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STUDY OF PHOTOCONDUCTIVITY OF THIN FILMS OF CADMIUM SELENIDE OBTAINED BY CHEMICAL DEPOSITION

L.N. Ibrahimova[a], N.M. Abdullayev[b], N.A. Gardashbeyova[a], A.S. Alekperov[c,d], S.R. Azimova[b], Y.I. Aliyev[c,d]*
[a] Nakhchivan State University, Nakhchivan, AZ-7012, Azerbaijan
[b]Institute of Physics, Ministry of Science and Education of Azerbaijan, Baku, AZ-1143, Azerbaijan
[c]Azerbaijan State Pedagogical University, Baku, AZ-1000, Azerbaijan
[d]Western Caspian University, Baku, AZ-1001, Azerbaijan
**Corresponding Author e-mail: yusifafshar@gmail.com*

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In this work, the photoconductivity (PC) spectrum of thin CdSe films was studied. In the course of studies on glass substrates, thin films of cadmium and selenium with a thickness of $h = 200$ nm and $h = 400$ nm were selected. The thickness of the samples obtained by chemical deposition was determined by the gravimetric method. Since CdSe crystal is a light-sensitive semiconductor material, the photoconductivity of thin films has been studied. The spectra obtained during studies carried out at a wavelength $\lambda = 600$-1100 nm were analyzed. It has been established that the spectrum is chaotic, since in the $h = 200$ nm layers the phase is not completely formed. In the layers $h = 400$ nm, a maximum centered at the wavelength $\lambda = 710$ nm was recorded.

Keywords: *Chemical deposition; CdSe; Thin film; Photoelectricity spectrum; Band gap*
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INTRODUCTION

Chalcogenide semiconductors occupy a special place among functional materials. Their interesting electrical and optical properties have been widely studied. It is established that changing the atoms in this crystal structure causes a change in the electronic configuration. Therefore, both the crystal structure and the electronic structure of chalcogenides are studied theoretically and experimentally [1-5]. The study of crystal structure, phase transitions and electronic processes determines the possibilities of using these materials. It is very important to study these processes in binary semiconductors, obtain new systems with cation-cation and anion-anion substitutions in these compositions, and predict and control in advance the processes occurring in these systems [6-9].

Cadmium selenide is one of the most studied chalcogenide semiconductors. This compound crystallizes in various modifications. It has been established that CdSe is an n-type semiconductor substance; in the sphalerite phase, this compound has a cubic crystal structure with space group F43m and $E_g = 1.74$ eV [10]. In the wurchite phase, it has a hexagonal crystal structure with space group P63mc and $E_g = 1.80$ eV [11]. Therefore, this material is used when purchasing various converters and solar panels in modern electronics.

Recently, electronic processes in thin layers of semiconductor materials have been studied. It has been established that materials retain their structural properties when producing thin layers [12,13]. The discovery of functional properties at small sizes makes it possible to obtain smaller converters based on them, which leads to the miniaturization of instruments and devices. Therefore, both the structural properties and various physical properties of thin layers of CdSe compounds are studied using modern research methods [14-17]. The processes of phase formation in thin layers of this compound were studied in the course of structural studies carried out by X-ray diffraction. It has been established that with increasing thickness, the process of phase formation begins in thin layers of cadmium selenide, and the phase corresponding to the CdSe compound is completely formed in the resulting layers with a thickness of $h = 400$ nm [14]. Although both the structural properties and a number of optical properties of these thin films have been studied, the photoelectric properties have not been studied. Interesting optical properties have also been discovered for thin CdS films with similar chemical shape and physical properties [17, 18]. Thus, CdSe thin films are expected to exhibit interesting photovoltaic properties with potential for practical applications.

It is known that the process of phase formation in thin CdSe films occurs at $h \geq 400$ nm. Therefore, to study the photoelectric properties, one sample from each phase was selected. The photoelectric properties of thin films with a thickness of $h = 200$ nm and $h = 400$ nm, obtained by chemical deposition on glass substrates, have been studied. In the course of research, the influence of phase formation processes in thin CdSe films on photoelectric properties was established.

