the solution was cooled to room temperature and insoluble selenium particles were removed from the solution through a filter. As a result, a clear solution of sodium selenosulfate was obtained. When using sodium selenosulfate as a selenium component in the production of CdSe, the best results can be obtained at a solution pH of 9. A thin layer of CdSe with a crystalline structure can be obtained only at a pH of 9, so that the pH of the solution in the above mixture is equal to 9. To measure the pH of the solution, an Aquilon pH-410 pH meter was used.

Amorphous glass substrates (38×26×1 mm) were kept in a chromium solution for several hours, washed with distilled water and air dried before being introduced into the solution. Glass coasters are placed vertically in a glass with a solution. The chemical deposition process was carried out at room temperature (27 ºC) for 48 hours without rotation. During the process, a white precipitate formed at the bottom of the glass. After three to four hours, this precipitate and the clear solution in the beaker first turned dark yellow and then red, consistent with CdSe. After this procedure, the saucer was removed from the glass, washed with distilled water and dried. As a result, homogeneous thin layers of red CdSe with good adhesion to the substrate were obtained. The thickness of the resulting layers was determined by the gravimetric method and it was found that their thickness d = 150-500 nm.

Structural studies of CdSe thin films were carried out using X-ray diffraction. The experiments were carried out at room temperature and under normal conditions. X-ray diffraction of the samples was carried out on a D8 Advance diffractometer (Bruker) with the following parameters: 40 kV, 40 mA, CuKα radiation (λ = 1.5406 Å). The resulting spectra were analyzed in the Origin program, and the crystallographic parameters of thin CdSe films were determined: diffraction peaks, Miller indices.

RESULTS AND DİSCUSSİONS

In order to study the processes of phase formation in thin films of cadmium selenide obtained by chemical deposition, structural studies were carried out. The crystal structure of CdSe thin films was studied by X-ray diffraction at room temperature. X-ray diffraction spectra obtained in the diffraction angle range $5° \leq 2\theta \leq 80°$ are presented in Fig. 1.

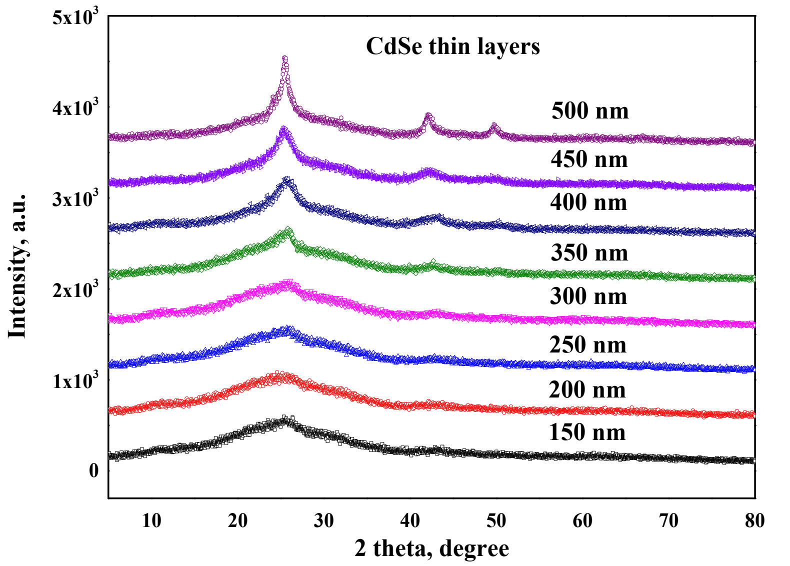

Figure 1. X-ray diffraction spectra of thin CdSe films obtained with different thicknesses.

From the spectra shown in Fig. 1, it is clear that in the resulting thin layers with a thickness of d = 150-500 nm, a phase corresponding to CdSe crystals was formed. The central peak, located at the diffraction angle 2θ = 25°, corresponds to the atomic planes belonging to the Miller indices in the crystal structure of the hexagonal symmetry (111) of the CdSe compound. It is clear from the spectra that the intensity of the peaks increases with increasing thickness of the thin layers. However, this phase was also observed in a thin layer d = 150 nm with the smallest thickness. To more accurately observe the peaks in the spectra, the X-ray diffraction spectra of the thinnest and thickest thin layers were analyzed separately. In Fig. 2 shows the spectrum of a thin CdSe film with a thickness of d = 150 nm. It can be seen from the figure that the peak is clearly visible at the diffraction angle 2θ = 25º. In addition, a new peak was also observed at the diffraction angle 2θ = 43°. From the results obtained when studying the crystal structure of the CdSe compound, it is known that this peak (220) corresponds to atomic planes belonging to the Miller indices [21].

To study the processes of phase formation in thin CdSe films, the X-ray spectra of thin films of greater thickness were also analyzed. Figure 1 shows that after a thickness of d = 400 nm, new peaks begin to appear. This is a sign of the formation of a more perfect phase. It is clear from the spectra that as the thickness of thin layers increases, the intensity of these peaks also begins to increase. Therefore, the spectrum with the greatest thickness was analyzed separately. The X-ray diffraction spectrum of a thin CdSe film with a thickness of d = 500 nm is shown in Fig. 3. From Fig. 3 it can be seen that 3 peaks are observed in the spectrum. Two of these peaks correspond to atomic planes belonging to the Miller indices (111) and (220), observed in previous spectra at diffraction angles $2\theta = 25°$ and 43°. It was found that the peak observed at diffraction angles $2\theta = 50°$ corresponds to the atomic plane belonging to the MIller indices (311).

