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Dimensional Effects in Strain-sensitivity Film Systems Based on Ni and Ag

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The paper describes research results of influence of a uniform magnetic field by induction of 200 mT on the longitudinal gauge factor of nanocrystalline film systems of Ni and Ag with different thickness of non-magnetic layer of Ag (or Ni) within elastic deformation up to 1 % are presented. Considered methods of forming two- and three-layer structure based on thin films Ni and Ag and research of the structure and phase composition of the obtained samples. The correlation between the factor value of the longitudinal gauge factor, structural-phase state of film systems and total thickness is set.

Keywords: Strain effect, Gauge factor, Dimensional effect, Phase composition.

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1. INTRODUCTION

A characteristic feature of multi-functional sensors application is a widely usage of multi-component film systems as a sensitive elements [1]. Working quality of these devices is largely depends on film electro-physical stability in some deformation and field ranges. Films elements high-optimization level needs to take into account their dimensional effects development. It is due to the presence of the films surface dispersion or on the crystalline boundary (inter-phase boundary) together with volume electrons dispersion mechanisms in dimensional-limited elements. So, the film and (or) crystalline grains geometrical restrict reduce to decreasing of the charge carriers mean free pass (MFP). It may be caused by applying of the films surfaces and crystalline (grain) boundaries limits on free charge carrier mobility during the approximation of the metal film thickness (d) or average crystalline size ($\tilde{L}$) to MFP. This effect is caused by the external (electrons dispersion on the films surface) or internal (electrons dispersion on the grains boundaries) dimensional effects. On this basis a problem of the dimensional effects presence on tension-resistivity provided by weak magnetic field impact is actually strong. Unconditional features in this case are: design of nano-dimensional films structures based on transition metals with unique physical and mechanical properties which are widely expand areas of their effective usage [2-4].

2. EXPERIMENTAL

In this work were investigated strain properties of Ni, Ag films and based on these materials two- or three-layered film systems by influence on them perpendicular magnetic field. For the computation of the gauge factor 5-7 deformation cycles "load ↔ unload" were performed without field action and in perpendicular to the plane of the sample magnetic field by induction of 200 mT. Films with substrates deformed in pace of 0.05 %. Patterns were prepared by thermal-resistance vacuum deposition onto Teflon substrates at room temperature in SELMI VUP-5M vacuum equipment (pressure level was 10^{-3}-10^{-4} Pa). For angular dependency ratio ΔR / R of gauge factor was calculated.

TEM and electron-graph investigations were performed by SELMI PEM-125 K transmission-electron microscope.

3. RESULTS AND DISCUSSION

Taking into account the possible influence of the phase composition and the structure of components on the mechanical properties of three-layer, two-layer samples and single-layer films Ni and Ag were investigated. Ag has fcc structure with the mean lattice parameter $\bar{a}$ (fcc-Ag) = 0,410 ± 0,001 nm. The value agrees well with the tabulated data a_0 (fcc-Ag) = 0,409 nm [5]. Single-layer film Ni also have fcc structure with the mean lattice parameter $\bar{a}$ (fcc-Ni) = 0,353 ± 0,001 nm, which corresponds to the tabulated value for bulk samples a_0 (fcc-Ni) = 0,352 nm [5].

It was estimated that single-layer Ag and Ni films (thickness 5-100 nm) have a correlation between the average grain size ($\tilde{L}$) and their thickness d: as-deposited Ni films were fine-crystalline and their $\tilde{L}$ = (0.2-0.3)d_{Ni} whereas in case of Ag films $\tilde{L}$ = (2.0-2.5)d_{Ag} with a presence of the negligible statistical deviation. Longitudinal gauge factors (GF) were determined by an elastic deformation conditions till 1 %. As a result of investigations were belt three-dimensional diagrams (see Fig. 1). They display an alteration of GF (γ_l) during the alteration of film thickness (or separate layer of the film structure) and average crystalline size by providing a magnetic field or its absence. An analysis of obtained results enables us to estimate some regularities of GF dimensional effect. Ag films characterized by comparative low γ_l values (1.5 (d = 50-100 nm) – 2.5 (d = 5-10 nm) arbitrary units (arb. un.). Under the influence of perpendicular magnetic field (200 mT) observe a negligible increase of γ_l (to 2.64) only in the range of thicknesses 5-10 nm. Ni films have GF value from 2.4 (d = 50-100 nm) till 6.2 (d = 5-10 nm) arb. un. At improve patterns on external magnetic field observed an increasing of GF independently on their thickness: in the range of lower thickness (10-20 nm) GF increasing was 23-27 % while films thickness was 40-55 nm GF increasing in magnetic field had a value of 18-22 %. In case of two- and three-layered film systems based on Ni and Ag GF was significantly increased compare to single-layer patterns. For example, γ_l value by films with equal thickness 45 nm was biggest for Ni(10)/Ag(5)/Ni(30)/S structure and its value - 9,5 arb. un. It's noticed, that in Ni(10)/Ag(d_{Ag})/S film systems during the increase of Ag layer thickness from 10 till 30 nm GF value should be lesser sensitive to external magnetic field and γ_l increasing is less than 10 % (Fig. 1f). At d_{Ag} thickness more than 45 nm the GF of film system hasn't a reaction on magnetic field and its value is ~ 5 arb. un.