EXPERIMENTAL PART

During the research, thin CdSe films obtained by chemical deposition were studied. The starting materials are designed to produce thin layers with a thickness of $h < 400$ nm and $h \geq 400$ nm. The solution used for chemical

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deposition of the CdSe thin film was prepared by taking equal amounts of each of the components (13 ml volume): 0.5 M cadmium chloride ($CdCl_2 \times 2.5H_2O$), 13.4 M (25%) sodium hydroxide (NH_3OH), 7.4 M triethanolamine ($C_6H_{15}NO_3$) and 0.2 M sodium selenosulfate (Na_2SSeO_3). The chemical precipitation process was carried out in a 60 ml beaker at room temperature. The technology for producing thin layers was carried out according to work [14]. Thin films of CdSe were obtained on glass substrates. The thickness of the resulting layers was determined by the gravimetric method. It was found that the thickness of the resulting thin CdSe films was $h = 200$ nm and $h = 400$ nm.

Thin CdSe films were examined by X-ray diffraction to determine structure formation. The studies were carried out on a D8 Advance diffractometer (Bruker, Germany) with CuKα radiation, 40 kV, 40 mA (λ = 1.5406 Å). The resulting spectra were analyzed in the Origin program and the Miller indices corresponding to the diffraction maxima obtained in the X-ray diffraction spectra were determined.

The photoconductivity spectrum of thin CdSe films obtained by chemical deposition was studied in an optical device based on an MDR-2 monochromator. The studies were carried out at room temperature, in the wavelength range λ = 600–1100 nm. A PZh-27 lamp with a vertical wire was used as a light source, and the photosignal generated when the thin layer was exposed to light was amplified by an E6-13 teraohmmeter and entered into a computer system. Silver paste was used to create thin layers of ohmic contacts. Based on the spectrum obtained during the research, the photoconductivity of thin CdSe layers with thicknesses $h = 200$ nm and $h = 400$ nm was recorded, and the band gap for CdSe was determined.

RESULTS AND DISCUSSIONS

A structural-phase analysis of thin CdSe films with a thickness of $h = 200$ nm and $h = 400$ nm, obtained by chemical deposition, was carried out. The spectra obtained by X-ray diffraction in the range of diffraction angles $5° \leq 2\theta \leq 80°$ are shown in Fig. 1. As can be seen from the spectra, two different diffraction maxima were observed in a thin CdSe layer with a thickness of $h = 200$ nm, and three different diffraction maxima were observed in a thin CdSe layer with a thickness of $h = 400$ nm.

