NANOSTRUCTURED COMPOSITE MATERIALS FOR 3D ELEMENTS OF ADVANCED OPTICAL SYSTEMS

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I. INTRODUCTION

Formation of various micro- and nanostructures plays an important role in the modern display and optical devices such as LCD, OLED-, PLED-displays, etc. Functional structures' pattering is achieved through the use of up-to-date technologies, which allows obtaining a light control systems [1].

Modern industry requires to use high-end technologies, such as roll-to-roll (R2R) processing. Usage of roll-to-roll technology for hologram manufacturing is due to its high throughput, 3D repeatability of mold and low cost of production [2, 3]. Application of nanocomposite materials with good wear resistance, high microhardness and good anti-sticking surface properties could improve lifetime of molds and reduce imperfection in roll-to-roll technology and nanoimprint lithography and production.

Application of high-grade coating with complex nanoscale geometry can improve electrical, optical characteristics and thus device performance of multiple optical systems.

Micro- and nanoelectromechanical systems (MEMS and NEMS) and microoptoelectromechanical systems (MOEMS) are the most promising state-of-the-art devices. Mechanical interaction between nano-, micro-, and macro world is the limiting factor for such a complex system. Moreover, reliability of the whole systems is determined by the reliability of the mechanical part. The use of nanocomposite materials is the most promising method to solve the reliability issue [4-7].

To solve problem integration of nanocomposite materials electroplating with UV lithography based on SU-8 photoresist is proposed.

II. UV LITHOGRAPHY OF SU-8 PHOTORESIST

To fabricate micromoulds in LIGA-like technology we use photoresists SU-8 2150 and SU-8 3050 on various substrates (glass, ceramic, metal, ITO, etc.). To remove all organic contaminants from the substrates chemical cleaning and UV treatment were used. Chemical cleaning was carried out in peroxysulphuric acid, which is a mixture of a 25 % hydrogen peroxide and 98% sulfuric acid in a ratio of 1:2. More feasible method is UV treatment with the use of Photo Surface Processor PL16-110D. Cleansing process consists of three steps. The first is ozone generation from atmospheric oxygen at a wavelength of 184.9 nm. The second step is ozonolysis, when atomic oxygen is generated at a wavelength of 253.7 nm. The final step is decomposition of organic pollutants. Atomic oxygen has a strong oxidative activity which helps it to react with pollutants and to form reaction products. This products, such as water, carbon dioxide, etc., then are simply evaporatedThin Omnicoat sublayer and thick photoresist layer was spincoated in two-stage mode by VTC-100 Spin Coater (MTI Corporation, USA). Dependence of coating thickness on rotational velocity, time, and temperature were determined.

One of the most important processes during fabrication of thick micromoulds is soft baking. It provides evaporation of the solvent from the photoresist. Soft backing was conducted on a hot plate Wise Stir MSH-D (Labortechnik, Germany).

Exposure of the SU-8 photoresist was performed by the contact lithography through a mask in the 365 nm wavelength. UV-LED module Lightningcure LC-L2 (Hamamatsu, Japan) was used as a light source. To expose photoresist layers with the thickness of 100-250 µm exposure energy was 250-300 mJ/cm^2.

Post exposure backing (PEB) carried out right away exposure. During PEB the absorption of the radiation by initiator occurs. It leads to local photochemical reactions, providing crosslinking of the polymer. Crosslinked regions are insoluble in the subsequent development process and uncured polymer removing.

To avoid spreading of the structures because of melting and also to reduce mechanical stresses next temperature mode was selected. Substrate was placed on a hotplate preheated to 65 °C for 5 min and then heated to 95 °C at 15 °C / min and stand at 95 °C for 15 min.

To remove the unpolymerized parts of the photoresist organic SU-8 Developer (Microchem Corp, USA) was used. After further hard backing at 150°C micromoulds become chemically and mechanically resistant.

III. NANOFABRICATION FOR STRUCTURES AND INTERCONNECTIONS OF INTEGRATED OPTICAL DEVICES

High-grade and precise coating of the complex patterns is a serious problem in polarizers, functional optical layers, optical retarders and other optical elements with irregular shape. Addressing this issue metallic materials and alloys based on nikel (Figure 1), cobalt (Figure 2) and copper (Figure 3) have been electroplated in trenches. Typical defects like voids, seams and reasonably coarse surface were not observed in the deposited coatings. The use of such coatings for optical systems interconnections will reduce their return loss.

