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# SURFACE PROPERTIES AND COMPOSITION ANALYSIS OF NANO-SIZED THIN FILMS OF CDSE: BY SEM ANALYSIS

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Thin films of cadmium selenide with a thickness *h* = 200-500 nm were obtained and their surface properties were studied. The studies were carried out using a Scanning Electron Microscope. It was found that with increasing thickness of thin layers, the surface structure becomes smoother. A compositional analysis of the surface of thin layers was also carried out. Elemental analysis was carried out in layers of various thicknesses, the percentage content of chemical elements and the energy spectrum of chemical elements were determined. It has been established that thin CdSe films obtained by chemical deposition are quite pure. The surface of thin layers with a thickness h > 400 nm turned out to be quite smooth, which is an indicator of the formation of a phase in these layers corresponding to the CdSe compound.
**Keywords:** *CdSe; Thin films; Compositional analysis; Surface structure; SEM analysis*
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## INTRODUCTION

Chalcogenide semiconductors occupy a special place among non-oxide functional materials. In these compounds, semiconductor, magnetoelectric, ferromagnetic and other physical properties are observed. Therefore, these materials have wide application possibilities. The study of the crystalline and surface structure of chalcogenide semiconductors plays an important role in the formation of their physical properties. Therefore, extensive research is being carried out in this direction [1-5].

It is known that studying the surface structure of materials allows one to obtain extensive information about their size effects. Since micro-composition analysis can be carried out using SEM, this method is widely used. It has been established that the percentage of elements present on the surface can be determined by analyzing the structure and composition of the surface [6-8]. In the course of studying the surface structure and size effect, it was found that changes in the chemical composition affect the size of crystallites. Crystallites that form polycrystals are formed as a result of the connection of elementary lattices. Therefore, when the atoms in the crystal lattice change, the size of the crystallites also changes [9].

The CdSe compound is one of the most studied compounds among chalcogenide semiconductors. The main reason for its interest is that it has different physical properties. In the course of structural studies, it was established that the crystal structure of this compound has high symmetry. The unit lattice parameters with hexagonal systems and space group $P6_3mc$ are: $a$ = 4.2985 Å, $c$ = 7.0152 Å, $V$ = 112.255 Å$^3$ [10]. This compound has semiconductor properties, the band gap $Eg$ = 1.74 eV [11]. Although many of the physicochemical properties of the CdSe compound have been studied, the properties of its thin films have not been sufficiently studied. Recently, thin layers of various substances have been studied [12,13]. It has been established that the properties of materials are maintained even in the case of thin layers. The production of thin layers of the CdSe compound and the study of its physical properties further expand the possibilities of its application. In this work, thin CdSe films were obtained on a glass substrate and their microstructure was studied in a Scanning Electron Microscope (SEM).

## EXPERIMENTAL PART

During the research, thin CdSe films with thicknesses of 200, 300, 400 and 500 nm were obtained and the structure of their surface was studied. Thin films of CdSe were obtained by chemical deposition. The solution used to obtain thin layers consists of a composition prepared in the following order: 0.5 M cadmium chloride ($CdCl_2{\times}2.5H_2O$), 13.4 M (25%) sodium hydroxide ($NH_3OH$), 7.4 M triethanolamine ($C_6H_{15}NO_3$), 0.2 M sodium selenosulfate ($Na_2SSeO_3$). The chemical precipitation process was carried out in a laboratory beaker with a capacity of 60 ml at room temperature and normal conditions using a specially developed technology. The method for obtaining thin layers and the phase formation processes is described in detail in [14].

The surface structure of thin films of cadmium selenide with a thickness *h* = 200-500 nm was studied in a Scanning Electron Microscope (SEM, ZEISS, ΣIGMA VP). The results obtained were analyzed and the process of phase formation in the layers, composition analysis and size effects were determined.

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## RESULTS AND DISCUSSIONS

The morphology of CdSe thin films obtained by chemical deposition was studied using a scanning electron microscope. In the course of research using an SEM microscope, not only an analysis of the surface structure of the layers was carried out, but also an analysis of the chemical composition, and the percentage of elements was determined. Surface structures obtained under normal conditions and at room temperature are presented in Figure 1.

