PECULIARITIES OF METALIZED SURFACES MODIFICATION OF SILICON ELEMENTS OF MICROELECTROMECHANICAL SYSTEMS WITH LOW-POWER ELECTRONIC FLOW

ОСОБЕННОСТИ МОДИФИЦИРОВАНИЯ МЕТАЛЛИЗИРОВАННЫХ ПОВЕРХНОСТЕЙ КРЕМНИЕВЫХ ЭЛЕМЕНТОВ МИКРОЭЛЕКТРОМЕХАНИЧЕСКИХ СИСТЕМ НИЗКОЭНЕРГЕТИЧЕСКИМ ЭЛЕКТРОННЫМ ПОТОКОМ

PhD. Bondarenko M.[1], PhD Bondarenko I.[1], Prof. dr. eng. Antonyuk V.[2], Telezhynskyi D.[3], Andriienko V.[4]
Faculty of Electronically Technologies[1], Department of International Relations [3] – Cherkassy State Technological University, Ukraine
Faculty of instrument-making [2] – National Technical University of Ukraine «Ihor Sikorsky Kyiv Polytechnic Institute», Ukraine
Faculty of Information Technologies and Systems[4] – Cherkassy State Technological University, Ukraine

Abstract: *The practical possibility of the atomic force microscopy method to evaluate uniformity of thin metal coatings on silicon wafers after electronic processing has been shown in the paper. It is established that after processing of metallized surfaces of silicon plates Kp0 by an electronic flow of continuous form, the microroughness decreases in 10-15 times and the* Adhesive *strength increases in 1.8-2 times. At the same time, it is noted that the surface of metal coatings on silicon after electronic processing has a more homogeneous structure and released from microdefects, unlike metallized coatings without electronic processing.*

KEYWORDS: *MICROELECTROMECHANICAL SYSTEMS (MEMS), SILICON PLATES, METALIZED SURFACES, ELECTRON- BEAM MODIFICATION, ATOMIC-FORCE MICROSCOPY*

1. Introduction

Structural features, thickness and microrelief of metallized coatings on silicon elements of microelectromechanical systems (MEMS) determine their performance characteristics, depending on the method of production. A device for electron beam polishing of wares has been described in the paper [1], which makes it possible to realize a combined method: the application of metal coatings and the subsequent processing of these coatings by a continuous electronic flow.

In modern instrument making for the MEMS wares production, thin (up to 1 mkm) metal coatings on silicon are widely used. Such coatings, obtained, in particular, by evaporation in vacuum, have properties (high adhesion strength, reflective power, etc.), which allow them to be used as functional wear-resistant coatings in precision instrument making [2].

The method for the production and the microrelief features of thin coatings determine the performance characteristics of MEMS elements linked with the instability of their properties over time. As shown in works [3, 4], the reasons for such instability are the dimensional effects (inequality of the coating thickness, surface structure) and the operating conditions of these elements (aggressiveness of the external environment, time and operating temperature, mechanical interaction with other elements).

The possibility of metallized surfaces modification by an electronic flow of the continuous form has been shown in the work [5]. Besides, the technical and operational, chemical and tribometric properties of coatings on silicon substrates have been improved.

At the same time, the method of atomic force microscopy possesses essential advantages in the research of the microrelief of metallized surfaces modified by an electronic flow, namely: high accuracy of fixed microroughnesses of the surface (up to units of angstroms) and sensitivity of the measuring console ($\approx 10^{-8}$ N), and this method refers to non-destructive research methods that do not require preliminary preparation of the material of the research and pretend to the rapid research.

The aim of the work is the study using atomic force microscopy of the microrelief of thin metal coatings on silicon plates modified by an electronic flow, whose surfaces are used in precision instruments industry for the production of MEMS elements.

2. Experimental method

The plane-parallel plates of circular form (20 mm in diameter and 0.5 mm in thickness) made of silicon Kp0 were metallized by aluminum.

Metallization and electronic modification was carried out on a special laboratory machine (Educational and Scientific Center "Micronanotechnologies and Equipment", ChSTU, Cherkassy), containing the evaporator and Pierce electronic gun.

The silicon plate, preheated to a temperature of 630 K, by using of revolving traveling mechanism it was located in a vacuum chamber above the evaporator unit, where for 5-8 sec the metallization of its surface was carried out under the following modes: the heating current of the evaporator is I = 115-125 A; voltage on the evaporator is U = 20-22 V; distance from the evaporator to the plate surface is h = 120 mm.

After the ending of metallization process, the plate moved unceasing over the electronic gun. At the same time, a low-energy electronic flow of continuous form (width 3.0 mm, length 60.0 mm) affected the metallized surface. Electronic processing was carried out at the following modes: accelerating voltage is 3.5 ... 4.0 kV; the current of the electronic flow is 175 ... 200 mA; the current of cathode heating is 14.5 A; The electron flow rate is 4.5 ... 5.0 cm / s; the distance from the anode of the electronic gun to the working surface is 40 mm; single pass processing.

