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Metallic Nanowires on the Base of Porous Matrixes: Obtaining by Galvanic Replication, Structure and Some Properties

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In this work nanowires (Co, Ni and Fe) were obtained via template synthesis, using etched track polymer matrix. The peculiarity of electrodeposition of Co and Ni was investigated and discussed: When filling the pores of a small diameter (0.1 and 0.2 microns) the dependence of current on time passes through a minimum. It can be supposed that the difficulties, appearing while filling nanosized pores, are related to the peculiarities of diffusion in narrow channels. The electrolyte for Fe deposition into nanosized pores was selected, the necessity of agitation was demonstrated. The results of X-rays analysis demonstrate that obtained wires have polycrystalline structure, which slightly depends on the deposition voltage. Mossbauer spectroscopy was used for investigation of Fe samples. The obtained sextet corresponds to α-Fe with polycrystalline structure. Two types of Fe atoms were found. The presence of two types of oxides was also detected.

Keywords: Nanowires, Template synthesis, Electrodeposition, Track membranes, Mossbauer spectroscopy.

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1. ABOUT THE METHOD OF TEMPLATE SYNTHESIS

One of the ways of production of nanomaterials is so-called template (or matrix) synthesis. The main idea is to fill the pores of specially prepared matrix (template) with desired materials. Most popular materials for matrix are porous zeolites, porous alumina oxide and track membranes. The last one has some advantages – low cost, flexibility, the ability to vary many parameters in wide range. On the other hand the commercial track membranes are not the best material for synthesis – for this process we need the matrix with parallel pores orientation and rather low surface density. One of the most perspective applications of these structures is their use in magnetic-memory devices. Since the size (diameter) of individual wire is much smaller than the size of a magnetic domain, the possibility of increasing the information storage density appears. That is why formation of nanowires of magnetic materials is of great interest now.

2. OBTAINING OF NANOWIRES

Specially irradiated polymer films were used in our experiments for production of template matrixes (all irradiations were done in JINR, Dubna).

The PET-polymer films (thickness 10 mcm) were irradiated by swift heavy ions (Ar, Kr or Xe with the energy 1-2 MeV/nucl) and then etched in alkali solution in order to obtain parallel pores. The pores diameters in these matrixes were 0.1 , 0.2, 0.3, 0.5 and 0.55 mcm.

2.1 Copper nanowires

In our first experiments copper micro- and nanowires were obtained. Possibilities to use ensembles of parallel oriented wires as: 1) emitters for ions in mass-spectroscopy as it was demonstrated in [1, 2] and 2) optically-active surfaces for non-linear optic.

2.2 Cobalt nanowires

Our first results on obtaining of Co-nanowires were published in [3,4]. Here we present new data for Ni: PET-polymer films (thickness 10 mcm, with the parallel pores, diameter in the range 0,1-0,5 mcm) were used as templates for matrix synthesis. The SEM image of obtained samples is given in Fig.1.

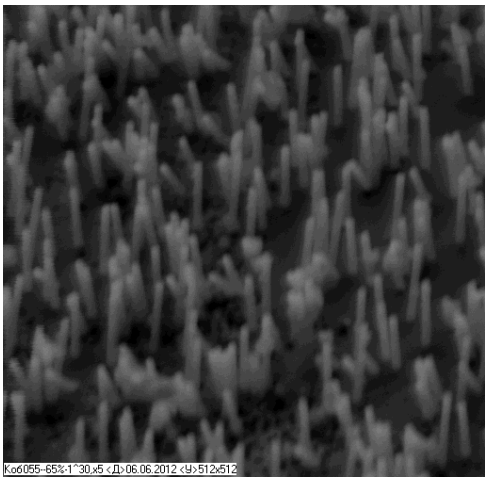

Fig. 1 – Cobalt wires with diameter 0,55 mcm and length 6.5 mcm. The size of the image is 30 × 30 mcm

2.3 Nickel nanowires

Deposition of Ni was successfully done in electrolyte $NiSO_4 \cdot 7H_2O$ – 200 g/l, H_3BO_3 – 30 g/l, $NiCl_2 \cdot 6H_2O$ – 20 g/l (pH 4.5, t 40–45 °C). The dependences of current on deposition time were measured and presented in Fig. 2.

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The SEM images of nanowires were obtained (see Fig.3): they demonstrated rather uniform filling of the pores and allows to calculate the growth speed.

