STRAIN RESISTIVE PROPERTIES OF FILMS ON THE BASIS OF COPPER AND COBALT IN WIDE DEFORMATION RANGE

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ABSTRACT

This paper presents experimental results of the investigation of strain resistive properties of Cu and Co films with thickness of 20 nm, 40 nm and Cu(30)/Co(30)/S film system. Thin films were analyzed in deformation range from 0 to 6 percents. With help of atomic force microscopy the moment of fracture formation was determined. According to obtained results the conclusions were made that up to 2 percents of deformation ratio (ε_l) the samples preserve their structural integrity. For thin films Cu(20) and Co(20) fracture occurs at $\varepsilon_l \cong 6$ percents. For thicker samples the moment of transition from quasielastic to plastic deformation differs and film destruction is observed at $\varepsilon_l \cong 4$ percents. The study of Cu(30)/Co(30)/S system showed that in spite of sample's thickness raise the deformation ratio of film destruction didn't decrease as for one layer films.

Key words: strain gauge, plastic deformation, atomic force microscopy, strain sensitivity coefficient, thin film

INTRODUCTION

Due to unique mechanical, physical and optical properties film materials are widely used as base for sensors. Multilayer film systems detectors have definite advantages over semiconductor ones, for example, under high temperature they possess more stable characteristics. Therefore, the study of film properties, such as electro physical properties, remains very important problem. The most common and promising systems for developing strain gauge are systems on the basis of Cu, Co, Cr and Fe. Strain resistive properties of these films and systems built on their basis are investigated well enough under deformation in the range from 0 to 2 %, i.e. elastic, quasielastic and partly under plastic deformation. The mechanism of deformation in range over 2 % for thin films is not well studied yet. So the aim of this work was to investigate how electro physical properties and structure of Co, Cu films and systems on their basis changes in the deformation range from 4 to 6 %. [1]

METHODS OF SAMPLE MANUFACTURING AND ANALYSIS

While carrying out the work Cu and Co films with thickness of ≅ 20 nm,

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40 nm and Cu(30)/Co(30)/S film system were investigated. Samples were built by thermal evaporation method in VUP-5M unit. Since the resistance of obtained films was about tens of ohms the contacts had to be done low-impedance to decrease their influence on strain resistive properties of samples. Therefore, polystyrene tapes with thickness ≅ 0.4 mm were used as substrate. They have smoothly polished surface and good elastic properties. The only disadvantage of these tapes is low temperature resistance, but in this case samples were not heated up. On the polystyrene surface the copper contacts with thickness of ≅ 70 nm were formed by vacuum evaporation method. To reduce the influence of contacts on strain resistive properties of the films polystyrene tapes were attached to aluminum plates in the way that only copper film and small area near its junction with contacts was under deformation. After obtaining the sample it was left for 3 hours in vacuum to stabilize the phase structural processes. Then deformation curves were traced dynamically. Each cycle "strain – relaxation" was followed by increasing of deformation range from 1 up to 4 – 6 % [2, 3].

For correct interpretation of results it is extremely important to control the structural integrity of the film during deformation. For this purpose atomic force microscopy (AFM) is used [4]. This is convenient method to explore the topology of surfaces. AFM – portraits were obtained in topology mode and surface profile mode.

RESULTS AND DISCUSSION

Figure 1 shows the examples of deformation dependencies for Cu (21) (a) and Cu (20) (b) films. In first case cycles "strain – relaxation" were traced up to 4 % of deformation (ε_l), in second – up to 6 %.

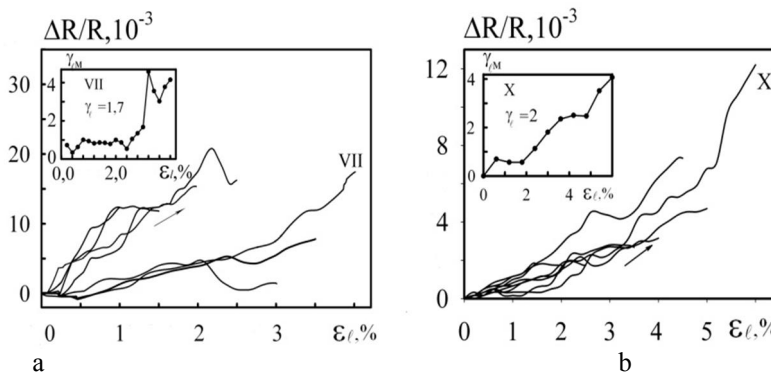

Fig. 1 – "Strain" curves for Cu (21) (a) and Cu (20) (b) films under deformation of 4 % and 6 % respectively.