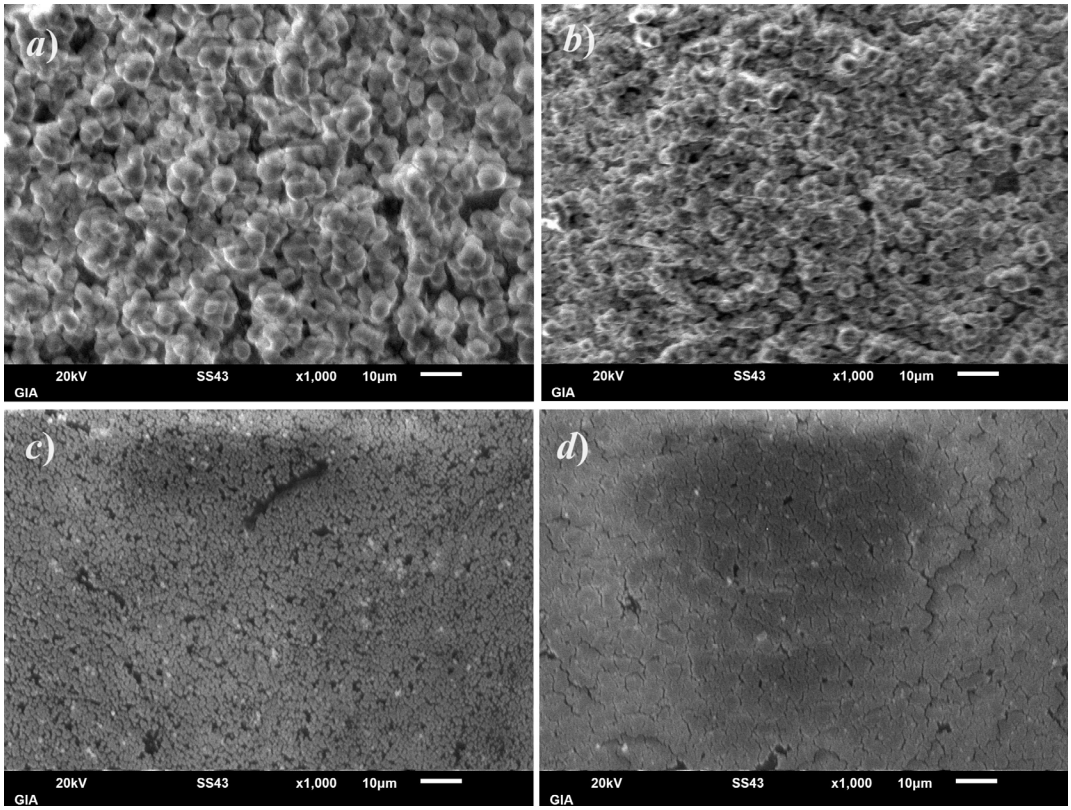


**Figure 1.** Surface structure of thin CdSe films of various thicknesses: *a*) $h$ = 200 nm, *b*) $h$ = 300 nm, *c*) $h$ = 400 nm and *d*) $h$ = 500 nm.

In Fig. 1 shows the morphology obtained at the 10 μm scale of thin films with thicknesses of 200 nm (*a*), 300 nm (*b*), 400 nm (*c*), and 500 nm (*d*). From the structure of the surface of the sample obtained with a thickness of $h$ = 200 nm, it is clear that in these thin layers the structure is not completely formed. An arrangement of crystallites with $d \sim 4$–5 μm was observed on the surface (Fig. 1*a*). From the surface structure of the resulting sample with a thickness of $h$ = 300 nm, it is clear that in these thin layers the crystallites begin to unite and form a surface structure. Although the structure is not completely formed, the crystallites are more densely packed (Fig. 1*b*). With increasing thickness in thin CdSe films, the process of phase formation becomes more complicated. From the surface structure of the sample obtained with a thickness of $h$ = 400 nm, it is clear that crystallites form a surface structure. Certain defects are observed on the surface, which are small-sized effects that arise during the synthesis of samples (Fig. 1*c*). The process of phase formation was also observed in thin CdSe films as the thickness increased. From the surface structure of the resulting sample with a thickness of $h$ = 500 nm, it is clear that the crystallites form a more closely connected surface structure. Compared to previous layers, the concentration of defects formed on the surface and the size of the defects are also smaller (Fig. 1*d*). As can be seen, during the formation of surface structures of thin layers, the phase formation process continues as the thickness increases.

