Specific Features of Technology of Preparation of Bi Nanowire Arrays by Electrochemical Deposition

Pavel GLOBA
Institute of Applied Physics, Academy of Sciences of Moldova
mypavmail@yahoo.com

Ana TSURKAN
Institute of Electronic Engineering and Industrial Technologies, Academy of Sciences of Moldova
aniuta@smtp.ru

Svetlana SIDEL'NIKOVA
Institute of Applied Physics, Academy of Sciences of Moldova
a.nikolaeva@iieti.asm.md

***Abstract* — In this work was solved a complex of problems caused by purely electrochemical characteristics of the technology of obtaining nanowires arrays of semimetal Bi, which concerns: (i) prediction of the growth rate of layers at electrodeposition and the achievement of desired thickness for a specified time; (ii) the revealing of the nature of the growth rate restrictions, and (iii) the revealing of the conditions of electrodeposition being uniform with respect to both the layer thickness and the surface. The solution of the mentioned problems relates to the kinetics of the specific electrochemical process being the basis of nanodimensional electrodeposition.**

***Index Terms* — bismuth, electrochemical deposition, kinetics process, nanowire arrays.**

I. INTRODUCTION

Nanomaterials find increasing application in various branches of physics, chemistry, materials science, electronics, and biomedicine [1, 2]. The development of microelectronic industry opens up the possibility of producing a variety of microdevices, such as microprocessors, microsensors, etc. Thermoelectric devices designed by the rules of proportional miniaturization [3-8] make it possible to increase specific power (W/cm3) with decreasing size of thermoelectric elements. Typically, such thermoelectric devices are prepared using integrated circuit technology and electrochemical deposition [9] of compound semiconductors.

II. EXPERIMENT AND DISCUSSION

In addition to the problems of studying the properties of materials obtained by electrodeposition and their relationship with the technology of synthesis, there appears a complex of problems caused by purely electrochemical characteristics of the technology of obtaining, including the following: (i) prediction of the growth rate of layers at electrodeposition and the achievement of desired thickness for a specified time; (ii) the revealing of the nature of the growth rate restrictions, and (iii) the revealing of the conditions of electrodeposition being uniform with respect to both the layer thickness and the surface.

The solution of the mentioned problems relates to the kinetics of the specific electrochemical process being the basis of nanodimensional electrodeposition [3].

The filling of pores with metal (bismuth) was investigated by the application of aluminum oxide membranes with a pore diameter of ~20, ~100, and ~200 nm and a porosity of ~50%. One side of the membrane was covered with a layer of silver, as a contact layer, by vacuum deposition. The deposition was performed on the mentioned layer.

Samples of the membrane were fixed in a special sealed fixture by means of conductive silver paste. Electrodeposition was carried out in a glass three-electrode cell at room temperature. The potential was measured relative to saturated Ag/AgCl electrode. Electrodeposition was exercised from an aqueous electrolyte solution of the following composition: 75 g/l $Bi(NO_3)_3 \cdot 5H_2O$; 125 g/l glycerin; 65 g/l KOH; 50 g/l tartaric acid at pH ~1 and t = 25°C. Cathode current density was calculated taking into account the porosity of aluminum oxide. Measurement of potential and maintenance of constant current density were carried out using a PI-50-1.1 potentiostat. The degree of pore filling with metal (the thickness and concentration of the metal) was determined by cross-section of the membrane sample, using a TESCAN scanning electron microscope and an INCA Energy EDX system for chemical analysis. The direct current density was varied within 3-5 mA/cm^2. The pulsed electrodeposition was also studied; it was implemented by rectangular unipolar current pulses. The pulse current density i_p was 3-5 mA/cm^2, the pulse

duration varied from τ_p = 0.01 to 0.5 s, the duration of a pause τ_{pp} varied from 0.05 to 2 s.

After passing of a certain amount of electricity (Q, C/cm2) studied transverse sections ("chips") of the membrane samples (Fig. 1).

