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Phase Composition and Magnetic Resistive Properties of Ni and Au Based Films Systems

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In this work structure-phase state and magnetic resistance investigation of Ni/Au/Ni film systems was carried out. Were studied dimensional magnetic resistance from thickness (d_{Ni} = 5-15 nm, d_{Au} = 5-15 nm) dependencies. It was shown that in Ni/Au/Ni film systems is preferentially presents magnetic resistance in perpendicular pane.

Keywords: Phase composition, Three-layer film systems, Magnetic resistance.

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1. INTRODUCTION

Investigations of ultrathin magnetic films and systems on their base have as fundamental, as a practical interest. In most cases a Ni/Au thin layers combinations due to their acceptable parameters (electrical conductivity, surface adhesion, morphology, etc) are used as a semi-transparent contacts for light-emission in diodes [1,2]. In recent time films based on Ni and Au regard as an ohmic contacts materials for high-sensitive magnetic field sensors (based on Hall effect) and as a magnetic memory cells in increased recording density devices [3].

At last time, as a liquid-crystal sensor displays components carbon nano-tubes due to their unique mechanical strength and flexibility pay a higher attention of investigators. For improvement a conductivity of these metals is used Au metal evaporation on Ni adhesive substrate (thickness is: Ni – 2 nm, Au – 10 nm). When the arrays thickness was 130, 194 and 257 µm – resistance decreased on 97,4 %, 95,6 % and 93,4 % respectively, transparence was 76,3 %, 66,9 % and 56,5 % [4].

Terms to fundamental investigations, Ni and Au based film systems are preferential interesting for study their magnetic ordering in two-dimensional magnetite and meta-stable phase formation conditions [5].

In this work was estimated experimental investigation of phase composition and magnetic resistance dimensional effects of three-layer Ni/Au/Ni film systems.

2. EXPERIMENTAL DETAILES

Ni/Au/Ni thin films were obtained by layer-by-layer condensation of Ni and Au on glass-ceramic substrates (S) at room temperature (T_s = 300 K) in SELMI VUP -5M vacuum equipment at residual gas pressure 10^{-3}-10^{-4} Pa. All patterns were obtained at similar technological conditions. Were used thermal (Au) and electron-beam (Ni) evaporation techniques. Deposited layers thicknesses were determined by quartz resonator method and were additionally checked by interferometrical method. To determine film systems structure and phase composition were performed transmission-electron microscopy (TEM) and electron-graph investigations by SELMI PEM-125K microscope.

Magnetic resistance of obtained films was measured at room temperature using the four-point scheme. Film systems magnetic resistance values were determined by the ratio $(\Delta R/R_s) = (R(B)-R_s)/R_s$, where R(B) and R_s patterns resistances at certain field value, and at field of saturation correspondingly. Measurements were performed in external magnetic field (induction was varied from 0 till 600 mT) in longitudinal, transverse and perpendicular geometries. Contacts position allows changing the current flow geometry relative to app external magnetic field without pattern's changing position. Investigations were carried out by CPP (current-parallel to plane) to the film surface.

3. RESULTS AND DISCUSSION

Constitutional diagram of Au-Ni system analysis shown that in solid state at temperature lower than 1085 K is present a broad Au and Ni immiscibility area [6] which allows to obtain multilayer film systems with clear interface. In our work were investigated two patterns series. In first case three-layer film systems had a fixed low-layer thickness Ni(25 nm), so the top-layer thickness was varied in the range of Ni(d_{Ni}) = (5 – 15) nm. In another case were studied film systems which have a thickness of non-magnetic layer was Au(d_{Au}) = (5-15) nm. TEM investigation shown, that all patterns had a highly-dispersed structure (Fig.1a). Average grain size of layers was ~ 20 nm. Electron-graphs analysis allowed us to determine the fact, that as-deposited film systems Ni(d_{Ni})/Au(5 nm)/Ni(25 nm)/S and Ni(5 nm)/Au(d_{Au})/Ni(25 nm)/S had a fcc-Au+fcc-Ni composition (see Table 1). Electron-graphs measurement (Fig.1b) shown that lattice parameters $\bar{a}$ (Au) = 0,408±0,002 nm and $\bar{a}$ (Ni) = 0,352±0,002 nm are similar to the lattice parameters of correspond single-layer and bulk films (a_0 (Ni) = 3,524 Å, a_0 (Au) = 4,078Å [7]).

In this work was carried out investigation of magnetic resistance (MR) vs thickness (non-magnetic and ferromagnetic layers - d = 5-15 nm) dependence or measurement geometry of Ni/Au/Ni(25)/S nanosize three-layer film structures. Further analysis allows to estimate that for all films systems at d_{Au} = 5-10 nm is character MR properties isotropy which expressed as a electro-resistivity decreasing in magnetic field regardless on measurements geometry. Longitudinal and transverse MR values were not bigger than 0.015-0.025 %, when geometry was perpendicular MR was in the range of 0.030-0.045%. Film system Ni(5 nm)/Au(5 nm)/Ni(25 nm)/S in perpendicular geometry have a biggest MR value, which reach to 0.042%(Fig.2a). By increasing of d_{Au} to 15 nm film systems MR should be anisotropic (its absolute value is 0,010- 0,070 %). The biggest MR value had Ni(25 nm)/Au(15 nm)/Ni(25 nm)/S film system. It was in longitudinal geometry as 0,07 %.