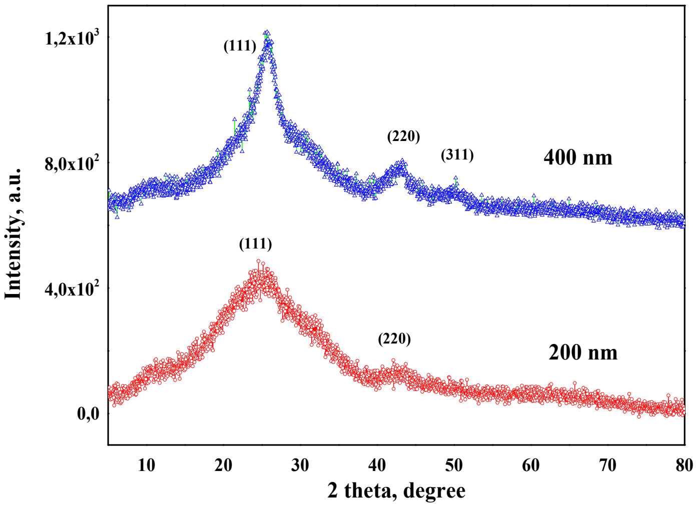

Figure 1. X-ray diffraction spectra of CdSe thin films at room temperature

When comparing the X-ray diffraction spectra shown in Figure 1 with the results obtained in previous studies, it was found that the center of the peak in the spectrum of a thin film with a thickness of $h = 200$ nm, located at a diffraction angle of $2\theta = 25°$, corresponds to the atomic planes belonging to the indices Miller in the crystal structure of hexagonal symmetry (111) of the CdSe compound. The central peak, located at the diffraction angle $2\theta = 43°$, corresponds to the atomic planes belonging to the Miller indices in the crystal structure of the CdSe compound with hexagonal symmetry (220) [19]. In thin CdSe films, in the spectrum of a thin film with a thickness of $h = 400$ nm, another diffraction maximum was observed at a central diffraction angle of $2\theta = 50°$, which corresponds to the atomic plane of the Miller index (311). It is known that in thin layers the structural properties are weaker than in bulk crystals. As can be seen from the analysis of the spectra presented in Fig. 1, in each of the thin layers a phase corresponding to a CdSe crystal was formed. However, better structural properties were found in a thin film with a thickness of $h = 400$ nm than in a thin film with a thickness of $h = 200$ nm.

The photoconductivity spectrum of thin CdSe films obtained on a glass substrate by chemical deposition was also studied. Photoconductivity spectra of thin CdSe films with thicknesses $h = 200$ nm and $h = 400$ nm, obtained at a wavelength λ = 600-1100 nm, are presented in Figures 2 and 3. A two-component photoconductivity model was used to interpret photoconductivity spectra and determine the properties of thin films [20]. According to this model, the photocurrent generated in a thin CdSe film consists of a positive component generated in the bulk of the film and a negative component generated on the surface of the film and heavily occupied by surface traps. During these processes, at certain wavelengths of light incident on the surface of a thin layer, a decrease in photoconductivity is detected due to the capture of charge carriers by traps.

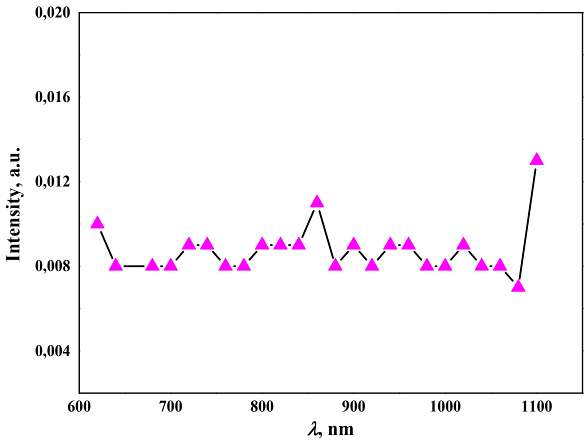

Figure 2. Photoconductivity spectrum of a thin CdSe film obtained with a thickness h = 200 nm

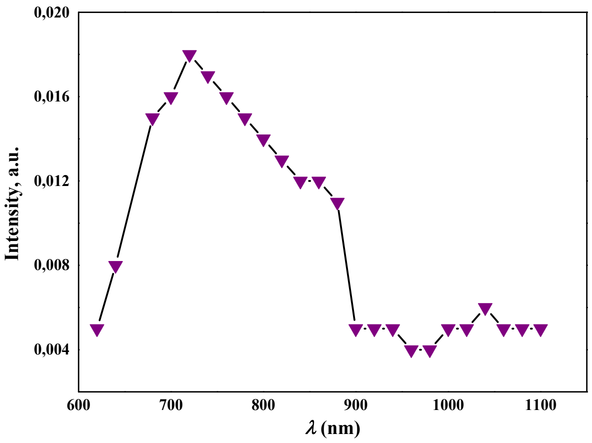

Figure 3. Photoconductivity spectrum of a thin CdSe film obtained with a thickness *h* = 400 nm

