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ON THE PHOTOCONDUCTIVITY OF POLYCRYSTALLINE LAYERS OF CADMIUM SULFIDE

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At present cadmium sulfide is attracting great interest because of its enormous photosensitivity. Numerous works have been devoted to studies of photoconductivity in CdS single crystals ([1–8]). However, in them the spectral range was restricted mainly to the visible region of the spectrum. The photoelectric properties of cadmium sulfide films, however, have been described only in a few brief communications ([9–15]), which also present results for the visible part of the spectrum.

We set ourselves the task of investigating the photoconductivity of polycrystalline CdS layers over a wide range of wavelengths of the exciting light, as a function of the technological conditions under which the specimens were prepared. In our case the layers were obtained by evaporating cadmium sulfide powder onto an insulating substrate (glass, quartz) in vacuum at a pressure of $5 \cdot 10^{-5}$ mm Hg, and also in an atmosphere of argon and hydrogen sulfide at pressures of 1.0–0.5 mm Hg. Depending on the experimental conditions, the substrate could be heated from room temperature to 550°. The films were deposited with thicknesses from $2 \cdot 10^{-6}$ to $2 \cdot 10^{-4}$ cm. In the course of the work more than 600 specimens were prepared.

Studies of the spectral photocurrent curves were carried out by us on a ZMR-3 mirror monochromator with quartz optics. The light source was a DKSSH-1000B direct-current xenon lamp. The spectral distribution of the lamp energy at the monochromator exit was measured with a bolometer. In addition, for the ultraviolet region of the spectrum, the spectral distribution of this same lamp and of the PRK-4 ultraviolet standard was recorded with an FEU-18.

The specimens were illuminated by rectangular pulses produced by a shaped disk. The operating frequency of light modulation was (36 ± 0.5) Hz. The electrical part ([16]) of the setup consisted of an electrometric cascade, a broadband amplifier, a millivoltmeter, and an EO-7 oscillograph.

All measurements were carried out in the linear part of the light characteristic of the specimens. The polycrystalline films investigated had linear current-voltage

Fig. 1

Figure 1: Fig. 1

characteristics in the operating voltage range and showed no dependence of the photocurrent on the polarity of the applied voltage.

We characterized the photosensitivity of the specimens by the value of the photocurrent per unit energy of the incident light, referred to the dark current. In our case the field strength was automatically kept constant, since indium ohmic electrodes were deposited on all specimens using the same stencil. The dark current and current-voltage characteristics of the films were recorded with an EMU-3 direct-current electrometric amplifier and an MOM-3 resistance meter.

In addition to photocurrent studies, on some films the spectral dependences of the intrinsic lifetimes of the photocarriers τ were recorded. Measu-

measurements of τ were carried out from oscillograms of the decay portion of the photocurrent pulse at the moment the light beam was interrupted by a disk ([6,16,17]). The accuracy of the photocurrent measurements was limited to 5%, and that of the photosensitivity to 20%; for the intrinsic lifetimes the measurement accuracy was 30%.

Our experiments established that cadmium sulfide films deposited in vacuum and in argon on specially unheated substrates at room temperature, as a rule, do not exhibit

Fig. 1. Spectral curves of the photosensitivity and lifetime τ of current carriers for CdS films deposited in vacuum on a substrate heated to 300° (a), in argon on a substrate heated to 350° (b), and in hydrogen sulfide on a substrate heated to 350° (c)

photosensitivity. Layers deposited in vacuum on a substrate previously heated to 150° also do not have photoconductivity. All these films are low-ohmic; their specific resistance is approximately 10^{-2}—1 $\Omega \cdot$ cm. Samples prepared in an atmosphere of hydrogen sulfide on an unheated substrate and having a specific resistance of no more than 1—10 $\Omega \cdot$ cm likewise do not possess photosensitivity. Photocurrents are observed only in films whose specific resistance exceeds 100 $\Omega \cdot$ cm.