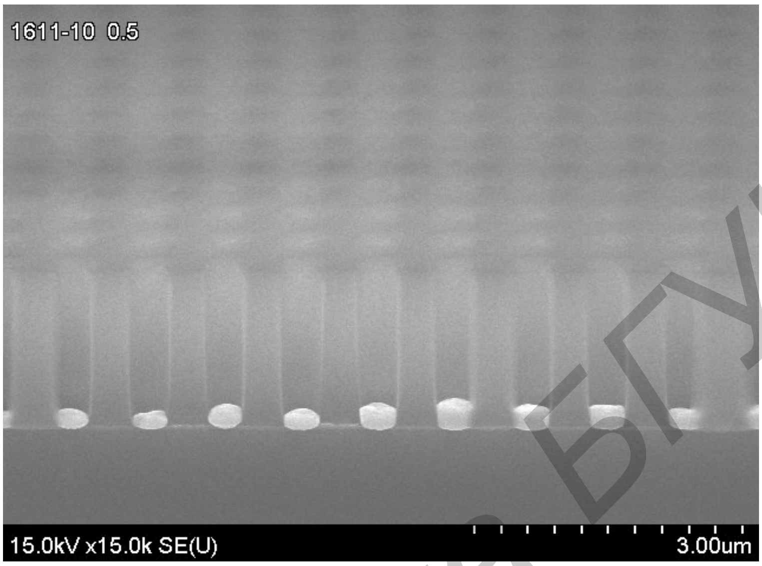

Figure 1 – Nikel-based coating

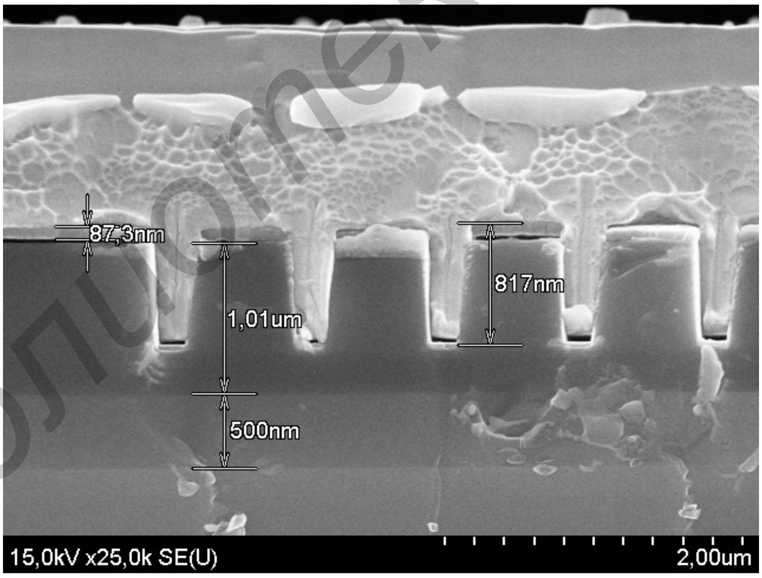

Figure 2 – Cobalt-based coating with 170 nm wide patterns in Si wafer

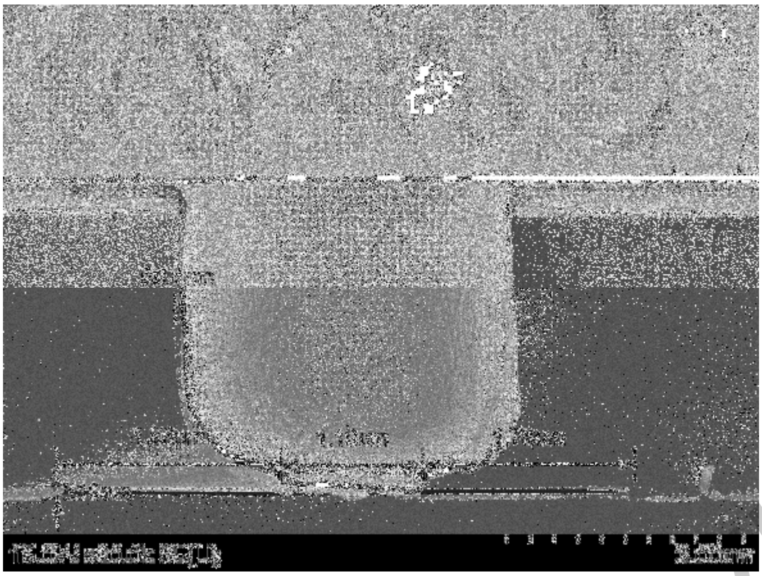

Figure 3 – Copper-based coating

IV. NANOCOMPOSITES FOR RELIABLE MICROOPTOELECTROMECHANICAL COMPONENTS

Composite coatings for MEMS and MOEMS applications based on nickel and cobalt were electroplated with inert nanoparticles of ultradispersed diamond (UDD), alumina, aluminium monohydrate, boron nitride. The size of the dispersed phase varied from 7 to 50 nanometers. The nanoparticles were incorporated into the metal matrix (Figure 4).