At small values of the thickness of thin layers (*h* = 200 nm), a sharp decrease in photoconductivity due to self-damping was recorded. As can be seen from the graph in Figure 2, chaos was observed over a wide range of wavelengths of the incident beam. This process can be explained by the incomplete formation of the CdSe phase in the thin film. As a result of defects in the structure of the thin layer and the capture of charge carriers by these defects, the special properties of the CdSe compound are not fully formed. A different picture was observed in the PE spectrum of a thin CdSe layer with a thickness of *h* = 400 nm. From the graph shown in Fig. 3, it is clear that this sample is photosensitive in the wavelength range λ = 700-900 nm and a photoconverter can be manufactured on its basis. The spectrum recorded a maximum with wavelength λ = 0.71 μm. Based on this maximum, the band gap of a thin CdSe film with a thickness *h* = 400 nm was calculated:

$$E_g = 1{,}24 / \lambda_{max} \text{ (eV)}$$

It was found that the band gap of this sample is E_g = 1.746 eV.

In the course of a comparative study of the structure and photoconductivity of thin films of cadmium selenide obtained by chemical deposition, it was found that the CdSe phase cannot be completely formed in these systems up to a thickness $h \leq 400$ nm. Therefore, it is impossible to obtain a photosensitive system of this size. At greater thickness, a cadmium-selenium phase may form and the photoelectric properties of cadmium-selenium may appear. Such systems provide a wide range of applications for CdSe thin films.

CONCLUSIONS

In parallel, the structure and photoconductivity of thin films of cadmium selenide obtained by chemical deposition were studied, and the structural aspects of photoconductivity were studied in a comparative manner. During the research, thin films with a thickness of *h* = 200 nm and *h* = 400 nm, obtained on glass substrates, were studied. The results obtained were analyzed and it was found that a thin layer of CdSe with *h* = 400 nm is a photosensitive substance in the spectral region of λ = 700-900 nm. The band gap was E_g = 1.746 eV. As the thickness of the thin layer decreases, photosensitivity sharply decreases due to the capture of charge carriers by traps on its surface.

ORCID

Y.I. Aliyev, https://orcid.org/0000-0001-8896-2180

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ДОСЛІДЖЕННЯ ФОТОПРОВІДНОСТІ ТОНКИХ ПЛІВОК СЕЛЕНІДУ КАДМІЮ, ОТРИМАНИХ ХІМІЧНИМ ОСАДЖЕННЯМ

Л.Н. Ібрагімова[a], Н.М. Абдуллаєв[b], Н.А. Гардашбейова[a], А.С. Алекперов[c,d], С.Р. Азімова[b], Ю.І. Алієв[d]
[a]*Нахічеванський державний університет, Нахічевань, AZ-7012, Азербайджан*
[b]*Інститут фізики Міністерства науки і освіти Азербайджану, Баку, AZ-1143, Азербайджан*
[c]*Азербайджанський державний педагогічний університет, Баку, AZ-1000, Азербайджан*
[d]*Західнокаспійський університет, Баку, AZ-1001, Азербайджан*

У даній роботі досліджено спектр фотопровідності (ФП) тонких плівок CdSe. У ході досліджень на скляних підкладках були відібрані тонкі плівки кадмію та селену товщиною h = 200 нм та h = 400 нм. Товщину зразків, отриманих хімічним осадженням, визначали гравіметричним методом. Оскільки кристал CdSe є світлочутливим напівпровідниковим матеріалом, досліджували фотопровідність тонких плівок. Проаналізовано спектри, отримані під час досліджень, проведених на довжині хвилі λ = 600-1100 нм. Встановлено, що спектр є хаотичним, оскільки в шарах h = 200 нм фаза сформована не повністю. У шарах h = 400 нм зафіксовано максимум з центром на довжині хвилі λ = 710 нм.

Ключові слова: *хімічне осадження; CdSe; тонка плівка; фотоелектричний спектр; зазор*