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Strain Properties of Nanodimentional Thin Film Systems Based on Ag and Co

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The results of research strain deformation properties of thin films Ag, Co and two-layer film systems Ag/Co in the range of deformation $\Delta\varepsilon_l = 0 - 1\%$ were presented. The plastic deformation in Co layer caused a similar deformation in the entire film system, even if the strain range of Ag layer is not reached the limits of the transition elastic/plastic deformation.

Keywords: Two-layer film systems, Strain effect, Gauge factor, elastic and plastic deformation.

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1. INTRODUCTION

The magnetoresistance of the multilayer or granular film systems based on Ag and Co has been widely studied in the last two decades in correlation with structural, magnetic and magneto-optic properties [1, 2]. However, as shown by the authors of [3, 4], multilayer film systems with spin-dependent electron scattering can be used as ultrasensitive strain sensor. The present paper shows the result of study strain properties of Ag/Co film systems.

2. EXPERIMENT

Thin films Ag, Co and bilayers were prepared by methods of thermal (Ag) end electron-beam (Co) evaporation in vacuum chamber (the base pressure was 10^{-4} Pa). The thickness of the films was measured during deposition by the method of quartz resonator, according to the recommendation of work [5], accurate within ± 10 %. Researches strain properties during eight cycles “load – unload” were carried out using modern devices of physical experiment automatization. This made it possible to execute computerized of experiment control and results analysis. In detail these automate system described at work [6].

The mean and instantaneous gauge factors were calculated, like at work [7], from the equations: $\gamma_l = \dfrac{1}{R}\dfrac{\Delta \mathrm{R}}{\Delta\varepsilon_l}$ and $\gamma_{li} = \dfrac{1}{R_i}\dfrac{\Delta \mathrm{R}_i}{\Delta\varepsilon_{li}}$ respectively, where R and R_i are resistances at strain $\varepsilon_l = 0$ and $\varepsilon_l = \varepsilon_{li}$ respectively. The value of γ_l was calculated as angular coefficient of dependence $\Delta R/R$ versus ε_l, γ_{li} – as graphical differentiation of this dependence.

The phase state and crystalline structure were investigated by electron diffraction and electron microscope methods (high resolution transmission electron microscope TEM-125K).

3. RESULTS

Analysis of structural-phase state of Ag and Co thin films and two-layer film systems Ag/Co was carried out to confirm the correctness of the analysis of further research strain properties. A typical diffraction and TEM-images of thin films Ag(20)/S, Co(20)/S and film system Ag(20)/Co(20)/S (S-substrate, the value of thickness is in nm) after condensation are shown in Fig. 1 and 2. The results of diffraction data analysis are presented in Tabl. 1. Ag has fcc structure with the mean lattice parameter $\bar{a}$(fcc-Ag) = 0,407±0,001 nm (Fig. 1a). The value agrees well with the tabulated data a_0(fcc-Ag) = 0,408 nm [8]. Co has two-phase state in comparison with Ag thin film (see. Fig. 1b). Diffraction rings from hcp-Co and fcc-Co fixed in the diffraction pattern of Co. The lines of fcc-Co corresponds to as reflections from stacking fault, as well as unfinished phase transition fcc→hcp at condensation of film Co(20)/S. The mean value of fcc-Co is $\bar{a}$(fcc-Co) = 0,354±0,001 nm, that agrees with the tabulated data a_0(fcc-Co) = 0,355 nm [8].

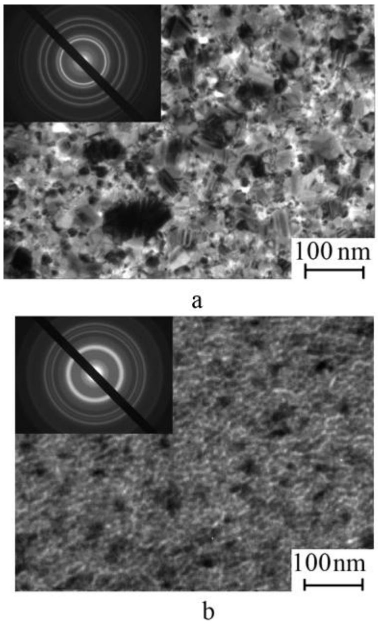

Fig. 1 – Diffraction pattern and crystalline structure of thin films Ag(20)/S (a) and Co(20)/S (b) after condensation

