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Dilyara Abay, Zhuldyz Otarbay, Madengul Token, Nazim Guseinov, Mukhit Muratov, Maratbek Gabdullin, Daniyar Ismailov
National Nanotechnology Laboratory of the Open Type, Al-Farabi Kazakh National University, Almaty 050040, Kazakhstan

dilyara.abai@mail.ru

Abstract. In the article studies the efficiency of using nanostructured nickel copper films as thin films for bending sensors. Thin films of nickel-copper alloy were deposited using magnetron sputtering technology followed by the appropriate masks. Scanning electron microscopy (SEM) and energy- dispersive X-ray spectroscopy (EDS) techniques were used to examine structure and surface of the Ni Cu coatings. The results of the bending sensors result indicated that the Ni Cu thin film strain gauge showed an excellent sensitive.

Keywords: resistive strain gauge, nanostructured films, nickel copper alloy, digital pressure gauge,

1. Introduction

Pressure measurement is a basic operation in technological processes. Disadvantages of measuring equipment in most cases can lead to errors in the measurements. Only reliable information about current parameters of the technological process determines the output from production lines of quality products. This is achieved by using modern methods of obtaining measurement elements. Recently, in the field of electronics, special interest was given to work aimed at creating nanosized arrays of porous structures on the surface of nickel- copper samples for further application of the resulting formations for practical purposes. Advanced thin film sensors, which are sputter deposited directly onto the surface of heating components, have thickness on the order of a few micrometers; therefore, they leave intact the surface structural integrity and add negligible mass to the surface and create minimal disturbance of the gas flow over the surface [1]. Thin film strain gauge can provide more effective method of accurate strain and other mechanical parameter measurement at high temperature environment. Nickel has a significant effect on the physical and mechanical properties of Cu-Ni alloys [2,3,4]. While tensile strength, 0.2% proof strength, hot strength, solidus and liquidus temperature and corrosion resistance increase with nickel content, thermal and electrical conductivity decrease. Tensile strength increases with nickel content, elongation remains almost constant after a slight decrease (up to 5% Ni) [5]. The desired pattern of the strain gauge is deposited by masking the non-conductive areas. The advantages of strain gauge technology: fast response time, ease of compensation of temperature effects, the relative freedom from the effects of acceleration [6]. One of the urgent problems in Kazakhstan is the transfer of all utilities to digital electronics and the most relevant of these is the measurement of pressure in the pipes of the city heating. Since high accuracy is required to control the pressure in the pipes, it is necessary to have appropriate instruments that have a high sensitivity. The task was to create a sensitive element based on nanostructured nickel-copper composite.

2. The experimental part

The coatings were applied on the experimental test bench to obtain functional metallic and oxide coatings by using a magnetron sputtering system based on a vacuum installation VUP-5M [7]. Vacuum universal post is designed to apply metal oxide thin-film coatings in vacuum to the surface of products made from various materials. In magnetron sputtering system, the ionization efficiency of the electrons is increased by increasing their path length by applying a transverse magnetic field normal to the electric field. Magnetron sputtering makes it possible to utilize the cathode discharge power very efficiently to generate high current densities at relatively low voltages and lower operating pressure to yield deposition rates which are higher than those in the nonmagnetron sputtering systems. Magnetron sputtering system operated in the following modes: voltage on the cathode was 500 V, the discharge current was 100 mA with a duration of 15 minutes, the pressure in the vacuum chamber was maintained at about 0.5 PA (Fig. 5.), the working gas was argon, the magnetron target was nickel-copper. The discharge power was maintained at 50 W.

The structure of the stand includes: the vacuum camera, the diffusion pump, a vacuum pump, the volume cylinder, the switching valves of the vacuum system, the thermocouple sensor PMT-2, the ionization sensor PMI-2 as shown in the diagram (Fig. 1).

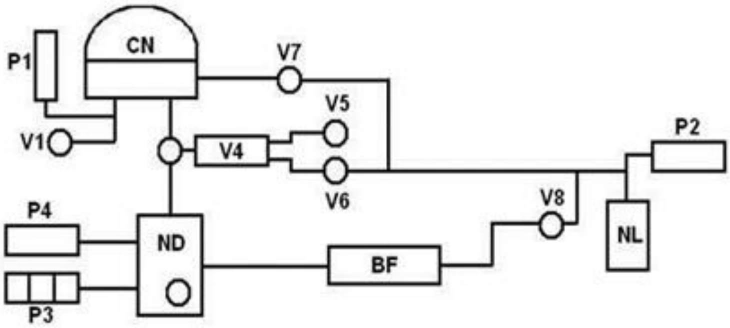


Figure 1. The scheme of the vacuum system VUP-5

The thin-film strain gauge was made on samples, as the bending element was the kapton material as shown in Figure 2.

Figure 2. A sample of Ni-Cu thin film resistive strain gauge

At the beginning of the spraying process an inert gas argon is supplied. When an electromagnetic field is created, a plasma is generated. The particles begin to break away from the target and movement is chaotic. The concentrated metal particles begin to break away and are deposited on the surface of the substrate. For the experiment we used 3 different materials as a substrate. At first, we sprayed on the glass to find out the suitable mode, then on silicon to see the thickness of the film with a scanning electron microscope, finally we used the kapton to look at the bend.

3. Discussion of result

The strain gage which we obtained by the magnetron sputtering method is attached to a beam then connected to an amplifier. The beam is under the action of a uniformly distributed load (Figure 3). When the beam is subjected to deformation from the neutral layer, one part of the cross section of the beam is subjected to stretching, another part – to compression.

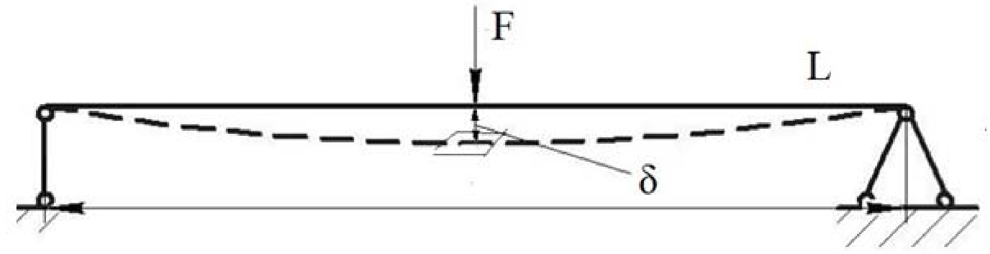


Figure 3. Calculate the beam of bending.

From two ends, evenly increasing, we set the moment of forces. Until the middle of the beam reaches maximum bending (for the experiment the maximum bend is f max = 3 mm), we simultaneously record the voltmeter's reading. We compare the value of the diagram with the theoretical bend. The maximum value of the bend will be in the middle, since the internal force of the beam will be a pure bend. Below are the formulas for measuring sensitivity and elongation. As shown in the formulas 1,2 we calculate the sensitivity and the relative extension.

$$K_F = \frac{\Delta R/R0}{Ex}; \quad (1)$$

$$E_x = \frac{\Delta L}{L_0}; \quad (2)$$

The dependence of relative resistance change from the relative extension shown in chart 1. It is possible to evaluate the sensitivity of the lode cell. As the graph shows we have reached the maximum for metal films.

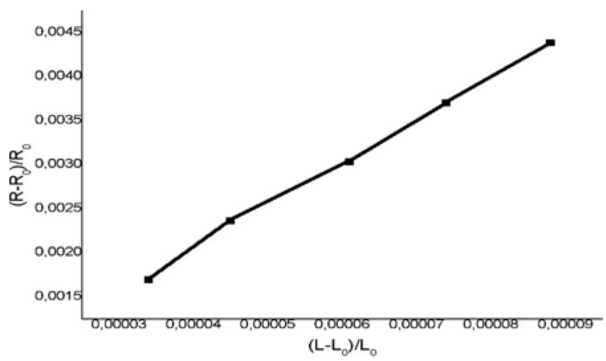


Chart 1.The dependence of relative resistance change from the relative extension

Scanning electron microscopy (SEM) was used to examine surface of the Ni Cu coatings. Thus, the films were deposited on the substrate at a deposition rate of 1.2 A / s, according to the SEMimages as shown in Fig. 4, one film with a thickness of 110.7 nm, a second film with a thickness of 205.4 nm. Samples have a uniform surface as shown in Figure 5.

