Meetings and Conferences

SCIENTIFIC SESSION OF THE DIVISION OF GENERAL PHYSICS AND ASTRONOMY, USSR ACADEMY OF SCIENCES (Baku, 19–21 May, 1969)

Usp. Fiz. Nauk 99, 503–514 (December, 1969)

ON 19–21 May there was held in Baku a scientific session of the Division of General Physics and Astronomy of the USSR Academy of Sciences, jointly with the Division of Physico-technical and Mathematical Sciences of the Azerbaĭdzhan Academy of Sciences, the Institute of Physics of the Azerbaĭdzhan Academy of Sciences, the Shemakha Astrophysical Observatory of the Azerbaĭdzhan Academy of Sciences, and the Scientific Council on Physics and Chemistry of Semiconductors of the USSR Academy of Sciences.

Two review papers were delivered at the session:

L. V. Keldysh, Electron Spectra of Semiconductors and the Transition to the Metallic State.

I. S. Shklovskiĭ, Pulsars.

The following scientific papers were delivered:

1. N. I. Ibragimov, G. M. Aliev, D. Sh. Abdinov, Sh. O. Mamedov, and S. I. Mekhtieva, Certain Results of Research on Selenium.
2. G. B. Abdullaev, Z. A. Aliyarova, G. A. Asadov, É. N. Zamoanova, and A. L. Shabalin, Electric Properties of Certain Chalcogenides in Contact with Metals.
3. F. M. Gashimazade and Yu. M. Seidov, Spectrum of Elementary Excitations in Magnetically Ordered Crystals. (Carbonates of Transition Metals).
4. G. D. Guseĭnov, Certain Results and Prospects of a Search for Complex Semiconductor Analogs.
5. G. B. Abdullaev, V. B. Antonov, R. Kh. Nani, Z. Y. Salaev, and T. É. Mekhtiev, Recombination Radiation in Certain Broad Band Semiconductors Under the Influence of a Beam of Fast Electrons.
6. I. M. Kopylov, Results of Investigations on the Physics of Stars in the SAO Observatory of the USSR Academy of Sciences During the Last Two Years.
7. G. F. Sultanov, Features of the Structure of the Planetoid Belt and Their Explanation.
8. I. A. Aslanov, Z. A. Ismailov, N. B. Ibragibov, and S. M. Azimov, Some Results Obtained with the 2 Meter Telescope.
9. R. É. Guseinov, Dynamic Processes Leading to Generation of Coronal Formations.
10. G. I. Abbasov, Use of Electronic Digital Computers for the Reduction of Spectrograms.

Certain Results of Research on Selenium.

N. N. Ibragimov, G. M. Aliev, D. Sh. Abdinov, Sh. M. Mamedov, and S. I. Mekhtieva. We present below a brief content of the scientific papers.

The physical properties of selenium are such that this material is used extensively in its polycrystalline and amorphous states even if not highly purified. Selenium has been the subject of a large number of investigations, but many of its properties have not been fully explained to this day. There have been no studies at all of donor-acceptor interaction processes in selenium or of the influence of the prior thermal history and of oxygen on the properties of the material.

The investigation of selenium at the Physics Institutes of the Azerbaĭdzhan Academy of Sciences was initiated with a study of the physical properties in selenium rectifiers. A cycle of investigations performed by G. B. Abdullaev has made it possible to establish that the p-n junction in selenium rectifiers occurs on the boundary of the selenium (p-type semiconductor) and cadmium selenide (n-type semiconductor), when contact is made between cadmium and selenium, even at room temperatures. This has made it possible to construct rectifiers with greatly improved characteristics by artificially depositing a layer of n-semiconductor, and resulted in noticeable progress in the manufacture of Soviet rectifiers.

The radio-isotope method was used to investigate the diffusion and electron transport of a number of elements in selenium. The results of these investigations increased our knowledge of the processes of electro- and thermoforming, and made it possible to improve the conditions under which these processes are effective.

A large number of investigations has been devoted to the study of electric, thermoelectric, thermal, mechanical, optical, and magnetic properties of amorphous and crystalline selenium. It has been established that amorphous selenium is an intrinsic semiconductor of the n-type. Upon crystallization, owing to the activation of the acceptor impurities (mainly oxygen), the conductivity changes to p-type, and selenium becomes an impurity semiconductor. The crystallization time, needed to transform selenium into a p-semiconductor depends on the temperature and on the content of the oxygen impurity in it. The process of crystallization of amorphous selenium includes the stages of formation of the nuclei (ΔE_1 = 17.6 kcal/mole) and their growth (ΔE_2 = 10.4 kcal/mole). The kinetics of crystallization of the selenium is well described by the Avraami-Kolmogorov equation.

The electric conductivity of crystalline and liquid selenium increases with temperature exponentially, this being due to the increase of the carrier mobility. The low mobility and its exponential growth with increasing temperature are connected with the presence of intermolecular energy barriers. When selenium melts, owing to the weakening of the action of the impurity centers and to the increase of the intermolecular distances, the concentration and mobility of the carriers decrease jumpwise.