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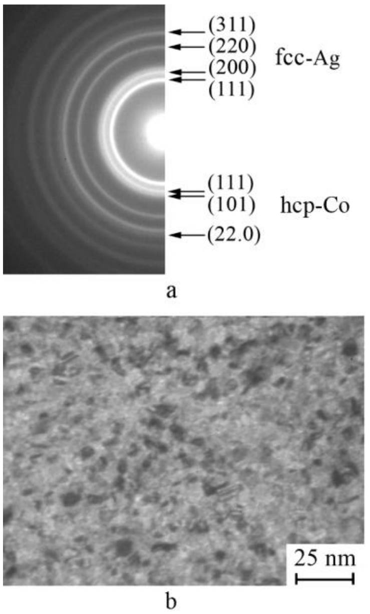

Fig. 2 – Diffraction pattern (a) and crystalline structure (b) of two-layer film systems Ag(20)/Co(20)/S after condensation

The results of diffraction data analysis for film system Ag(20)/Co(20)/S (see Fig. 2, Table 1) shown that sample has two-phase state after condensation. Diffraction rings from both layers fixed at diffraction pattern (see Fig. 2). This makes it possible to conclude that for the systems based on Ag and Co has place identity of layers without formation solid solution and stabilization of a granulated state. This conclusion agrees with results of investigation of diffusion processes by method SIMS at work [9].

Dependences $\Delta R/R$, R and γ_{li} versus ε_l for thin films Ag, Co and two-layer system Ag/Co are shown at Fig. 3 – 5 respectively. The main characteristic properties of deformation dependences are as follow: the first cycle at dependences for thin films Ag, Co differ from another in consequence of recrystallization processes (partial grains rotations, redistribution crystalline defect, microplastic deformation); strain properties stabilized from the second cycle; the change character of dependence $R(\varepsilon_l)$ and $\Delta R/R(\varepsilon_l)$ at $\varepsilon_l = 0{,}3$ % for Co(70)/S (Fig. 4a) correspond to transition from elastic to plastic deformation. Notice, the elastic deformation has place till $\varepsilon_l \cong 1$ % for Ag (Fig. 3a).

First cycle of deformation dependences for two-layer system differ from another too. Besides, the elastic deformation has short range and dependent on concentration of Co atom, which has a lower limit of elastic deformation in comparison with the Ag film.

During the research of strain deformation properties of two-layer film systems was observed the effect of abnormal increase of instantaneous longitudinal strain deformation coefficient γ_{li} under the deformation ε_l (see insert at Fig. 5a). The deformation value, for which maximum is observed, corresponds to transition from elastic to plastic deformation. This effect at dependences γ_{li} versus ε_l was observed in previously investigations [10, 11].

Table 1 – The interpretation of diffraction pattern for samples Ag(20)/S, Co(20)/S and Ag(20)/Co(20)/S after condensation

Film	№	I, a.u	d_{hkl}, nm	hkl	phase	a_{hkl}, nm	d^0_{hkl}, nm [8]
Ag	1	V H	0,235	111	fcc-Ag	0,408	0,236
	2	m	0,204	200	fcc-Ag	0,407	0,204
	3	m	0,143	220	fcc-Ag	0,408	0,144
	4	m	0,122	311	fcc-Ag	0,406	0,123
	5	l	0,117	222	fcc-Ag	0,406	0,117
	6	l	0,102	400	fcc-Ag	0,407	0,102
	$\bar{a}$ (fcc-Ag) = 0,407 nm; a_0(fcc -Ag) = 0,408 nm [8].						
Co	1	H	0,215	100	hcp-Co	0,248	0,216
	2	V H	0,204	111	fcc-Co	0,354	0,204
	3	m	0,192	101	hcp-Co	–	0,191
	4	m	0,177	200	fcc-Co	0,354	0,177
	5	m	0,125	220 110	fcc-Co hcp-Co	0,354 0,250	0,125
	6	l	0,106	311	fcc-Co	0,355	0,107
	$\bar{a}$ (fcc-Co) = 0,354 nm; $\bar{a}$ (hcp-Co) = 0,249 nm a_0(fcc-Co) = 0,355 nm; a_0(hcp-Co) = 0,250 nm [8].						
Ag/Co	1	V H	0,236	111	fcc-Ag	0,407	0,236
	2	H	0,218	100	hcp-Co	0,251	0,215
	3	m	0,204	200	fcc-Ag	0,408	0,204
	4	v l	0,190	101	hcp-Co	–	0,191
	5	m	0,143	220	fcc-Ag	0,408	0,144
	6	l	0,123	22.0	hcp-Co	0,251	0,125
	7	v l	0,122	311	fcc-Ag	0,406	0,123
	$\bar{a}$ (fcc-Ag) = 0,407 nm; $\bar{a}$ (hcp-Co) = 0,251 nm; a_0(fcc-Ag) = 0,408 nm; a_0(hcp-Co) = 0,250 nm [8].						

