DIFFERENT TYPES OF NANOWIRES – SYNTHESIS, STRUCTURE, PROPERTIES AND MAGNETIC PROPERTIES

D. Zagorskiy[1*], *I. Doludenko*[1], *D. Khairetdinova*[1,2], *R. Khaibullin*[3], *D. Cherkasov*[4], *A. Gippius*[5,6], *S. Zhurenko*[5], *O. Zhigalina*[1], *S. Chigarev*[7], *E. Vilkov*[7], *L. Fomin*[8]

[1]FSRC "Crystallography and Photonics", Russian Academy of Sciences, Moscow, Russia
[2]NUST "MISIS", Moscow, Russia
[3]Zavoisky Physical-Technical Institute, Kazan Scientific Center of RAS, Kazan, Russia
[4]Moscow Institute of Physics and Technology, Dolgoprydny, Russia
[5]Moscow State University named by M.V. Lomonosov, Moscow, Russia
[6]P.N. Lebedev Physical Institute, Russian Academy of Sciences, Moscow, Russia
[7]Fryazino branch of IRE named by V.A. Kotelnikov of RAS, Fryazino, Russia
[8]Institute of Microelectronic technology and High-purity materials of RAS, Chernogolovka, Russia
[*]E-mail: dzagorskiy@gmail.com

Nanowires (NWs) are one-dimensional threads with a diameter of several tens of nanometers and a length of several microns. Such structures are of great interest for practical applications. For example, NWs made of 3d-metals have unique magnetic characteristics. For NWs made of alloys, it is possible to change the magnetic properties over a wide range by changing the concentration of metals. For layered NWs – consisting of layers of different composition alternating along the length – properties can be varied by changing the composition and thickness of layers. These objects could be used in electronics and spintronics – for example, as sensors.

One of the promising ways to obtain arrays (ensembles) of such NWs is the method of matrix synthesis [1]. In this case, the pores of the matrix (template) are filled with the required alloy or alternating layers of different metals. The main problem here is the regulation of NWs' parameters during synthesis. Such regulation is carried out by choosing a matrix with the required pore structure, by changing the electrolyte composition and deposition conditions. At the same time, in the case of multicomponent structures, the solution of this problem can be rather complicated. It is necessary to investigate the dependence of the synthesis conditions on the structure, and the correlation of the structure with the properties.

In this work, various types of layered NWs obtained by the method of matrix synthesis based on polymer track membranes are investigated. Matrix synthesis was carried out using track membranes with pores 100 nm in diameter and the surface density of 10^9 pores per sq. cm (produced by JINR, Dubna). Electrolytes with sulfate salts of the corresponding metals and various additives were used. During deposition, both "single-bath" and "two-bath" methods were used. In the first case, the growth was carried out in a two-component electrolyte, while the alternation of layers was obtained by changing the potential. In the second case the growth electrolyte was changed in order to alternate the growth of layers with different compositions.

<u>NWs consisting of layers of magnetic and non-magnetic metals</u> – Co/Cu, Ni/Cu have been obtained. The geometric parameters of the layers, their composition, and the nature of the interlayer boundary were estimated by the TEM method. Methods for controlling the thickness of layers, reducing their thickness, and obtaining flat interlayer boundaries ("interfaces") are described. These include: the use of dilution of the solution, the use of special deposition modes (the method of controlling the thickness not by the duration of the pulses, but by the passed charge), the transition to the three-electrode method (with the reference electrode). The state of the interfaces between the layers was estimated. It is known that the quality of interfaces (thickness, flat shape) determines the characteristics of interlayer transitions in spintronic applications. The X-ray diffraction analysis

made it possible to determine the phase composition of the samples. In the above mentioned cases the layers in NW consist of both pure metals and solid solutions of a ferromagnetic metal with Cu.

The investigations of the direction of the easy magnetization axis in layered NWs, started in [2], are continued. The magnetic properties of layered Co/Cu NPs with different ratios of the thickness of magnetic cobalt to the thickness of the nonmagnetic copper interlayer have been studied by magnetometry. It was shown that the magnitude of the magnetic response and the magnetic anisotropy of an array of such NWs are strongly affected not only by the aspect ratio of the magnetic layer thickness to the diameter of an individual NW, but also by the magnetic dipole interaction both between the magnetic layers in the NW and between the NWs in the array. In fact, by changing the thickness of the magnetic layer of cobalt and non-magnetic copper interlayer, it is possible to change the direction of the easy magnetization axis in the NWs array.

Application of resonance methods. Previously (in [3]), Co-59 NMR was used to study layered Co/Cu NWs. A significant number of cobalt atoms with one, two or more copper atoms in the coordination of the probe nucleus was revealed. Conclusions were made about the state of the Co/Cu interfaces. In this work, we measured the NMR spectra on Fe-57 nuclei in a zero magnetic field at 4.2 K for single-component, homogeneous NWs of various diameters from 30 to 200 nm, containing only iron. The resulting spectra demonstrate a significant (up to 1 order) broadening of the line, compared with the NMR spectrum of bulk alpha iron. The possibilities of applying this approach to the analysis of iron-containing layered NWs are discussed.

Generation of electromagnetic radiation. In this work, NW arrays of another type were synthesized – consisting of alternating layers of two different magnetic metals or alloys (for example, Ni/Co or FeNi/FeCo, respectively). It was shown that in such samples, when a current is passed through them, the generation of electromagnetic radiation of the terahertz frequency is possible [4]. In this work, we compare two methods for the synthesis of such NWs and show the advantages of the "double-bath" method. It was shown that NWs with layers from alloys usually generate more intensive signal than NWs consisting of "pure-metal" layers. Various methods have been studied to "output" a signal from a sample. It is known that template matrix with NWs is usually coated on both sides with a copper film. This film absorbs the emerging radiation. In the work, a non-continuous current-carrying coating was made – contacts were deposited on the surface in the form of thin conductive strips. It is shown that the intensity of the emitted signal in this case increases many times. The angular dependence of radiation propagation has been studied. The features of the signal increase in time proved it`s "non-thermal" character. The prospects for using devices with arrays of layered NWs as generators and/or detectors of the radiation of THz frequency are discussed.

This work was supported by the Russian Science Foundation N 22-22-00983 and was done (in part) within the State Tasks of Federal Scientific Research Center (FSRC) "Cryst. and Phot." RAS (Moscow), Zavoisky Physical-Technical Institute (Kazan), Lebedev Physical Institute (Moscow), IRE (Fryazino).

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