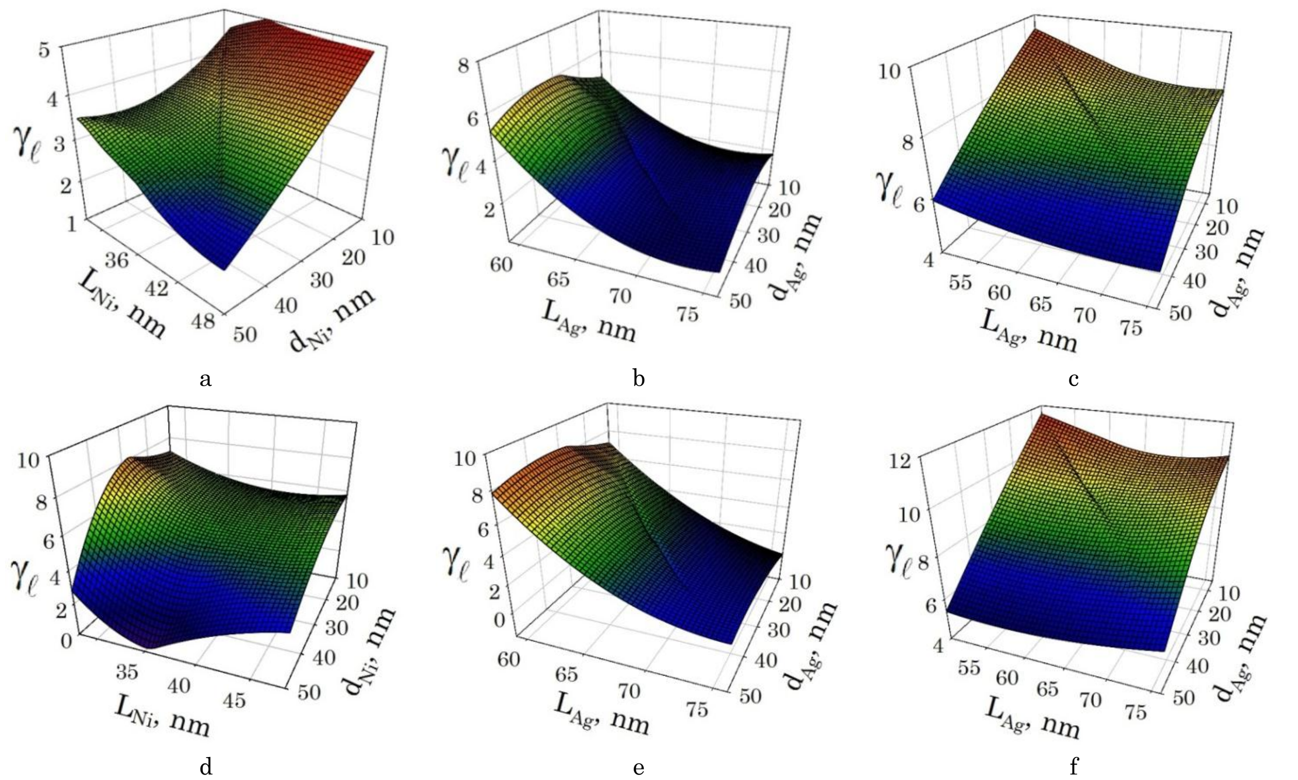

Fig. 1 – Dependences vs. d and $\tilde{L}$ for thin film system Ag(10)/d_{Ni}/S (a, d), Ni(10)/d_{Ag}/S (b, e) and Ni(10)/d_{Ag}/Ni(30)/S (c, f): without field (a, b, c) and in perpendicular magnetic field induction of 200 mT (d, e, f)

By Ni thickness varying a $\tilde{L}$ increasing in magnetic field is observed in all range of the layers thickness and was 25-40 %. Such character of γ_l is also typical for Ni(10)/Ag(d_{Ag})/Ni(30)/S films system. Therefore, by changing of nano-dimensional systems internal structure it is possible to influence on their electrical [6] and strain properties.

4. CONCLUSIONS

It is determined that two- and three-layer film systems based Ni and Ag have gauge factor greater than single-layer films Ni or Ag films of the same thickness do. With decrease in the average grain size of film system, gauge factor increases.

It was estimated that a controlling a values of gauge factor of film systems based on Ni and Ag inside magnetic field is possible by the increasing of, generally, Ni film thickness or by changing of the external magnetic field value.

It is shown that in magnetic field induction of 200 mT GF of film systems Ni(10)/Ag(d_{Ag})/Ni(30)/S increases. In the samples with thickness $d_{Ag} < 10$ nm the growth of gauge factor in magnetic field is 21-22 %, while at $d_{Ag} > 40$ nm the growth decreases and is 13-16 %. This effect may to spotting gauge factor values in magnetic field by increasing of Ni layer thickness generally.

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