Electro-optical properties of the metal oxide-carbon thin film system of CdO-LCC

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Abstract. This article presents the results of a study electrical and optical properties of the thin film system of CdO-LCC. Cadmium oxide films were obtained by method of thermal oxidation. CdO-LCC thin film system was produced by applying on a CdO film a linear chain carbon film in thickness of 100 nm using the ion-plasma method, after which the obtained system was annealed. The studies showed that the obtained CdO-LCC films are quite transparent in the visible region; it has polycrystalline structure, thickness around 300 nm, the band gap to 2.3 eV. The obtained thin film system has photosensitive properties.

1. Introduction
One of the main features of modern high technology is the desire to create and use a new thin film materials, have the ability to actively respond to changing conditions or external influence. Currently the attention of many researchers aimed at studying various photoconductive compounds. This is due to the possibility of the practical application of these compounds as photoresistors, various sensors, solar cells. Photoconduction - increase in conductivity when exposed to light. As is known, photoconductive properties often exhibit cadmium compounds, tellurium, selenium. Binary compounds of these elements is quite well understood. To one of such materials include thin film metal oxide-carbon system comprising carbon various allotropic modifications. However, at present insufficiently known issue is the interaction of carbon in sp-1 state (linear-chain carbon, LCC) with oxides of metals not forming a chemical compound with carbon. In this respect metal oxides thin films which have unique properties such us high transparency in the visible regions and high conductivity, are of outstanding interest. Transparent conductive oxides are used as electrodes in the liquid crystal display, photo diodes, solar cells and other devices. One of them is the cadmium oxide (CdO). CdO is an AlIBVI semiconductor with the band gap of 2.1–3.3 eV, generally with n-type conductivity. CdO thin films have unique properties such us high transparency in the visible regions and high conductivity. It is used in photodiodes, solar batteries, phototransistors and gas sensors [1-3].

Linear chain carbon films create a two-dimensional-ordered structure consisting of carbon chains banded by sp1-hybridization. Linear chain carbon is synthesized using the ion-plasma method in the form of a film. Carbon chains are oriented vertical to the substrate surface and are organized in a close-packed hexagonal lattice. The distance between carbon chains is about 5 Angstroms. The films have one-dimensional conductivity along carbon chains and, according to our research, enhance electrooptical properties of many alloys and elements.
This article presents the results of a study of the influence of films linear-chain carbon (LCC) on the properties of the thin film of CdO.

2. Methodology

Linear chain carbon is synthesized using the ion-plasma method in the form of a film, the model of which is presented in Figure 1.

Cadmium oxide films were obtained by method of thermal oxidation which does not require any special conditions and much time to product an oxide film. In order to select optimum conditions for CdO thin film synthesis Cd films were applied on a silicon or glass substrate by evaporation. Then the films were annealed in air in a furnace at different temperatures (from 250 to 400 °C) and for different time intervals (20-40 min). CdO-LCC thin film system was produced by applying on a CdO film a linear chain carbon film in thickness of 100-200 nm using the ion-plasma method, after which the obtained system was annealed [4].

For investigation of CdO-LCC thin films structural properties the Raman spectroscopy method was used. The surface's topology and the thickness of the film was investigated by scanning probe microscopy and scanning electron microscopy. Optical properties were investigated by spectrophotometer Lambda 25 in the spectral range 200 - 1100 nm. Electrical properties were investigated using a digital multimeter Source Meter 2400.

3. Results and discussion

Figure 2 illustrates the Raman spectra of CdO-LCC system. From an analysis of the graphs, it can be concluded that the CdO-LCC system going Raman shift wavenumber upwards compared to pure oxide [1]. The presence of G- and D- bands on graph indicates obtaining a composite material in which cadmium oxide and carbon are present.

Topology of surfaces were obtained with a scanning probe microscope SolverNext in an atomic force mode. After annealing the film of cadmium surface structure changes, clusters increase in size, the diameter of the cluster is 150-200 nm. CdO film becomes polycrystalline structure. Film thickness was determined by using SPM steps in an atomic force mode, totaled about 200 nm. Figure 3 shows scanning electron micrographs (SEM) of the film CdO-LCC. Implementation in CdO linear-chain carbon also leads to change and streamline the structure of the film surface. The thickness of the resulting CdO-LCC system is approximately 300 nm.

The optical studies (Figure 4) showed that the obtained CdO-LCC films are quite transparent in the visible region, which indicates the perspectives of the application of them as transparent conducting coatings. The obtained cadmium oxide film has photosensitive properties demonstrated by films applied on both silicon and glass substrates. The linear chain carbon film increases photoresponse of the system under research. Figure 5 shows photoresponse of system Si-CdO-LCC.
The CdO film optical band gap was estimated using the method described in [5] and amounted to 2.5 eV (Figure 6). The optical band gap of the CdO-LCC system amounted to 2.3 eV (Figure 7). In other words, implantation of linear chain carbon into the cadmium oxide film decreases its band gap.
The obtained systems with high transparency and photosensitive properties may be used as transparent electrode in photo cells, phototransistors and optical heaters.

Acknowledgments
The research has been carried out as a part of the scholarship of the President of the Russian Federation for young scientists and postgraduate students СП-2698.2015.1

References
[1] Islam M M, Islam M R, Podder J 2008 Journal of Bangladesh Academy of Sciences 32 1 pp 97-105
[2] Bagheri A, Khatibani, Hallaj Z A, Rozati S M 2015 The European Physical Journal Plus 130 254
[3] Mahaboob Beevi M 2010 International Journal of Chemical Engineering and Applications 1(2) pp 151-154
[4] Kokshina A V et al. 2015 Alternative Energy and Ecology 19(183) pp 112-117
[5] Vasilevsky A M et al. 2011 Optical and physical methods of research: guidelines for laboratory work