The layers exhibit stable photosensitivity if their deposition was carried out on substrates previously heated to not less than 300°. This applies both to samples prepared in vacuum and to samples deposited in an atmosphere of argon and hydrogen sulfide. Only some of them do not show appreciable conductivity; in such samples the specific resistance amounts to units or tens of $\Omega \cdot$ cm, which is several orders of magnitude lower than in photosensitive layers. All films deposited on substrates previously heated to 450°, regardless of the medium in which sublimation of the cadmium sulfide powder was carried out, are photoconducting.

Fig. 2. Spectral curves of photosensitivity and lifetime τ of current carriers for CdS films deposited in vacuum (a), argon ( ), and hydrogen sulfide ( ) on substrates heated to 450°.

Figure 2: Fig. 2. Spectral curves of photosensitivity and lifetime τ of current carriers for CdS films deposited in vacuum (a), argon ( ), and hydrogen sulfide ( ) on substrates heated to 450°.

Figures 1 and 2 present the spectral curves of the relative photosensitivity of some CdS films prepared in vacuum (a),

as well as in an atmosphere of argon ( ) and hydrogen sulfide ( ). Spectral curves of the intrinsic lifetime of photocarriers τ for some samples are also given there.

As follows from the figures, the magnitude of the photosensitivity of the films varies. Samples possessing high photoconductivity have a resistivity several orders of magnitude higher than low-sensitivity ones. Thus, for example, the resistivity of film 234 is $\rho \simeq 2 \cdot 10^6\ \Omega \cdot \text{cm}$, while that of sample 244 is $\rho \simeq 1.2 \cdot 10^3\ \Omega \cdot \text{cm}$ (Fig. 1a).

Fig. 2. Spectral curves of photosensitivity and lifetime τ of current carriers for CdS films deposited in vacuum (a), argon ( ), and hydrogen sulfide ( ) on substrates heated to 450°.

As can be seen from the graphs, photocurrents of cadmium sulfide films are observed over a wide range of wavelengths of the exciting light—from 225 to 700 mμ. In specimens with low sensitivity the photocurrent falls mainly in the visible region of the spectrum. Samples with high photosensitivity exhibit photocurrent both in the visible and in the ultraviolet part of the spectrum. In most samples, in the ultraviolet the photosensitivity reaches a very large value.

Thus, the spectral curve of the photoconductivity of polycrystalline cadmium sulfide films is complex in character and has at least two maxima of photoactivity in the range 225–700 mμ. The maximum photocurrent of low-sensitivity films lies at $\lambda = 510$ mμ, whereas highly sensitive samples possess photocurrent maxima both in the ultraviolet part of the spectrum and in the visible region ($\lambda = 510$ mμ). The latter coincides in position with the maximum photocurrent of CdS single crystals ([1–8]).

The intrinsic lifetime of photocarriers for all the samples investigated by us proved to be approximately $(1\text{–}6)\cdot 10^{-3}$ sec. It is of the same order as for cadmium sulfide single crystals ([18]). As follows from Figs. 1 and 2, τ is practically independent of the wavelength of the exciting light. Only in regions of the spectrum where the photoactivity of CdS films is insignificant and the quanti-

there are few photocarriers, the proper lifetime increases somewhat. This is observed both in the visible and in the ultraviolet parts of the spectrum.

As an analysis of the experimental data of our experiments shows, the magnitude

and spectral distribution of the photosensitivity of cadmium sulfide films do not depend on their thickness. Thus, for example, the highly sensitive specimen 592 (Fig. 1c) has approximately the same thickness as the low-sensitivity film 584 ($1.8 \cdot 10^{-4}$ and $2.7 \cdot 10^{-4}$ cm, respectively). Nor is any dependence found of the spectral distribution of the photocurrent on the temperature of the substrate and of the medium in which the specimen is prepared. However, the magnitude of the photosensitivity is connected with the specific resistance of the deposited layer. As the substrate temperature is increased, the specific resistance and the photosensitivity of the films increase.

In addition, on the basis of our experiments it may be asserted that the different photosensitivity of the layers is not connected with a difference in their surface properties. After preparation all the films were stored in a desiccator under identical conditions, and therefore this effect cannot be attributed to a diversity of surface properties.

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