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The Technology of Laser-Induced Deposition of Nanostructured Metallic Conductors on the Dielectric Substrate

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This article describes a new method for planar copper-oxide coatings with controlled topology and the nanostructured surface. The structure obtained by laser-induced deposition of copper-containing aqueous solutions of a semiconductor laser (532 nm) radiation in a continuous mode. The method Energy Dispersive X-Ray spectroscopy to study the composition of the obtained nanoparticles. Particle sizes were determined by scanning electron microscopy.

Keywords: Copper nanoparticles, Laser deposition, Dielectric substrate, Liquid-phase deposition.

PACS numbers: 81.15.Fg, 81.16.Mk

1. INTRODUCTIONS

Interest in the laser-induced chemical liquid phase deposition stems from the prospects of its use in microelectronics due to the ability to create localized metal structures on dielectric surfaces. Scanning a dielectric surface with a focused laser beam in an electrolyte solution allows chemical copper reduction to be locally initiated in this regard, of particular interest is the laser deposition of copper, because copper has a low electrical resistivity.

The objective of this work was to indicate the fundamental possibility nanoparticles and nano-coatings in the regime of laser-induced liquid phase chemical copper deposition instead of laser ablation [1], usually utilized for these purposes.

2. THE EXPERIMENTAL PROCEDURE

2.1 Description of the process

Laser-induced chemical liquid phase deposition used for metal deposition from solutions onto surfaces of dielectrics [3] is based on the local impact of laser beam focused at the interface of a solution and a dielectric surface. This results in the initiation of metal reduction within the focal zone of laser beam yielding metal structures of a micrometer range at the interface of the solution and the surface. By scanning of the surface with laser beam it is possible to form conductive metal structures at a high resolution without employing any photo templates [2].

2.2 Technical characteristics of the process

We have used the device for laser-induced deposition of copper from the solutions described in the article [4]. The dielectric substrate in the experiment was a ceramic plate thickness of 1 mm of material Polycore "VK-96" contains 96 % Al_2O_3. This material has been selected as one of the most heat-resistant types of ceramics, indifferent to the laser ablation. Semiconductor laser diode power 300 – 2100 mW (at a wavelength of 532 nm) operating in continuous mode was utilized for laser-induced deposition. The highest scanning speed at which the deposition of copper is controlled by the structure proceeded, was 0.01 mm/s. The shape of the reaction region, a zone defined by the focus of the laser beam, is a distorted sphere with a diameter of 15 μm.

The composition of the solution we used was selected on the basis of the results of previous studies on laser-induced deposition of copper [5,6]. An aqueous deposition solution contains: 0.02 mol/L of copper chloride (II), 0.5 mol/L ammonia, 0.075 mol/L ethylene glycol, 0.3 mol/L potassium bromate.

The study of the structures obtained was carried out on an optical microscope at 20 × magnification. The size of the nanoparticles was determined with an electron microscope Zeiss Supra 40VP. Elemental composition of the deposited structure was investigated by X-ray microanalysis in Energy Dispersive X-Ray spectroscopy Oxford Instruments INCAx-act.

3. RESULTS

In the process of laser deposition an intense gas evolution and fluid convection usually takes place.

During current series of experiments gas evolution during the reaction is virtually absent. Color track (black), and the presence of significant oxygen peak on the spectrogram of elemental analysis (see Fig. 4) indicates that the initially formed copper nanoparticles immediately subjected to surface oxidation with the formation of copper oxide (II). Power incident on the substrate surface of the laser radiation in the series of experiments was 1300 mW.

The experiment is obtained with the nanostructured surface fractal topology (see Fig. 2) with strong adhesion to the surface of the ceramic substrate. (see Fig. 1). The characteristic size of nanoparticles was 30 nm (see Fig. 3).

4. DISUSSIONS

The technical novelty of the proposed method consists of the following differences from the well-established methods of laser ablation [7], chemical reduction (or thermolysis) of copper salts [8] and the method of laser photochemical deposition of silver [9].

