# New anomalous photoconductors

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Results are presented of a study of the photoconducting properties of the semiconducting systems Se–HgSe, $Sb_2S_3$–HgSe, HgSe, $Sb_2S_3$–HgS, $As_2Se_3$–HgSe, and $As_2S_3$–HgSe. It is established that the stationary level of the conductivity in the foregoing systems is determined by the energy of the radiation quanta and does not depend on the light intensity.

The phenomenon of anomalous photoconductivity (AP) of amorphous selenium films activated with mercury, which differs radically in its properties from the known types of photoconductivity, was observed back in 1961.[1] The stationary conductivity excited in such films by monochromatic light does not depend on the light intensity and changes by several dozen times (and sometimes by a thousand times) when the illumination wavelength is varied within the range of the visible spectrum.

No rigorous theory of this phenomenon has been developed as yet. There are only known a phenomenological theory of AP,[2] in which it is presumed that the samples contain special centers ($U$ centers) for the capture of carriers, and a model of the anomalous photoconductor in the form of a three-layer structure.[3] However, neither the three-layer model nor the model using the $U$-center concept is fully applicable to a quantitative description of the AP of amorphous-selenium films. This possible reason why it is difficult to develop a theory is that only mercury-activated films of amorphous selenium have exhibited anomalous photoconductivity.

We report here new semiconducting systems having anomalous photoconductivity properties, and present some of their properties.

AP was observed by us in the following semiconducting systems: Se-HgSe, $Sb_2S_3$-HgSe, HgSe, $Sb_2S_3$-HgS, $As_2Se_3$-HgSe, and $As_2S_3$-HgSe. The samples of the investigated systems had a construction shown schematically in Fig. 1. In all cases, the thickness of the HgSe layer was $\lesssim 100$ Å, while the $As_2Se_3$, $As_3S_3$, Se, and $Sb_2S_3$ films were ~1 $\mu$ thick. Measurements of the photoconductivity were made at $T \sim 100$ °K by the procedure described in[2].

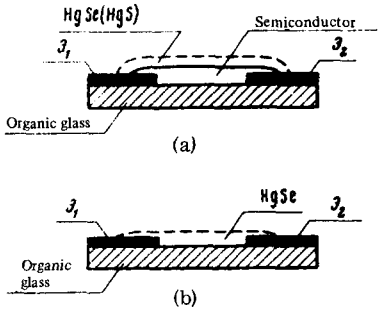


FIG. 1. Schematic picture of the investigated samples.

It was established that samples illuminated with monochromatic light of equal intensity leaves the stationary residual conductivity in darkness at the quasi-dark value and dependent on the energy of the light-flux quanta. The spectral distribution of the stationary conductivity is similar for all the investigated systems. The corresponding characteristics for the systems $Sb_2S_3$-HgS and HgSe on organic glass are shown in Fig. 2, curves 1 and 2. The same figure shows for comparison the analogous dependence (curve 3) for films of selenium activated in mercury vapor.

A study of the lux-ampere characteristics of the samples has shown that the stationary conductivity remains practically constant in the entire spectral range following an extensive variation of the light intensity. The lux-ampere dependence for the $As_2S_3$-HgSe system is shown in Fig. 3.

The steady-state value of the quasi-dark conductivity can be changed by applying light of a different wavelength. This change takes place with a characteristic relaxation time $\tau$ that depends, at equal intensity, on the photon energy. Individual numerical values of $\tau$ for the investigated systems are listed in the table.

A common property of all the samples is the inverse proportionality of the conductivity relaxation time to the radiation intensity $L$, so that the product $\tau L$ is constant.

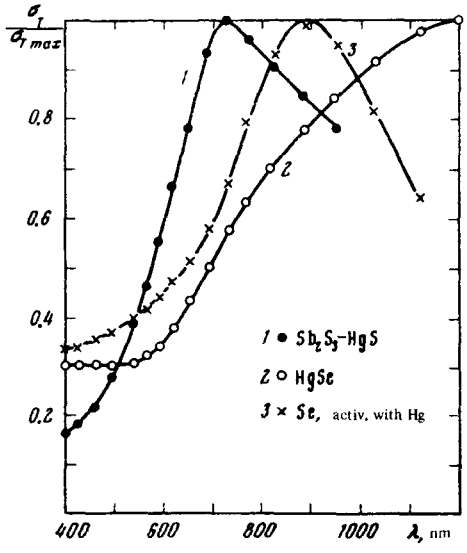


FIG. 2. Spectral distribution of stationary conductivity for the systems $Sb_2S_3$-HgS and HgSe.

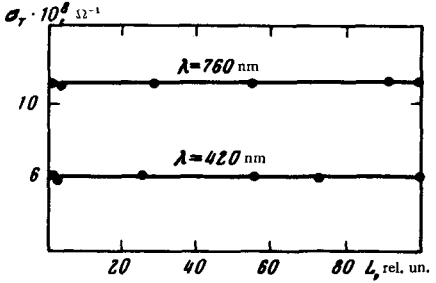


FIG. 3. Lux-ampere characteristic of the $As_2S_3$-HgSe system at a potential difference – 5 V between the electrodes.

Thus, the systems listed above exhibit an aggregate of properties previously known to be possessed only by activated amorphous-selenium films. The ability to "remember" an optical signal, with the quasi-dark conductivity levels independent of the light intensity, offers evidence of the presence of spectral memory in the samples. The presence of such a common property makes it possible to classify the observed semiconductor systems as belonging to a single group having anomalous photoconductivity.

As follows from Fig. 2. and the table, the anomalous photoconductors can have different characteristics of the spectral distribution, of the quasi-dark conductivity,

| $\tau$ (λ) | Anomalous photoconductors | | | | | |
|---|---|---|---|---|---|---|
| | Se activated in Hg vapor | $As_2Se_3$–HgSe | $As_2S_3$–HgSe | $Sb_2S_3$–HgSe | $Sb_2S_3$–HgS | HgSe |
| (730 nm) sec | 230 | 10 | 220 | 80 | 114 | 500 |
| (410 nm) sec | 0.54 | 1.2 | 17 | 1.3 | 1.4 | 300 |

and of the ratio of the relaxation times $\tau$. The location of the long-wave maximum depends on the material on which the HgSe film is coated. The substrate material affects particularly strongly the absolute value and the ratio of the relaxation times. It should be noted that the anomalously photoconducting properties of the $Se_2S_3$ films coated with HgSe or HgS do not differ significantly. This circumstance can serve as evidence of the role of the structure of the deposited thin film in the excitation of the anomalous photoconductivity.

For more detailed conclusions it is necessary to make a special study of the obtained anomalous photoconductors.

[1]M. I. Korsunskiĭ, N. G. Pastushuk, and G. D. Mokhov, Fiz. Tverd. Tela **3**, 2667 (1961) [Sov. Phys.-Solid State **3**, 1942 (1962)].
[2]M. I. Korsunskiĭ, Anomal'naya fotoprovodimost' (Anolalous Photoconductivity), Nauka, 1972.
[3]S. M. Ryvkin, ZhETF Pis. Red. **18**, 376 (1973) [JETP Lett. **18**, 221 (1973)].