The decrease or increase of the electric conductivity of the crystalline selenium upon introduction of impurities, and also the number of impurities at which the

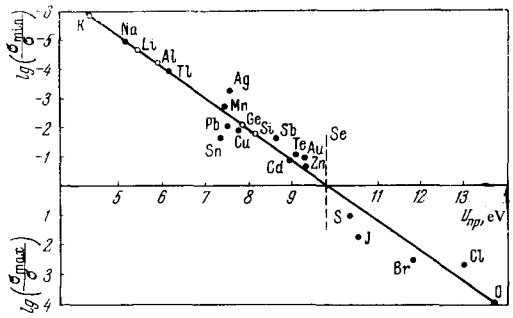

FIG. 1

minimum or maximum electric conductivity is obtained, are determined by the affinity of the impurity to oxygen. Impurities having an ionization potential U_{imp} which is smaller than that of selenium, U_{Se}, form electrically neutral molecules with oxygen and decrease the electric conductivity of the selenium, whereas impurities with $U_{imp} > U_{Se}$ do not interact with the oxygen and, forming local levels, increase the conductivity. Figure 1 shows the plots of log (σ_{min}/σ) and log (σ_{max}/σ) against U_{imp}; here σ is the electric conductivity of pure but not oxygen-free selenium, σ_{min} and σ_{max} are the extremal values of the electric conductivity as functions of the concentration.

The thermal conductivity of amorphous selenium increases linearly with temperature, experiencing a jump (~ 40%) at the vitrification point (~ 31° C). This jump is connected with the appearance of rotational vibrations in the individual links of the long chains of selenium. By varying the intermolecular coupling (by introducing different impurities) it is possible to vary the vitrification temperature, and thereby extend the technical usefulness of amorphous selenium.

It was established that up to 80° C the heat in crystalline selenium is transported by acoustic phonons, and above this temperature it is carried also by the photons.

Since there is no saturation of the bonds on the ends of the selenium chains, unpaired electrons are produced. These were investigated by the EPR method, and a signal with g = 2.0035 ± 0.0005 and ΔH_m = 5—Oe was observed in the selenium. In the initial pure material, there was no EPR absorption, regardless of whether selenium was in the form of a powder or a monolithic piece, although the presence of chains was not subject to any doubt. In all cases, the signal was produced only in the presence of acceptor impurities (oxygen, iodine, bromine), a large ratio of the surface of the volume, and after preliminary heat treatment.

Figure 2 shows the dependence of I/I_{st} on the heat treatment temperature T_{tr}. The maximum concentration of the EPR centers is ~ 10^{17} cm^{-3}. An analysis of the dependence of I on T_{tr} shows that the process of EPR center formation has an activation character. The aggregate of the data allows us to conclude that the EPR absorption in selenium most probably caused by states with charge transfer, produced as a result of donor-acceptor interaction of the chains of selenium with the acceptor molecules of oxygen and the halides. It is also seen from Fig. 2 that the signal becomes indistinguishable after heat treatment at $T_{tr} \gtrsim 600°C$—an irreversible decay of the paramagnetic centers is produced as a

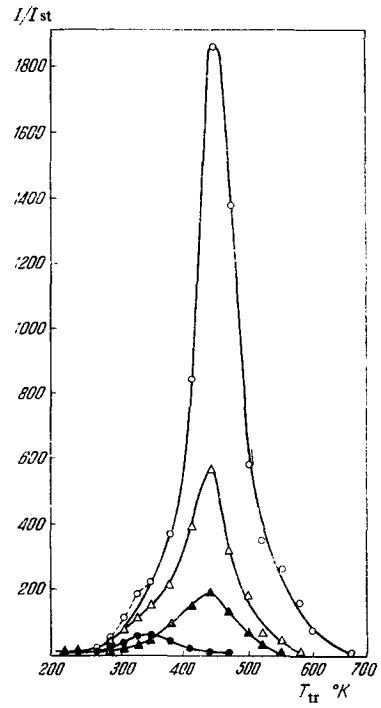

FIG. 2. Dependence of the EPR signal intensity in selenium on T_{tr}. ○ – Se B-2, powdered, p = 10^{-4} mm Hg: △ – Se B-2, granule, p = 10^{-4} mm Hg; ● – Se B-2, p = 760 mm Hg; ▲ – Se B-5, p = 10^{-4} mm Hg.

result of the chemical binding of the acceptor with the selenium. The character of the variation of the linewidth with changing T_{tr} indicates the presence of exchange narrowing due to the increased local concentrations of the paramagnetic centers as a result of their uneven distribution in the sample. During the cooling of the liquid selenium, regions with more or less ordered packing of the molecules are apparently produced in it spontaneously and their aggregate forms a definite supermolecular structure. The minimum dimension of such formations is determined by the nature of the selenium itself as a polymer. Only under this assumption are large local concentrations of paramagnetic centers and their uneven distribution in the selenium possible.

The concentration of the oxygen in the selenium was determined by the EPR and IR spectroscopy methods, and turned out to be ~ 0.1 wt.%.

The proposed existence of supermolecular formations and states with charge transfer explains many properties of selenium.

G. B. Abdullaev, Z. A. Aliayarova, G. A. Asadov, É. N. Zamanova, and A. L. Shabalov. Electric Properties of Certain Chalcogenides in Contact with Metals.

Interest has increased recently in solid-state phenomena connected with negative resistance. Negative conductivity was observed by many authors in thin oxide films of crystalline and vitreous semiconductors[1-4]. Most authors connect the appearance of negative differential resistance with double-injection[5] and microscopic heating[6].

We have studied the electric properties of the relatively little investigated chalcogenide semiconductors