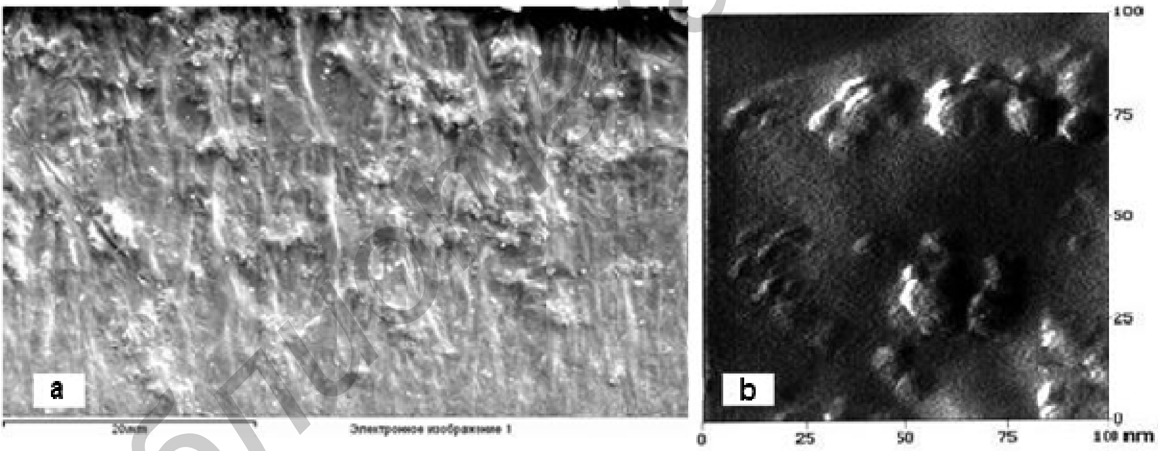

Figure 4 – Cross-section SEM (a) and AFM surface image (b) of nikel nanocomposite coating

In comparison with homogeneous coatings, nanocomposite coatings showed improved mechanical properties: The microhardness was increased on 20-80 %, the wear resistance was increased in 4 times, the friction coefficient was reduced in 2 times. Nanocomposite materials with such mechanical properties will improve the reliability of moving parts and the whole system of such MEMS and MOEMS as moving micromirrors, optical shutters, MOEMS-actuators, etc.

III. CONCLUSIONS

This paper describes positive prospects of the nanocomposite and nanostructured electroplating introduced in modern technologies. Application in NEMS, MEMS, SOFC, ULSI, roll-to-roll, nanoimprint and other advanced systems and technologies makes it possible to improve quality and reliability of end products and enables their industrial development.

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INTERNAL STRESS IN ALUMINUM LAYERS DEPOSITED ON DIELECTRIC SUBSTRATES FOR SENSOR APPLICATIONS

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I. INTRODUCTION

In recent years, there is an intensive development of sensor technology that reaches a new level of sensitivity. Electrochemical, acoustic, optical sensors and biosensors are developed. Among the optical sensors, it should be noted the devices on the surface plasmon resonance (SPR), reflectometric spectroscopy sensors, waveguide sensors, including waveguide sensors on a metal underlayer (WSMP). WSMP which is a thin film structure consisted of a waveguide layer of porous anodic aluminum oxide on the aluminum sublayer is of particular interest. Technology of coatings based on anodic alumina for sensor applications (SPR- sensors and WSMP) includes the following stages: the vacuum deposition of aluminum films on the dielectric substrate; the one-step anodic oxidation for the formation of the alumina film and a translucent aluminum film; the chemical etching for widening of pores with controlled optical parameters of nanostructured coatings. So, control of mechanical stress of the film on the basis of which the device is formed is very important for designing devices with required parameters [1-3].

II. EXPERIMENTAL

Electron-beam evaporation was used for the aluminum deposition on the 165-μm thick rectangular glass strips in the length-to-width ratio of 10:1 to measure stresses by the console method as the simplest and easy-to-use method for the vacuum evaporated films. The stress σ was calculated by the Stoney’s formula:

$$\sigma = \frac{Ed^2\mathrm{x}}{3l^2h(1-\mu)}, \tag{1}$$

where *E* is a modulus of elasticity (Young modulus) for the substrate; d is a substrate thickness; *x* is a flexure of the free end; *l* is a substrate length; h is a thickness of the evaporated film; μ is a Poisson's ratio.

The modulus of elasticity for the substrate was measured by hanging of a plummet to the console end and determining of the glass flexure. This was calculated by the formula: