2. D.M. Kondrakhova , I.M. Pazukha, I.Yu. Protsenko, *Univ. J. Phys. and Appl.* 2, No 2, 85 (2014).
3. I. Bakonyi, L. Péter, *Prog. Mater. Sci.* **55**, 107 (2010).
4. I.M. Pazukha, Z.M. Makukha, Yu.M. Shabelnyk, I.Yu. Protsenko, *J. Nano- Electron. Phys.* **4** No 3, 03020 (2012).
5. I.V. Cheshko, D.M. Kondrakhova, L.V. Odnodvorets, et al., *Universal J. Mater. Sci.* 1 No 2, 25 (2013).
6. I.V. Cheshko, I.M. Pazukha, S.I. Protsenko, et al., *Proc. NAP* **2** No 1, 01NTF40 (2013).
7. L.M. Socolovsky, P.H. Shingu, *Physica B* **320**, 149 (2002).
8. L.M. Socolovsky, F.H. Sanchez, P.H. Shingu, *J. Magn. Magn. Mater.* **226-230**, 736 (2001).