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REFLECTION SPECTRA OF POLYCRYSTALLINE FILMS OF CADMIUM SULFIDE AT A TEMPERATURE OF 77.3° K

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Spectroscopic studies of the absorption of polycrystalline cadmium sulfide films ([1]) established that, at room temperature, in the region of 5000 Å the spectrum of thin layers, depending on the conditions of their preparation, shows one or two absorption maxima. The presence of these maxima is due to absorption by cadmium atoms in excess over the stoichiometric composition and is associated with the transition of an electron from the normal impurity level $^1S_0$ to the levels of its excitation $^3P_1$ and $^3P_2$. When the temperature of the study is lowered from room temperature to that of liquid nitrogen, the long-wavelength absorption maximum, corresponding to the transition to the $^3P_1$ level, undergoes doublet splitting, while the short-wavelength maximum, associated with the transition to the $^3P_2$ level, splits into a triplet. However, such a pattern of splitting is not observed in all specimens, but only in those whose deposition was carried out on substrates preliminarily heated to a temperature not lower than 450°C.

In order to obtain new, additional information on the nature of the impurity absorption of CdS in this spectral region, we undertook a study of its reflection spectra. In the literature there are no indications that similar investigations have been carried out on polycrystalline cadmium sulfide films. Therefore, we set ourselves the task not only of obtaining data on the spectral distribution of reflection of thin CdS layers, but also of clarifying its dependence on the preparation conditions of the specimens under study. The study of this question is also of independent interest, since it was not known whether there is a correspondence between the number of bands in its absorption and reflection spectra. The existence of such a correspondence would make it possible to determine the absorption spectra of cadmium sulfide powders from their reflection spectra.

Studies of reflection spectra at the temperature of liquid nitrogen were carried out by us on the very same specimens on which optical absorption had been studied ([2]). The films were prepared by sublimation of cadmium sulfide powder in vacuum, in an atmosphere of argon and of hydrogen sulfide, onto substrates preliminarily heated to temperatures of 300, 350, 450, 500, and 550°C, as well as onto substrates which at the beginning of deposition were at room temperature.

Fig. 1

Figure 1: Fig. 1

As the experiments showed, cadmium sulfide films obtained on cold substrates, irrespective of the medium in which their deposition took place, at the temperature of liquid nitrogen do not possess a fine reflection structure in the region 460–490 mμ. These data fully coincide with the results of studies of their absorption spectra.

The presence of reflection extrema is observed only in specimens deposited on substrates preliminarily heated to 300° and above. In this case the reflection spectra of specimens obtained at a substrate temperature of 300° in the region studied, as a rule, have only one minimum, the position of which for all films deposited in vacuum is rather uniform.

and occurs at λ4777 Å. As is seen from Fig. 1, where, for comparison, microphotograms of the reflection and absorption spectra of samples deposited in vacuum at a substrate temperature of 300° are shown, the position of this minimum in sample No. 232 (Fig. 1A,) coincides with the position of the absorption maximum (Fig. 1A,). The absorption spectrum of specimen No. 244 does not reveal absorption bands (Fig. 1A,). However, in its reflection spectrum (Fig. 1A,) one minimum is observed. Sample No. 234, which possesses a fine absorption structure (Fig. 1A,), preserves it also in reflection (Fig. 1A,).

Fig. 1 , and shows microphotograms of the reflection spectra of CdS films deposited in vacuum on substrates preliminarily heated to 450°. As is seen from the figure, the number of minima in such specimens is not the same. They are shallow, and their position is not constant from sample to sample. It should be noted that the number of absorption maxima in the spectra

Fig. 1. Microphotograms of the reflection and absorption spectra of CdS films deposited in vacuum at substrate temperatures of 300° (A), 450° ( ), and in hydrogen sulfide at a substrate temperature of 350° ( )

of absorption of the indicated samples (Fig. 1 , ,) is the same. Thus, there is no correspondence in the absorption spectrum to the long-wavelength reflection minimum. In addition, as may be noticed from Fig. 1 , for sample No. 260 the positions of the absorption maxima coincide with the positions of the reflection minima, whereas for sample No. 262 a coincidence of the absorption and reflection maxima takes place.

With an increase in the temperature of the preliminary heating of the substrate to 500°, the reflection minima become deeper and, as a rule, narrower (Fig. 1 ,). At the same time the short-wavelength minima are expressed more clearly. According to the positions of the first two long-wavelength minima, the samples are divided into three types: in the first, the positions of the minima correspond to $\lambda\lambda$4875 and 4871 Å; in the second, to $\lambda\lambda$4869, 4830 Å; and in the third, to

$\lambda\lambda$4867, 4836 Å.

The fine structure of reflection of films deposited in an atmosphere of hydrogen sulfide with preliminary heating of the substrate to 350° consists of one, two, or three minima (Fig. 1 , , ,).

In some samples the minima are broad and shallow; in others, on the contrary, deep and narrow. In films having three long-wavelength reflection minima, their positions are constant and correspond to $\lambda_1 = 4833$ Å, $\lambda_2 = 4868$ Å, $\lambda_3 = 4905$ Å. In the remaining specimens the position of the first minimum changes from sample to sample from 4871 to 4880 Å, and that of the second from 4836 to 4843 Å. This is manifested especially strongly in samples having deep, narrow minima. As is seen from Fig. 1 , in the absorption spectrum of sample No. 577 (curve) there are three absorption bands, whereas in the reflection spectrum of this sample (curve) only one minimum is observed.

With an increase in the temperature of the preliminary heating of the substrate to 450°, all films deposited in an atmosphere of hydrogen sulfide have very deep and narrow long-wavelength reflection lines. Such samples, as a rule, exhibit two long-wavelength minima. Their positions for one series of samples occur at $\lambda\lambda$ 4875, 4836–4845 Å, and for another at $\lambda\lambda$ 4869, 4836–4841 Å. The short-wavelength reflection minima, in comparison with the preceding case (Fig. 1B, *a, v, g*), become more distinct.

Films deposited in an atmosphere of argon on substrates preheated to 350°, like the samples prepared in an atmosphere of hydrogen sulfide, have one, two, or three long-wavelength reflection minima. In specimens obtained on substrates preheated to 450 and 550°, the reflection spectra show both two and three long-wavelength minima—very deep ones.

Thus, studies of the reflection spectra of thin cadmium sulfide films at the temperature of liquid nitrogen have shown that specimens deposited in various atmospheres on substrates not preheated beforehand, in the region 460–490 mμ, do not exhibit a fine structure of reflection. It is observed only in samples deposited on preheated substrates; moreover, in films obtained on substrates heated to 300°, as a rule, only one reflection minimum occurs at λ 4777 Å. This minimum is observed even in specimens in whose absorption spectrum no absorption bands are found. With a further increase in the temperature of the preliminary heating of the substrate, the number of minima increases and reaches five at a temperature of 450–500°. The fact that, in a number of samples, the reflection spectrum corresponds to the absorption spectrum indicates that the nature of the fine structure of the reflection of cadmium sulfide is the same as the nature of its absorption bands.

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2. N. V. Pirogova, DAN, **139**, No. 5 (1961).

Note: Figure translations are in progress. See original paper for figures.