The microgeometry of the surface of the deposited coatings and the "coating-plate" boundary was investigated by atomic force microscopy method using the "NT-206V" instrument, (manufacturer:
ALC "Microtestmashiny", Belarus) with silicon probes "Ultrasharp CSC12", microposition system and built-in optical long-focus Logitech microscope.

3. Results and discussion

As a result of the conducted researches it is established that the gold coverings on silicon plates received by evaporation in vacuum are non-uniform, have the increased porosity and contain microdefects of a surface (cracks, points and etc.), Fig. 1.

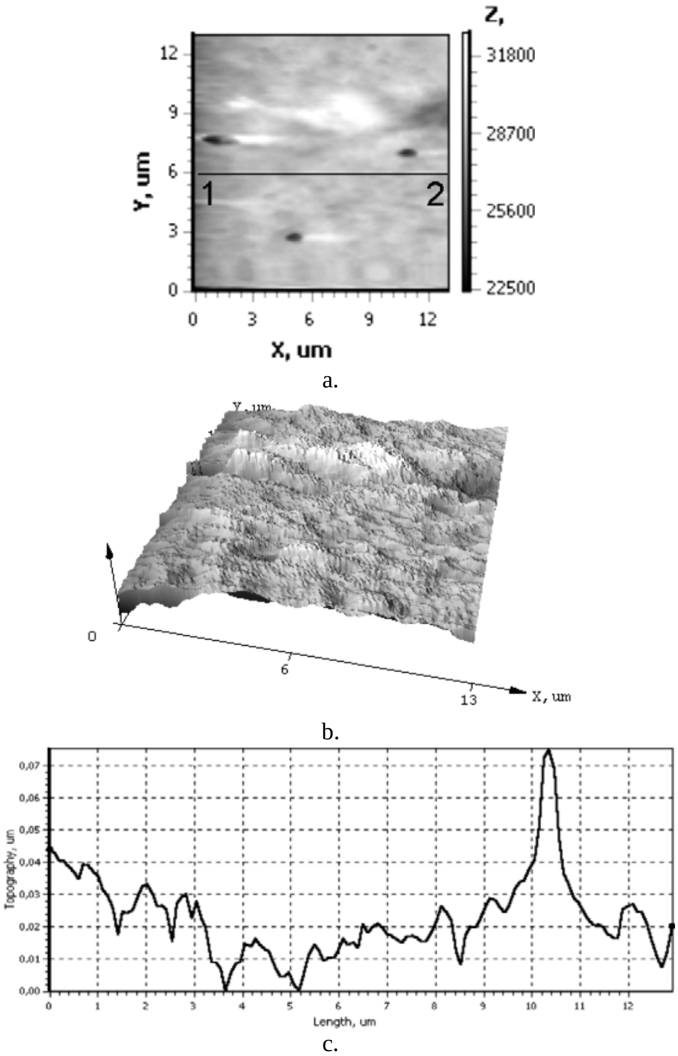

Fig.1. The topogram (a), the microrelief (b) of the surface of the metal coating (Au) on the 13×13 mkm section on a silicon plate Kp0 and a profile along the line 1-2 (c).

At the same time, the average roughness of a surface of such coverings makes 50-75 nanometers. The adhesive strength of the metal coating to the board was set by the method described in [6] and was 20-25 MPa.

After metallized surfaces processing by a low-energy electron stream of the ribbon shape, the metal coating melts, which somewhat reduces the residual microroughness (up to 35-50 nm), and its partial fusion into the surface layer of silicon increases the adhesive strength of the coating to 34-45 MPa, Fig.1.