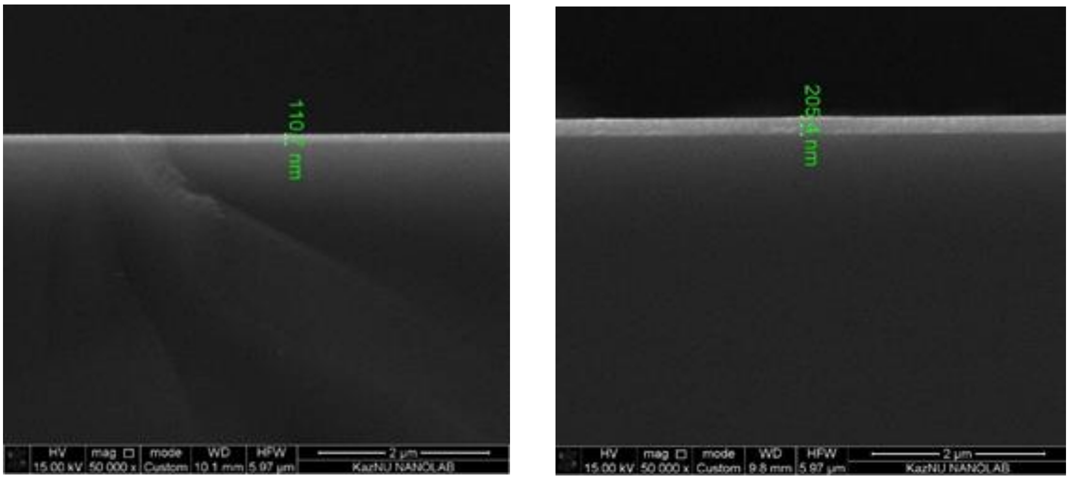


Figure 4. SEM images of the cleaved Cr on which the Ni+Cu alloy is deposited to measure the thickness

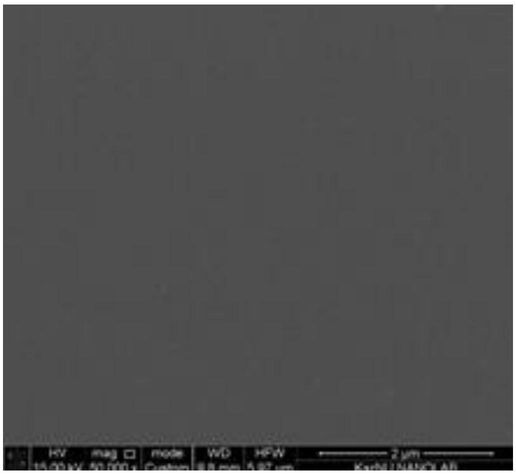
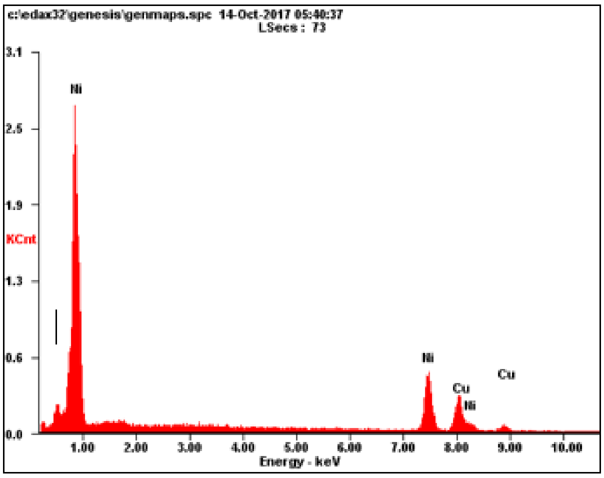


Figure 5. SEM images of the cleaved Cr surface of sample

In the experiment, the mask was made of aluminum foil. Energy-dispersive X-ray spectroscopy (EDS) techniques was used to examine elemental analysis. As seen from the elemental analysis(Fig 6), it amounted to Nickel 54% and Cu 45%.



Element	Wt%	At%
NiK	54.55	56.50
CuK	45.45	43.50
Matrix	Correction	ZAF

Figure 6. Elemental analysis

In this work, results indicated that measuring devices based on nanostructured materials have a good sensitivity. The sensitive strain gauge on the basis of nanostructured nickel-copper alloy with sensitivity Kf=5 at a voltage of 3V was made. The coatings were applied by using a magnetron sputtering method. Scanning electron microscopy was used to study the film surfaces. Energy-dispersive X-ray spectroscopy (EDS) techniques was used to examine elemental analysis. The calculation the beam of bending was made.

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