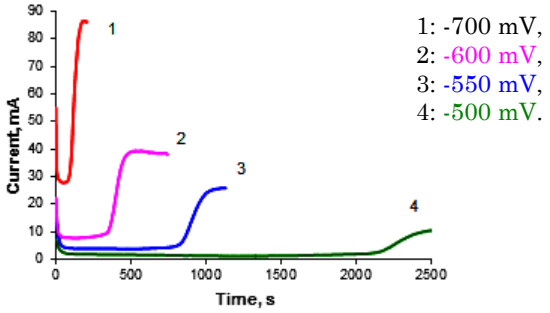

Fig. 2 – The curves for potentiostatic electrodeposition of nickel wires with diameter 0.5 mcm (for different potentials).

We found that deposition of Ni have the same features as deposition of Co: When filling the pores of a small diameter (0.1 and 0.2 microns) the dependence of current on time passes through a minimum. This minimum is most significant for smaller diameter pores and for higher overvoltage. Thus, in the pores of small diameter the effect of deceleration of the wires growth rate is observed in the process of electrofilling the pores. It can be supposed that the difficulties, appearing while filling nanosized pores, are related to the peculiarities of diffusion in narrow channels.

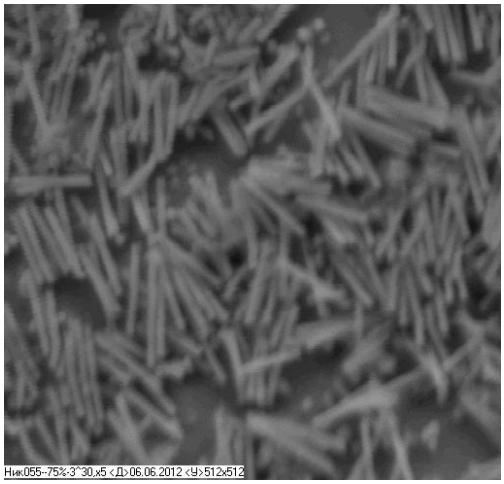

Fig. 3 – Nickel wires with diameter 0,55 mcm and length 7.5 mcm. The size of the image is 30 · 30 mcm.

2.4 Iron nanowires

For deposition of Fe into the pores we used the electrolyte: $FeSO_4 \cdot 7H_2O$ – 200 g/l, $AlCl_3 \cdot 6H_2O$ – 50 g/l, ascorbic acid – 2 g/l. (pH ~1,5, at room temperature). The additions of acid into the solution was used in order to prevent oxidation of Fe^{2+}. The SEM images of the obtained wires (see Fig.4) have demonstrated that the problem of nanowire growth is the release of hydrogen, the bubbles of which blocked some of the pores. Later the agitation of solution during the deposition process was used for removing these bubbles.

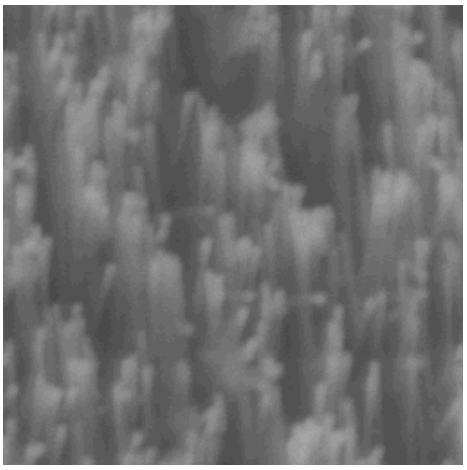

Fig. 4 – Iron wires with diameter 0,2 mcm. Image 15·15 mcm.

3. INVESIGATION OF THE PROPERTIES OF THE OBTAINED NANOWIRES

3.1 X-rays analysis

X-rays analysis was done for Co and Ni samples. The results demonstrate that obtained wires have polycrystalline structure, which slightly depends on the deposition voltage. Preferential orientations were not found. The presence of additional peaks for copper (contact layer), corresponding oxides and polymer matrix was also detected.

3.2 Mossbauer spectroscopy

We used Mossbauer spectroscopy for investigation of obtained Fe samples. As a source 57Co in Rh matrix was used. The obtained sextet corresponds to α-Fe with polycrystalline structure. Two types of Fe atoms were found. The presence of two types of oxides was also detected: 15% of all Fe atoms are in two oxidation states Fe^{2+} and Fe^{3+} – probably in oxides FeO and α-Fe_2O_3.

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