H – high, m – medium, l – low.

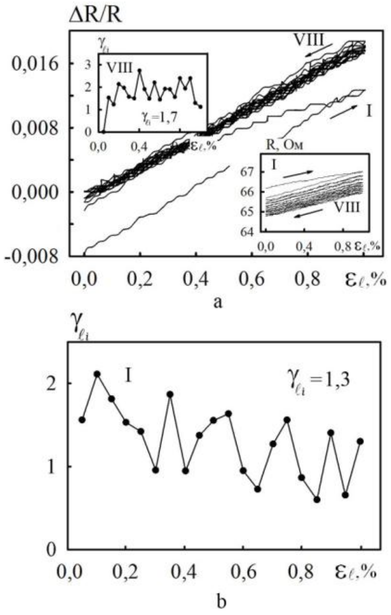

Fig. 3 – Dependences $\Delta R/R$, R and γ_{li} vs. ε_l (a) and dependence γ_{li} vs. ε_l for I deformation cycle (b) for thin film Ag(38)/S. I, VIII – number of deformation cycles "load – unload"

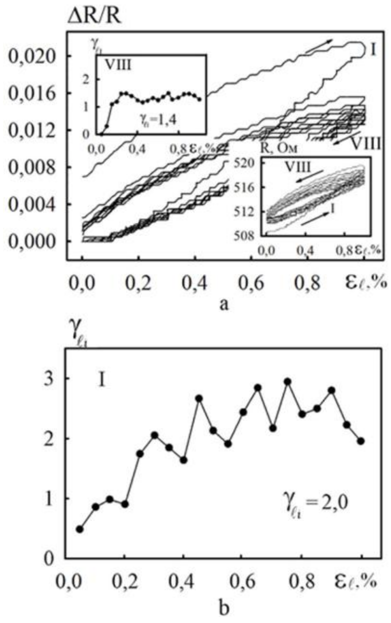

Fig. 4 – Dependences $\Delta R/R$, R and γ_{li} vs. ε_l (a) and dependence γ_{li} vs. ε_l for I deformation cycle (b) for thin film Co(70)/S

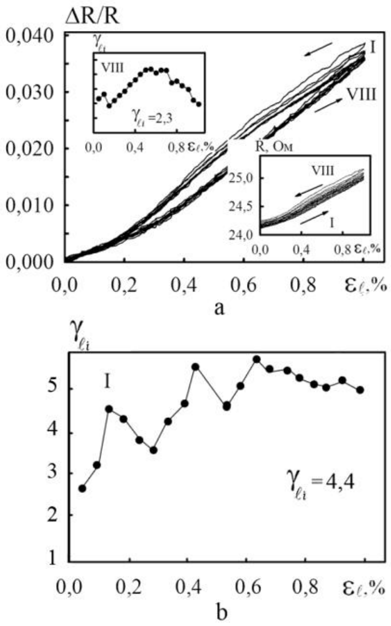

Fig. 5 – Dependences $\Delta R/R$, R and γ_{li} vs. ε_l (a) and dependence γ_{li} vs. ε_l for I deformation cycle (b) for film system Ag(45)/Co(36)/S

To explanation the maximum at dependence γ_{li} vs. ε_l for two-layer film systems was analyzed the condition of extremum (maximum), which is obtained by simplified equation $\partial\gamma_{li}/\partial\varepsilon_l = 0$. Analysis indicates that the appearance of a maximum in dependence γ_{li} vs. ε_l is caused by the nonlinear variation of the resistivity that occurs under corresponding deformation or is the result of structural changes in the film system during the transition from elastic to plastic deformation or other deformation mechanism.

4. CONCLUSION

Dependences $\Delta R/R$, R vs. ε_l for two-layer systems Ag/Co characterized short range of strain deformation, the limits of the transition elastic/plastic deformation for Ag/Co and Co dependence on total thickness.

The appearance of a maximum in dependence γ_{li} versus ε_l is caused by the transition from elastic to plastic deformation.

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