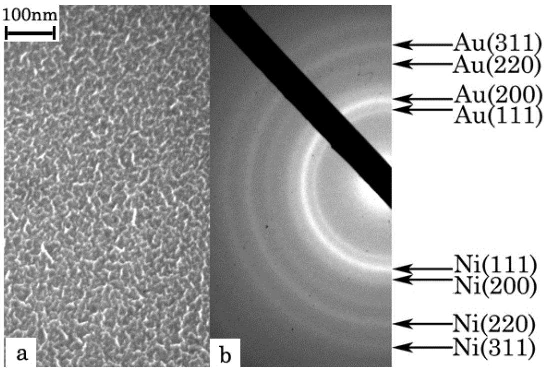

Fig 1 – Surface morphology (a) and electron-graph (b) of as-deposited Ni(25)/Au(15)/Ni(25)/S film. In brackets is presented layers thickness (nm).

In case of changing the top-layer Ni(d_{Ni}= 5-15 nm) thickness in systems Ni(d_{Ni}) /Au(5 nm)/Ni(25nm)/S for all patterns MR was isotropic. The biggest MR values observed at perpendicular measure geometry in the range of (0,035 – 0,050) %. So, for system Ni(15nm)/Au(5nm)/Ni(25nm)/S (Fig.2b) MR in perpendicular plane was more than 5 times bigger as in longitudinal and transverse geometries.

Table 1 – Electron-graph descript of as-deposited Ni(25)/Au(15)/Ni(25)/S film system

№	I, a.u.	d_{hkl}, nm	*hkl*	*a*, nm	Phase composition
1	strong	0,236	111	0,409	fcc -Au
2	very strong	0,204	111	0,353	fcc -Ni
3	medium	0,203	200	0,406	fcc -Au
4	medium	0,177	200	0,354	fcc-Ni
5	weak	0,145	220	0,410	fcc -Au
6	medium	0,124	220	0,351	fcc -Ni
7	medium	0,123	311	0,408	fcc -Au
8	medium	0,107	311	0,354	fcc -Ni
$\bar{a}$ (Au) = 0,408±0.002 nm; $\bar{a}$ (Ni)=0,352 ±0.002 nm					

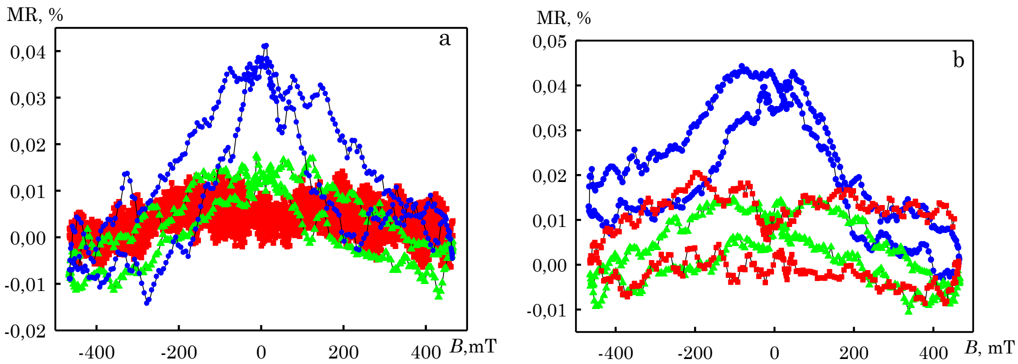

Fig. 2 – *MR* vs *B* (magnetic field induction) dependencies of Ni(5)/Au(5)/Ni(25)/S (a) and Ni(15)/Au(5)/Ni(25)/S (b) film systems by three measurement geometries: (■) - longitudinal; (▲) - transverse; (●) - perpendicular.

4. CONCLUSION

An analysis of structure and phase investigations allows us to conclude that in as-deposited film systems based on Ni and Al is presented an individual nature of layers by changing the their thickness.

An investigation of magnetic resistive properties shown that for Ni(d_{Ni}) /Au(5nm)/Ni(25nm)/S systems is typical isotropy of field dependencies *R*(*B*), in all cases of measurement geometry. In case of Ni(5 nm)/Au(d_{Au})/Ni(25nm)/S an isotropy of these dependencies is character only for Au thickness from 5 to 10 nm. For patterns series Ni(d_{Ni}) /Au(5 nm)/Ni(25 nm)/S and Ni(5 nm)/Au(d_{Au})/Ni(25 nm)/S a value MR at perpendicular geometry is in several (3-5) times bigger than MR at longitudinal and transversal measurement geometries.

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