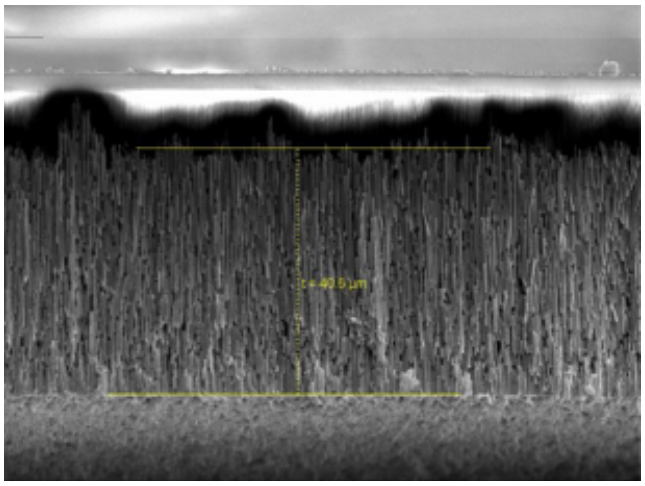

Fig. 1. SEM microphotographs of cross-section after the electrodeposition of Bi at i = 1 mA/cm^2 and Q = 30 C/cm^2.

The results of SEM and EDX analysis allowed us to determine the average thickness of the obtained layer of nanofragments (nanowire) and the content of element (Bi) in the pore depth, which is given below as a weight percent of the total content of elements recorded at a given point of the membrane.

TABLE I. THE CONTENT OF BI IN NANOWIRE ARRAYS PORE

Element	Weight%	Atomic%
O K	20.60	60.77
Al K	13.98	24.46
Bi M	65.42	14.77
Totals	**100.00**	

The specific feature of the method used was that the content of elements was recorded in the volume 2 x 2 x 2 μm^3. The results corresponded to the average content of elements in the above amount. It is obvious that they contained several fragments of the Al_2O_3 matrix/metal system instead of one. On the basis of these data, we calculated the average rate of electrodeposition V_{av} (mm/h) and the degree of pore filling with metal.

At the next stage, we will study the thermoelectric properties of nanowire arrays in the temperature range 4.2 - 300 K as a function of wire diameter.

ACKNOWLEDGMENTS

This work was supported by the Moldovan youth grant no. 09.819.05.05F.

REFERENCES

[1] Ch. R. Martin, "Nanomaterials: A Membrane – Based Synthetic Approach", Science, vol. 266, pp. 1961, 23 December 1994.

[2] T. M. Whitney, J. S. Jiang, P. C. Searson, C. L. Chein, "Fabrication and Magnetic Properties of Arrays of Metallic Nanowires", Science, vol. 261, pp. 1316, 3 September 1993.

[3] J. P. Fleureal, G. I. Snyder, I. Patel, C. K. Huang, M. A. Ryan, R. Averback, C. Hill, G. Chen, Proc. 20th Internat. Conf. on Thermoelectrics, Beijing (China), pp. 24, 2001.

[4] M. S. Dresselhaus, Y. M. Lin, O. Rabin, A. Jorio, A. G. Souza Filho, M. A. Pimenta, R. Saito, Ge. G. Samsonidze, and G. Dresselhaus, Mater. Sci. Eng., C 23, pp. 129, 2003.

[5] L. D. Hicks and M. S. Dresselhaus, Phys. Rev. B 47, pp. 12727, 1993.

[6] Z. Zhang, X. Sun, M. S. Dresselhaus, and J. Y. Ying, Appl. Phys. Lett. 73, pp. 1589, 1998.

[7] J. Heremans and C. M. Thrush, Phys. Rev. B 59, pp. 12579, 1999.

[8] T. E. Huber, O. Anakoya, and M. Ervin, J. Appl. Phys. 92, pp. 1337, 2002.

[9] J. P. Fleureal, NASA Tech. Briefs, vol. 24, N 56 NPO-20472, Mai 2000.