As we can see from the charts, the resistance doesn't increase rapidly till 2 % and the dependency of $\Delta R/R$ on ε_l has linear behavior that indicates the elastic and quasielastic deformation in this area. With further increase of ε_l the transition to plastic deformation proceeds that in its turn causes the growth of coefficient of strain sensitivity (CS). For deformations higher then 4 % the

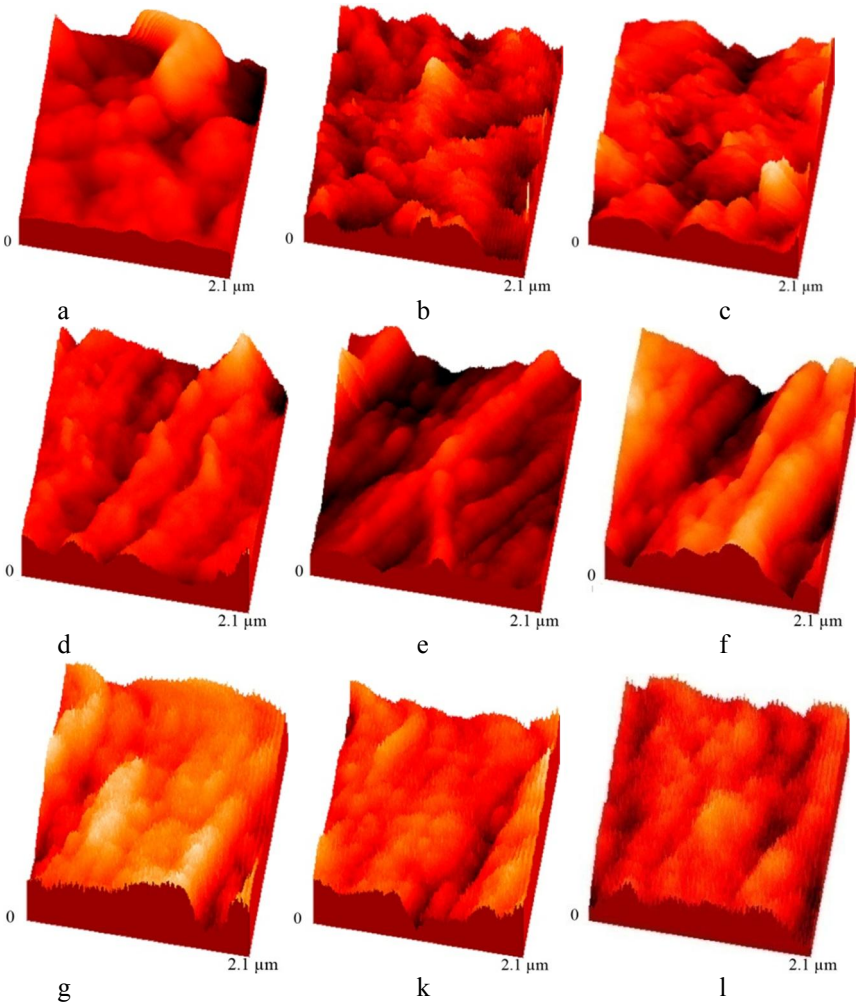

Fig. 2 – AFM – portraits for ε_l = 0 %, 2 % and 4 % in profile mode respectively: Cu(20) (*a, b, c*), Co(20)(*d, e, f*), Cu(30)/Co(30)/S (*g, k, l*).

rapid growth of film resistance and CS occurs that indicates the fracture of copper. Similar results were obtained for Co films and for Cu(30)/Co(30)/S system.

Figure 2 presents some AFM – portraits of Cu, Co films and Cu(30)/Co(30)/S system in profile mode for different values of ε_l.

The analysis of AFM experimental data indicates that for deformation values less than 2 percents the depth of micro fractures in all samples changes insignificantly (approximately on 1 nm). At $\varepsilon_l = 4$ % the changes have more effect, e.g. for Cu(20) – 4 nm and for Cu(30)/Co(30)/S – 3 nm. Further increase of deformation value leads to film destruction.

CONCLUSIONS

During the research deformation curves were traced for copper and cobalt films with thickness of ≅ 20 nm, 40 nm and for system on their basis at ε_l up to 4 – 6 %. At $\varepsilon_l \cong 6$ % the fracture of samples with thickness of 20 nm occurs that is indicated by the rapid growth of film resistance and its CS. For samples with thickness of 40 nm the destruction appears at lower deformation ratio (≅ 4 %). But the system Cu(30)/Co(30)/S has good strain resistive properties like 20 nm film in spite of big total thickness. The structural integrity of the samples was controlled with AFM help. The portraits that were taken in profile mode prove the intensive appearance of fractures only at high deformation ratio.

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REFERENCES

[1] E.O. Zabila, I.V. Koplik, I.Yu. Protsenko, Visnyk SSU. Physics, mathematics and mechanics section. (in Russian).
[2] S.I. Protsenko, D.V. Velykodnyi, V.A. Kheraj, et al. J Mater Sci, 2009, 44, P. 4905–4910.
[3] D.V. Velykodnyi, S.I. Protsenko, I.Yu. Protsenko, PSE, 2008, 6(1-2), P. 37-42. (in Russian).
[4] C. Coupeau, J.F. Naud, F. Cleymand et al., Thin Solid Films, 1999, 353(1), P. 194-200.