To perform elemental analysis of CdSe thin films, a chemical elemental spectrum was also obtained. It has been established that elemental analysis of thin layers also identifies elements with a glass substrate. Because some high energy electrons can penetrate into the substrate. Therefore, elemental analysis was carried out on a thin CdSe layer with a thickness of $h$ = 500 nm. The resulting spectrum of chemical elements is shown in Fig. 2. As can be seen from the spectrum, the elements Cd and Se were predominantly found in the thin layer. However, small amounts of the elements Si, S and Ca were also detected, which are also impurities present in the substrate or included in the sample when the layers were produced by chemical deposition.

To determine the amount of chemical elements in thin CdSe films, the percentage of elements in a thin film with a thickness of $h$ = 500 nm is given in Table 1.

From the spectrum shown in Fig. 2 and the values given in Table 1, it is clear that the samples were obtained of sufficiently high purity. When studying the surface structure of thin CdSe layers using scanning electron microscopy, it was found that in these layers obtained by chemical deposition, the properties of the original material are retained. The process of phase formation in thin layers occurred after $h$ = 400 nm.

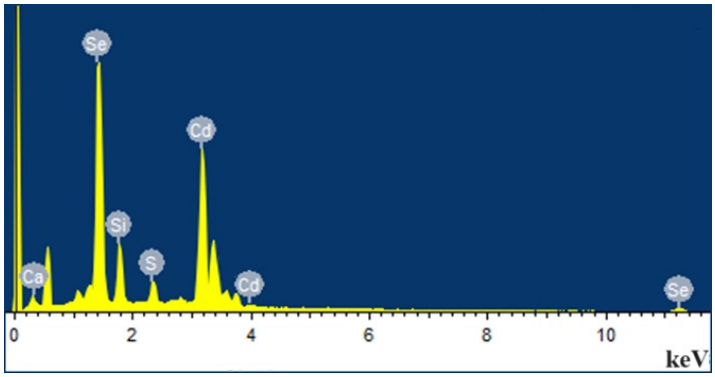


**Figure 2.** Energy spectrum of chemical elements of a thin CdSe film with a thickness of $h$ = 500 nm

**Table 1.** Percentage content of chemical elements in a thin CdSe layer with a thickness of $h$ = 500 nm

| Chemical element | Mass (%) | Atom (%) |
|---|---|---|
| Si | 7.77 | 20.96 |
| S | 2.22 | 5.24 |
| Ca | 1.44 | 2.71 |
| Se | 40.02 | 38.38 |
| Cd | 48.55 | 32.71 |
| Sum | 100 | 100 |

## CONCLUSIONS

SEM studies of thin CdSe films obtained by chemical deposition were carried out. During the research, both studies of the formation of the surface structure and analysis of the microcomposition were carried out. As a result of analyzing the spectrum of chemical elements obtained for thin layers, it was found that thin layers obtained on a glass substrate have a fairly high purity. The elements Cd and Se account for 88.57% of the sample mass. It is shown that the remaining elements found in the composition consist of small amounts of impurities that entered the system when purchasing the glass base and sheets. It has been established that the process of phase formation in these layers begins after $h \sim 400$ nm. Starting from these sizes, CdSe crystallites on a glass substrate combine to form a surface.

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**ВЛАСТИВОСТІ ПОВЕРХНІ ТА АНАЛІЗ СКЛАДУ НАНОРОЗМІРНИХ ТОНКІХ ПЛІВОК CDSE: SEM АНАЛІЗ**

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Отримано тонкі плівки селеніду кадмію товщиною h = 200-500 нм і досліджено властивості їх поверхні. Дослідження проводили за допомогою скануючого електронного мікроскопа. Встановлено, що зі збільшенням товщини тонких шарів структура поверхні стає більш гладкою. Також проведено аналіз складу поверхні тонких шарів. Проводено елементний аналіз шарів різної товщини, визначено процентний вміст хімічних елементів та енергетичний спектр хімічних елементів. Встановлено, що тонкі плівки CdSe, отримані хімічним осадженням, є досить чистими. Поверхня тонких шарів товщиною h > 400 нм виявилася досить гладкою, що є показником утворення в цих шарах фази, що відповідає сполуці CdSe.

**Ключові слова:** *CdSe; тонкі плівки; композиційний аналіз; структура поверхні; SEM аналіз*