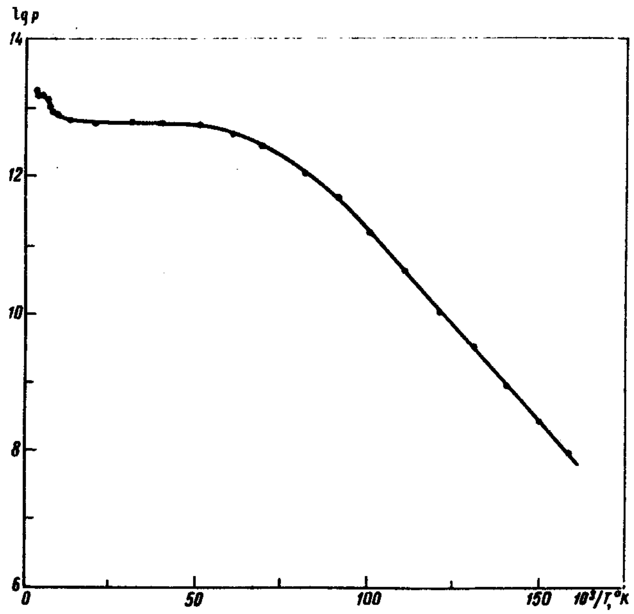


Fig. 2. Temperature dependence of the hole concentration for the irradiated sample in the "limiting" state.

Thus, even if the sum of the states appearing in the forbidden band $\Delta\Sigma N_A$ were to equal or exceed N_D^V, the "limiting" state of the system at 0°K can be obtained only if the bulk of the group-V donors are bound into complexes whose electronic states lie in the valence band.

It is possible that the localization of these states is one of the conditions that determine the difference in the "limiting" position of the Fermi level, in n-type germanium and silicon, since the levels of the complexes in silicon lie near the middle of the forbidden band [5, 6].

The authors are grateful to S.M. Ryvkin for interest in the work and to G.L. Bir for taking part in a discussion of the results.

[1] V.S. Vavilov and N.A. Ukhin, Radiatsionnye effekty v poluprovodnikakh i poluprovodnikovykh priborakh (Radiation Effects in Semiconductors and Semiconductor Devices), Atomizdat, 1969.
[2] A. Seeger and K.P. Chik, Phys. Stat. Sol. 29, 455 (1968).
[3] N.A. Vitovskii, M. Maksimov, and T.V. Mashovets, Fiz. Tekh, Poluprov. 4, 1030 (1970) [Sov. Phys.-Semicond. 4, 880 (1970)].
[4] N.A. Vitovskii, M. Maksimov, and G.T. Mashovets, ibid. 4, 2276 (1970) [4, 1960 (1971)].
[5] G.D. Watkins and J.W. Corbett, Phys. Rev. 134, A1359 (1964).
[6] G.D. Watkins, Proceedings of the Santa Fe Conference on Radiation Effects in Semiconductors, p. 67, Plenum Press, New York, 1968.
[7] J.S. Blakemore, Semiconductor Statistics, Pergamon, 1961.

OBSERVATION OF THE HIGH-TEMPERATURE QUANTUM SIZE EFFECT IN A SEMICONDUCTING CuS FILM

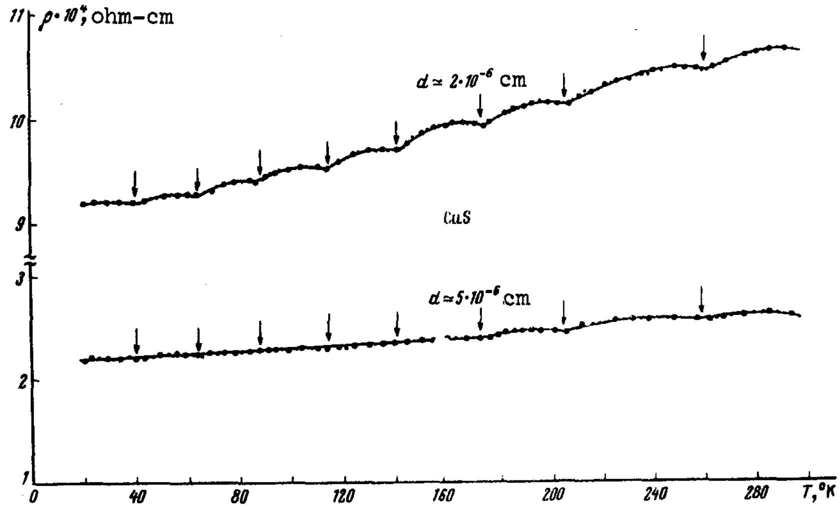
F.Yu. Aliev, F.R. Godzhaev, I.G. Kerimov, and E.S. Krupnikov
Physics Institute, Azerbaidzhan Academy of Sciences
Submitted 7 May 1971
ZhETF Pis. Red. 13, No. 12, 679 - 681 (20 June 1971)

We investigated semiconducting quantizing CuS films. The dispersion law in the subband is $\varepsilon = \varepsilon_n(\vec{P}_\perp)$ (n = 1, 2, 3, ..., $\vec{P}_\perp$ is the quasimomentum with components P_x and P_y) [1, 2]. The distance between the subbands is given by

$$\Delta\epsilon_{n,n+1} = \frac{\pi^2\hbar^2}{2m^*}\,\frac{2n+1}{L^2}$$

where m* is the effective mass in the direction normal to the film, and depends on the masses in the bulky sample [3].