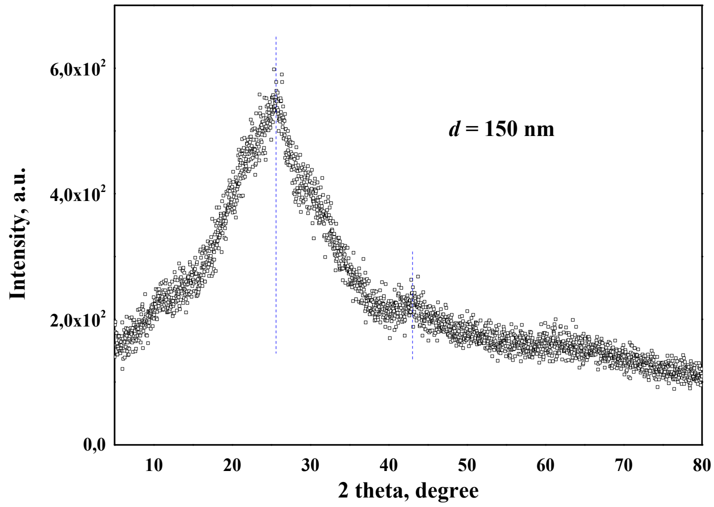

Figure 2. X-ray diffraction spectrum of a thin CdSe film with a thickness of $d = 150$ nm

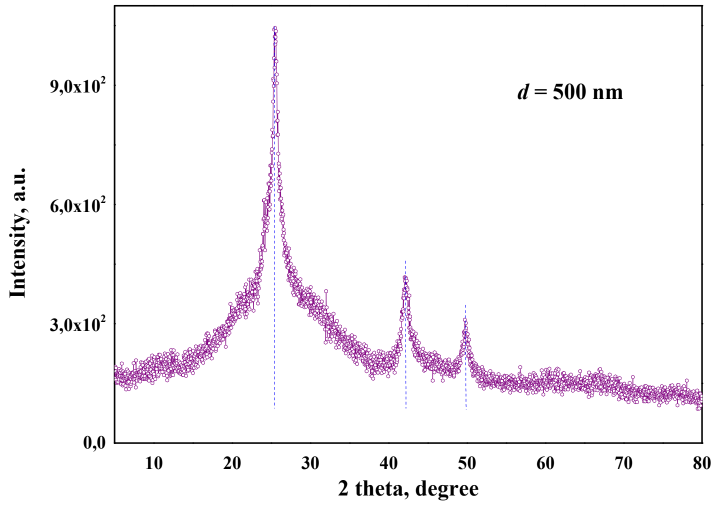

Figure 3. X-ray diffraction spectrum of a thin CdSe film with a thickness of $d = 500$ nm

The lattice parameters of the CdSe compound are $a = b \approx 4$ Å (0.4 nm), $c \approx 7$ Å (0.7 nm) [12]. Since CdSe thin films with dimensions $d \sim 100$ nm consist of several layers, structural features cannot be completely formed. However, as the layer thickness increases, the process of phase formation begins. First, the peak corresponding to the (220) plane along with the (111) plane is fully formed. At thicknesses $d > 400$ nm, the process of phase formation begins and a peak corresponding to the (311) plane is also formed. As can be seen, thin CdSe films starting with a size $d \sim 100$ nm can retain their properties. It is known that the semiconductor CdSe is a material that is widely used in modern electronics. A study of the structure of thin layers obtained by chemical deposition shows that using them it is possible to obtain converters of smaller sizes.

CONCLUSIONS

In this work, thin CdSe films were obtained and their structure was studied. There is extensive information on the technology for producing thin films of the semiconductor CdSe. It has been established that the chemical deposition method can produce thin layers of this material on glass. Layers of varying thicknesses were obtained depending on the synthesis conditions and the stoichiometric amount of chemical elements. The process of phase formation in thin films with a thickness $d = 150$-500 nm has been studied. The studies were carried out using the X-ray diffraction method. Each of the spectra obtained at room temperature was analyzed separately. It was found that in layers of different thicknesses 3 different diffraction peaks are obtained. Analysis revealed that these peaks correspond to the (111), (220) and (311) atomic planes. Although the structural features of the CdSe compound were observed in each of the thin layers, the phase formation process began at a size of 400 nm.

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ПРОЦЕС ФАЗОУТВОРЕННЯ В ТОНКІХ ПЛІВКАХ CdSe

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У даній роботі методом хімічного осадження отримано тонкі плівки селеніду кадмію різної товщини та досліджено процеси фазоутворення в них. Отримано тонкі шари товщиною d = 150 – 500 нм. Структурні дослідження проводили методом рентгенівської дифракції. Аналізували спектри, отримані при кімнатній температурі. Встановлено наявність структурних особливостей сполуки CdSe в тонких шарах. Після товщини d = 400 нм починається процес фазоутворення. Визначено спостережувані атомні площини та індекси Міллера в процесі фазоутворення.

Ключові слова: *хімічне осадження; тонка плівка CdSe; кристалічна структура; рентгенівська дифракція*