INVESTIGATION OF THE EFFECT OF IRRADIATION ON THE CHANGE IN THE PHASE COMPOSITION OF COBALT-ZINC NANOSTRUCTURES

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The paper presents the results of a study of the effect of irradiation with heavy xenon ions on the structural properties of CoZnO-based nanostructures. The dependences of the change in the phase composition as a result of irradiation are obtained; critical irradiation doses are established at which nanostructures undergo partial destruction.

Keywords: nanostructures; ionizing radiation; amorphization; defects.

Introduction

An important factor for the practical application of nanostructures is the study of the effect of ionizing radiation on the structural and conductive properties of nanomaterials, as well as the assessment of the possibility of using ionizing radiation for directional modification of the physicochemical and structural properties of nanostructures. When nanostructured materials are irradiated with beams of heavy ions, additional defects appear in the crystal structure, which can change the properties of nanomaterials both in a negative direction (formation of amorphous regions, partial destruction of the structure) and in a positive direction (annealing of defects arising during the synthesis, improvement of conductive properties) [1-3]. Control over the processes of directed modification of structural properties is a promising task for research [4-6].

Experimental part

Synthesis of nanostructures in the pores of template matrices was carried out by the method of electrochemical deposition in a potentiostatic mode with a potential difference of 2.0 V at an electrolyte temperature of 25°C. The composition of the electrolyte solution: $CoSO_4 \cdot 7H_2O$ (167 g/l), $ZnSO_4 \cdot 7H_2O$ (58 g/l), H3BO3 (45 g/l), ascorbic acid (1.5 g/l). The irradiation of CoZnO samples of nanotubes in polymer matrices was carried out at the DC-60 heavy ion accelerator of the Astana branch of the Institute of Nuclear Physics with Xe^{22+} ions with a fluence of 1×10^{10} to 5×10^{11} ion/cm^2. Fluence change was carried out by changing the exposure time. Irradiation with heavy ions was carried out at a pressure of 10^{-6} mbar along the length of the nanotubes and perpendicular to the surface of the polymer membranes with nanotubes. To determine the mean free path of accelerated ions in metallic nanostructures, a theoretical calculation of the energy loss on electrons and nuclei of the studied nanostructures was carried out using the «SRIM 2013 Pro» program. Accelerated Xe^{22+} ions with an energy of 1.75 MeV/nucleon were considered as an incident beam. The maximum mean free path of Xe^{22+} ions in CoZnO nanotubes was 12.3 μm, which is comparable with the length of nanotubes (12 μm).

Results and discussion

When nanostructures are irradiated with heavy ions with energies above 1 MeV/nucleus, there is an enormous release of energy into the electronic subsystem of nanostructures. In this case, a large amount of energy can bring to an increase in the degree of electronic excitations, which in turn, give rise to structural defects: local melting, inelastic sputtering of materials, amorphization, and partial destruction or embrittlement. To study the effect of irradiation on the structural properties of CoZnO nanotubes, the method of x-ray structural analysis was applied. Figure 1 shows the X-ray diffraction patterns of the studied samples before and after irradiation.

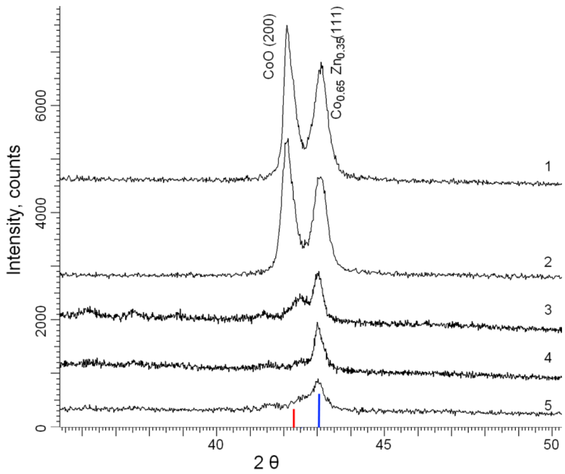

Fig. 1. X-ray diffractograms of the studied samples of CoZnO nanotubes exposed to Xe^{22+} ions; 1) initial; 2) 1×10^{10} ion/cm^2; 3) 1×10^{11} ions/cm^2; 4) 5×10^{11} ions/cm^2

The type of diffractograms of the samples under study is characteristic of X-ray diffraction on polycrystalline nanoscale structures (broad low-intensity peaks). An analysis of the diffractograms of the nanotubes under study made it possible to establish that the samples under study have a polycrystalline structure. According to the data obtained, the initial nanotubes are two-component systems consisting of two oxide phases of CoO of a cubic syngony and a phase of a solid solution of substitution of $Co_{0.65}Zn_{0.35}$ of a cubic syngony. Figure 2 presents the data on changes in the phase composition of the nanostructures under study before and after irradiation.

According to the data obtained, an increase in the radiation dose leads to an increase in the lattice parameter, which indicates an increase in distortions and deformations of the crystal structure. By fitting the lines on X-ray diffraction patterns with the required number of symmetric pseudo-Voigt functions, the width of the recorded FWHM lines was determined, which allowed us to characterize the perfection of the crystal structure and estimate the crystallinity degree (Figure 3). As a result of processing, it was found that the crystallinity degree of the initial sample is 79.1%.

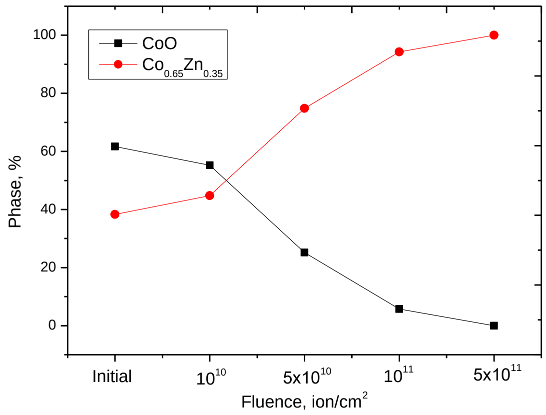

Fig. 2. Dynamics of changes in the phase composition of nanostructures before and after irradiation

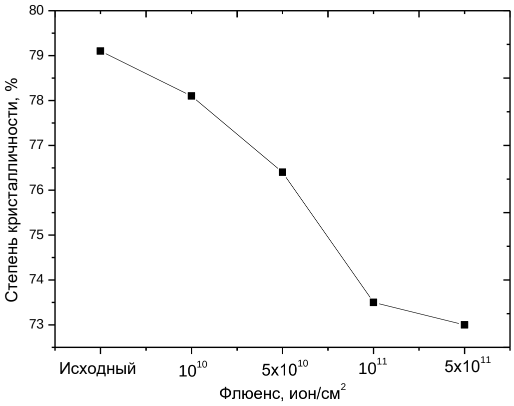

Fig. 3. Data of changes in the crystallinity degree of nanostructures as a result of irradiation

According to the data obtained for samples irradiated with Xe^{22+} ions, an increase in the crystallinity degree is observed with increasing irradiation dose, which confirms the results of observations of amorphous inclusions and partial destruction of nanotubes under irradiation.

Conclusions

According to X-ray phase analysis, the original nanotubes are two-component systems consisting of two oxide phases of CoO of a cubic system and a phase of solid solution of substitution for $Co_{0.65}Zn_{0.35}$ of cubic system. In this case, irradiation leads to a change in the phase composition by reducing the contribution of the oxide phase CoO, as well as reducing the crystallinity degree. According to the data obtained, an increase in the radiation dose leads to an increase in the lattice parameter, which indicates an increase in distortions and deformations of the crystal structure.

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