The conditions for the appearance of superconductivity in a semiconducting film, according to [4], differs from the conditions in a bulky sample. This is



Temperature dependence of the resistivity of CuS films of thickness 200 and 500 Å.

connected with the dependence of the electronic density of states on the film thickness on the special character of the Cooper pairing, which makes the study of thin semiconducting films much more promising from the point of view of raising the existing transition temperature.

We have therefore investigated semiconducting CuS films of various thicknesses. The transition temperature T_c in the bulky sample is 1.62°K [5]. A superconducting transition was observed in a film 6×10^{-6} cm thick at a temperature 3 ± 0.3°K.

Further, an investigation of the entire course of the temperature dependence of the film resistivity at definite thicknesses (200 and 500 Å) resulted in an oscillatory picture.

The CuS films were obtained by sputtering on glass from a bulky sample and accompanying enrichment with sulfur in a vacuum not lower than 10^{-5} mm Hg. The error in the determination of the film thickness was 50 Å, and the temperature was maintained constant within 1°K and measured with a platinum thermometer. An essential manifestation of the presence of the observed effect is the creation of a low-resistance ohmic constant which was realized by us[1]. The measurements were performed by a null method, using the formula [6]

$$\rho^{-1} = \sigma = \frac{I}{2\pi UL} \ln\left[\frac{a + (\ell/2)}{a - (\ell/2)}\right]^2 .$$

where $a = [(\ell/2)^2 - d^2]^{1/2}$; ℓ is the distance between contacts, d the diameter of the contacting surface, U the potential difference between contacts, and I the current flowing through the sample ($I = 4.6$ μA, $\ell = 10$ mm, $d = 1.5$ mm).

The figure shows a plot of the resistivity of the CuS films 200 and 500 Å thick against the temperature, with the measurement errors indicated.

As seen from the figure, in the temperature interval 20 - 60°K the ρ(T) dependence is so weak that the plot is a straight line parallel to the temperature axis. This makes it possible to state, assuming that the mobility is

[1] A patent application was filed for this work (disclosure 1423472/26-25).

independent of T in this interval, that the electron gas is degenerate.

Measurement of the Hall effect at room temperature has shown that the electron density in the CuS film is of the order of 10^{20} cm^{-3} at thicknesses 200 and 500 Å.

In the case of films of these thicknesses, the values of the maximum measurement error referred to the values of the amplitude is on the average 0.4 and 0.3, respectively.

Thus, the observed temperature oscillations are beyond the measurement error and the maximum value of the amplitude corresponds to a temperature ~150°K.

The periods of the oscillation change insignificantly with decreasing thickness (by approximately 1°K).

It is also seen from the figure that the smaller the film thickness the stronger the oscillatory dependence of ρ on T and the ratio of the two succeeding periods for a given thickness increases with increasing temperature like

$$\frac{\Delta T_n}{\Delta T_{n+1}} \approx \frac{T_n^{1/2}}{T_{n+1}^{1/2}} .$$

The authors believe that the observed temperature oscillation of the resistivity of the CuS films is due to the non-equidistant arrangement of the subbands in the high-temperature quantum size effect, in accord with the theory of S.S. Nedorezov [7].

In conclusion, the authors thank G.M. Abdullaev and B.G. Lazarev for help and support during the performance of the work, and to M.I. Kaganov, V.B. Sandomirskii, S.S. Nedorezov, and A.M. Rustamova for a discussion of these results.

[1] V.B. Sandomirskii, Zh. Eksp. Teor. Fiz. 52, 158 (1967) [Sov. Phys.-JETP 25, 101 (1967)].
[2] S.S. Nedorezov, ibid. 51, 868 (1966) [24, 578 (1967)].
[3] M.I. Kaganov, S.S. Nedorezov, and A.M. Rustanov, Paper at Soviet-Japanese Conference on Low-temperature Physics, Novosibirsk, 1969; Fiz. Tverd. Tela 12, 2277 (1970) [Sov. Phys.-Solid State 12, 1820 (1971)].
[4] B.L. Tavger and V.Ya. Demikhovskii, Usp. Fiz. Nauk 96, 61 (1968) [Sov. Phys.-Usp. 11, 644 (1969)].
[5] W. Meissner, Z. Physik 1 (12), 570 (1929).
[6] Yu.P. Kozhevnikov, Izv. Vuzov. Fizika 2, 173 (1964).
[7] S.S. Nedorezov, Zh. Eksp. Teor. Fiz. 59, 1353 (1970) [Sov. Phys.-JETP 32, 739 (1970)].

SINGLET AND TRIPLET EXCITON-IMPURITY STATES IN SEMICONDUCTORS

I.S. Gorban', V.A. Gubanov, and A.P. Krokhmal'
Kiev State University
Submitted 7 May 1971
ZhETF Pis. Red. 13, No. 12, 682 - 685 (20 June 1971)

The approximations on the basis of which exciton-impurity complexes in crystals are considered usually do not take into account exchange, spin-orbit,