MINISTRY OF EDUCATION AND SCIENCE OF UKRAINE

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SUMMARY

of the diploma paper for the bachelor's degree

PHYSICAL PROPERTIES OF Cu(Co) SOLID SOLUTION NANOWIRES

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CONTENT

Magnetic properties are widely used in sensors and controllers of magnetic fields, in information storage devices, in the medicine, etc. For such a purpose, a combination of ferromagnetic and non-magnetic material is usually used. Nanowires of Cu(Co) solid solution (s.s.) is distinguished among others because of the fact that these materials have unlimited solubility according to its state diagrams. Due to the use of various methods, it is possible to obtain both layered structures and solid solutions from these elements.

The purpose of this work is to review nanowires based on Cu(Co) (s.s.), its crystal structure and magnetic properties. Another goal is to synthesize nanowires and study its domain structure and magnetic properties.

Actuality: Since the development of electronics as a separate branch of science and technology, a huge step forward has already been made. An example of this is that over the past 50 years, the technological process has decreased by 3 orders of magnitude. Therefore, the years of widespread application of the simplest principles and approaches are long gone. At this stage of development, there is a need for fundamentally and qualitatively new principles, that can be partially solved with the help of nanowires - nanoscale structures having the shape of an elongated, thin thread, usually with a diameter of tens of nanometers and a very large length compared to diameter (usually more than 3 orders of magnitude or 1000 times). Otherwise, it is a 1-D nanoobject, only one size of which is much larger than nanometers. From the geometric parameters of such structures, it becomes obvious that the significant contribution to its physical properties is made by quantum mechanical effects. It should be noted, that despite the fact, that the first nanowires were obtained at the end of last century, wortwhile researches have begun to appear in the mid-2010s.

From the above follows the obvious relevance of this work. The synthesis of nanowires, a comprehensive study of its properties, conducting various experiments on them – major tasks of electronics and applied physics at the present stage. That is why it is clear that my work has scientific and practical significance.

The object of the study: Cu(Co) (s.s.) nanowires.

The subject of the study: magnetic properties of Cu(Co) (s.s.)-based NWs.

The objectives of the research:

- to describe the widely-used synthesis processes of the nanowire arrays;
- to show typical results of nanowire's research;
- to obtain samples using electron-beam litography and electrochemical deposition;
- to research the obtained samples for domain structure and magnetic properties.

Methods: review of the literature and the results of actual publications, synthesis of nanowire arrays, description of the obtained samples' properties.

The structure and scope of diploma for the bachelor's degree: the paper consists of introduction, three chapters, conclusion and references, which contains 31 names. The total volume of diploma paper for the bachelor's degree is 36 pages, including 28 Figures.

The first chapter describes general information about nanowires and its synthesis, crystal structure and magnetic properties. According to a common classification, real samples of nanowires can be synthesized in two ways: top-down and bottom-up ones. A «vapor-liquid-solid» and an anodic alumina template or electron-beam lithography with electrodeposition are used for metallic nanowires. As for crystal structure, it is presented that Cu(Co) (s.s.)-based nanowires forms face-centered cubic lattice.

It is important to note that the properties of a single nanowire differ from the properties of an array of them. This is explained by dipolar interaction, that is a problem for all magnetic materials. Such kind of an interaction is a very important component, but also difficult to take into account due to its long range. From the hysteresis loops, the coercive force and remanent magnetization have greater absolute values than in the samples of a perpendicular field, therefore, when the field is parallel to the length, the sample is magnetically harder. The Co/Cu nanowires have the greatest value of magnetoresistance at a thickness of the Co layer of 50 nm and a thickness of the Cu layer of 5 nm at 200 repeating bilayers (the diameter of the nanowire - about 50 nm, height - 11 μm).

The second chapter shows the method and technique of sample's obtaining. The synthesis of nanowires was performed by electron-beam lithography and electrochemical deposition. The technique of electrochemical deposition on the one hand is simple for technical use, it allows to achieve a good automation process, high repeatability, it doesn't demand expensive controlling equipment; and consumables include only the components of the electrolyte. On the other hand, the deposition process is uneven and difficult to predict. During electrodeposition, it was shown that the final concentration of the elements depends on the applied potential.

The third chapter presents domain structure and magnetic properties of obtained in the previous stages of nanowires, illustrative Figures and explanation of the reasons for the given results. Firstly, domain structure of synthesized arrays is showed. For freshly condensed samples, magnetic domains have dimension along the entire width of the sample. As a result of annealing, the geometric parameters of the magnetic domains are halved and its shape is changed. That fact can be explained by formation of vortex domains with different chirality, that is proven by recent publications. Secondly, the magnitude of the external magnetic field that can remagnetize the annealed sample decreases significantly and is H = 5 kOe when for a direction of the field that is parallel to the length of the

nanowires. In addition, this value is less dependent on temperature for freshly condensed sample. For a perpendicular filed, the value increases from H = 200 Oe to H = 650 Oe for annealed sample.

CONCLUSION

It is stated that nanowires are such nanostructures that have a high potential for electronics application, as they possess special physical properties. The following conclusions were obtained:

1. The synthesis of nanowires was performed according to the sequence: a mask formation with the desired shape, deposition of the material (by electrochemical method), removal of the forming mask, and research/use of obtained samples.

2. From the recent publications, the value of the giant magnetoresistance in the system of nanowires based on Cu and Co is in the range of 0.05–5% (at T = 300 K) and up to 10% (at T = 77 K), but in multilayers $[Co\ (50\ nm)/Cu\ (5\ nm)]_{x200}$ reaches 13%.

3. During the project, nanowires were experimentally synthesized by the method of electron beam lithography followed by electrochemical deposition. The width of samples was 200 nm and a total length was 1 μm. The calibration dependence of the working electrode potential value on the concentration of Co in the sample in at. % was obtained. At U = -1 – -0.6 V, Cu is deposited mostly, but at U = -1.2 – -1.6 V, both Co and Cu are deposited

4. The study of magnetic properties at parallel and perpendicular geometries of measurement was carried out. In the first case, the hysteresis loops have a two-stage of magnetization: at fields of 100 E and 5 kE, in the second one - a sharp switch at 50 E.

5. Due to the annealing of the samples for an hour at 800 K, the size of the domains decreases, and the reversal field is 800 E and 600 E for both measurement geometries respectively.