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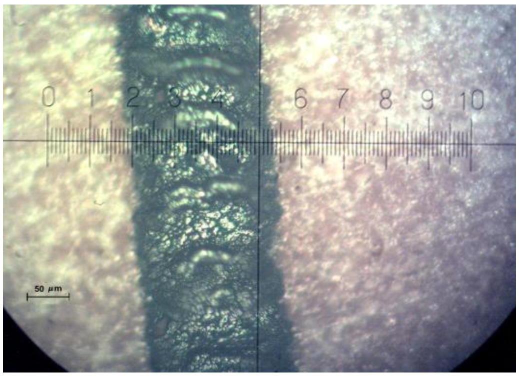

Fig. 1 – Optical micrograph of the structure deposited out of solution composition: 0.02 M chloride copper(II), 0.5 M ammonia, 0.075 M ethylene glycol, 0.3 M potassium bromate, the power of 1300 mW, the rate of 0.01 mm/s, the substrate Polycore VK-96

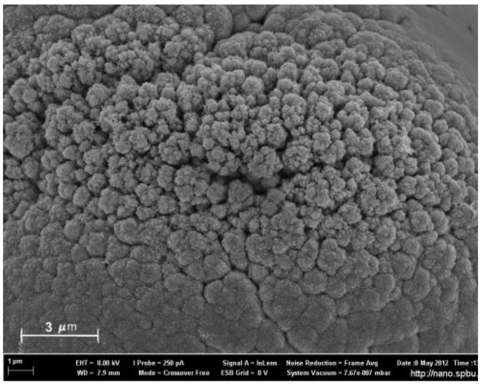

Fig. 2 – Scanning electron microscopy image of the structure deposited out of solution composition: 0.02 M chloride copper(II), 0.5 M ammonia, 0.075 M ethylene glycol, 0.3 M potassium bromate, laser power 1300 mW, the scanning rate 0.01 mm/s, the substrate Polycore VK-96

Versus laser ablation, our proposed method avoids centrifugation and separation of phases obtained nanoparticles and their subsequent application to the desired surface. Laser deposition from the liquid phase with no intermediate steps leading to a nanostructured surface of the desired geometry.

Versus photochemical method of laser deposition of silver, could be developed for deposition of almost all 3d, 4d, 5d elements, regardless of photolytic properties of their compounds.

Our method may be promising for the creation nanomodified ion-selective electrodes and transistors, gas sensors and catalysts with highly developed surface.

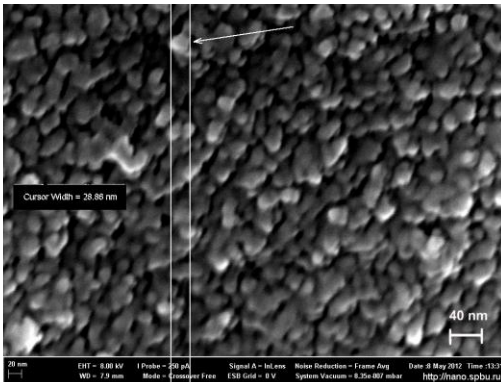

Fig. 3 – In this scanning electron microscopy micrograph can be seen the minimum structural element (30 nm) of the deposited material

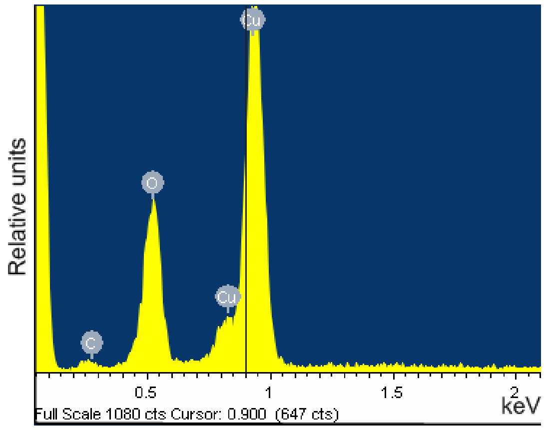

Fig. 4 – Energy Dispersive X-Ray spectrum of deposited structure surface area

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