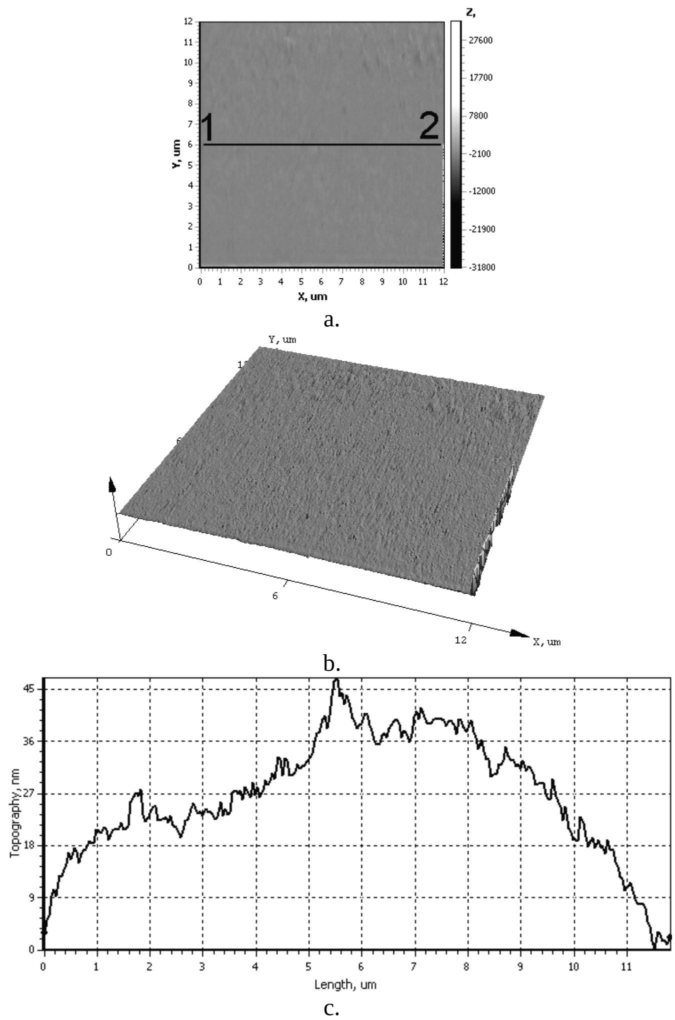

Fig.2. The topogram (a), microrelief (b) of the surface of the metal coating (Au) on the 13×13 micron section on a silicon plate Kp0 and a profile along the line 1-2 (c) after modification by an electronic stream.

4. Conclusion

The practical possibility of atomic force microscopy method to estimate uniformity of thin metal coverings on silicon plates after electronic processing which are used in precision instruments industry is shown.

Using atomic force microscopy method, it was established that after processing of the metalized surfaces of silicon plates Kp0 by a low-energy electron stream of the ribbon form, microroughness decreases from 50-75 nm (metalized surface) to 3.5-5 nm (metalized surface after electron processing) and Adhesive strength increases from 20-25 MPa to 34-45 MPa.

At the same time it is noticed that the surface of metal coverings on silicon after electronic processing has more homogeneous structure and it is saved from microdefects unlike the metalized coverings without electronic processing.

5. Literature

1. Bondarenko M.A. Yzučenye mexanyzma formyrovanyja ul'tratonkyx funkcyonal'nyx pokrytyj na optyčeskom stekle pry kombynyrovannoj elektronno-lučevoj mykroobrabotke (*Study of the mechanism of formation of ultrathin functional coatings on optical glass in combined electron-beam microprocessing*) / M.A.Bondarenko, Ju.Y.Kovalenko, Ju.Ju.Bondarenko, S.A.Bylokon y dr. // Sovremennye problemy fyzyky kondensyrovannoho sostojanyja, nanotexnolohyj y nanomateryalov: III meždunar. nauč. konf., 15-16 maja 2014: mater.dokl.– Almaty: Kazax unyversyteti, 2014. – S.64-65.
2. Yatsenko I. Influence of parameters by electronic ray on properties of superficial layers of optical elements of exact instrument-making / I.Yatsenko, V.Antonyuk, M.Bondarenko, V.Vashchenko // Innovations in engineering: Intern. scien.-tech. conf., 9-12 september 2015. – Burgas, Bulgaria. – Vol. 20/183. – 2015. – pp. 64-66.
3. Antonyuk V.S. Formation of Wear-Resistant Coatings on Silicon Probes for Atomic Force Microscopy by Thermal Vacuum Evaporation / V.S.Antonyuk, S.O.Bilokin,

M.O.Bondarenko, Yu.Yu.Bondarenko [etc.] // Journal of superhard materials. – 2015. – Vol.37. – No. 2. – pp.112-119.

4. Bondarenko M.O. Doslidžennja mexaničnyx xarakterystyk elementiv pryladiv točnoho pryladobuduvannja metodom atomno-sylovoji mikroskopiji (*Investigation of mechanical properties of elements Precision Instrument by atomic force microscopy*) / M.O.Bondarenko // Visnyk Čerkaskoho deržavnoho texnolohičnoho universytetu. Serija: Texnični nauky. – Čerkasy: ČDTU, 2015. – #2 – S. 21-28.
5. Pokryttja u pryladobuduvanni (*Coverage of instrument-making*) [Tekst]: monohrafija / V.S.Antonyuk, H.S.Tymčyk, Ju.Ju.Bondarenko, Ju.I.Kovalenko, M.O.Bondarenko ta in. // K.: NTUU «KPI», 2016. – 360 s.
6. Bondarenko M.A. Yssledovanye poverchnosty kremnyja posle mykroobrabotky nyzkoenerhetyčeskym lentočnym elektronnym potokom (*Investigation of the silicon surface after microprocessing by a low-energy ribbon electron beam*) / M.A.Bondarenko, Ju.Ju.Bondarenko, O.V.Svyrydova // Rastrovaja elektronnaja mykroskopyja y analyt. metody yssledovanyja tverdych tel: XIX Ros. sympoz., 1-4 yjunja 2015 h: tezysy dokl., h.Černoholovka, 2015.