MEETINGS AND CONFERENCES

Scientific session of the Division of General Physics and Astronomy of the USSR Academy of Sciences (25–26 May 1988)

Usp. Fiz. Nauk 156, 365–372 (October 1988)

A scientific session of the Division of General Physics and Astronomy of the USSR Academy of Sciences was held on May 25 and 26, 1988 at the S. I. Vavilov Institute of Physics Problems of the USSR Academy of Sciences. The following reports were presented at the session:

May 25

1. *G. L. Belen'kiĭ.* Electron-hole liquid and two-dimensional electron gas in layered group A^3B^6 semiconductors.
2. *A. S. Kotosonov.* Electronic properties and energy spectra of quasi-two-dimensional graphites.
3. *M. A. Obolenskiĭ.* Superconductivity and energy spectra of layered dichalcogenides of transition metals.

May 26

4. *R. L. Sorochenko.* Highly excited atoms in physics and astronomy.
5. *G. A. Askar'yan, G. M. Batanov, I. A. Kossyĭ, and A. Yu. Kostinskiĭ.* Aftereffects of microwave discharges in the stratosphere.

Summaries of three reports are presented below.

G. L. Belen'kiĭ. *Electron-hole liquid and two-dimensional electron gas in layered group A^3B^6 semiconductors.* The existence of planes of weak coupling in a lattice of layered semiconductors leads to singularities in the mechanical properties and vibrational spectra of these materials[1,2] and gives rise to energy bands, whose widths along k_z on the one hand and k_x, k_y on the other are significantly different.[3] In a real crystal weakly coupled layers form, on joining, numerous plane defects, oriented perpendicularly to the axis.[4] Physical effects that cannot be understood without taking into account the effect of the structural characteristics on the electron spectrum are observed in layered crystals. This concerns the formation of a high-temperature electron-hole liquid (EHL) in InSe, GaSe, and GaS[5] and the observation of regions of two-dimensional (2D) electron gas,[6,7] responsible for the quantum Hall effect (QHE), in the bulk of InSe.

Figure 1 shows the form of the sample; the results of the study of the sample are presented in Fig. 2 (data of G. L. Belen'kiĭ, E. A. Vyrodov, and V. N. Zverev). For an oblique magnetic field the period of the oscillations of $\rho_{xx} \sim V_{\parallel}$ on the H^{-1} scale decreased in proportion to the cosine of the angle between **H** and c (see Fig. 1), while the dependence $\rho_{xx} = f(T)$ in the region $4.2 \leqslant T \leqslant 1.3$ K for $\mathbf{H} = 0$ had a metallic character, indicating the existence of macroscopic regions of two-dimensional electron gas in InSe. The density of this gas $N_{2D} = (2–4)\cdot 10^{11}$ cm^{-2} was determined from the period of the oscillations of $\rho_{xx}(\mathbf{H})$, while the mobility $\mu = 10^4$ cm^2/V·sec was determined from the dependence $\rho_{xx}^{\min} = f(T)$.[7] The values of the resistances of the Hall plateaus, evaluated taking into account the fact that the regions of the 2D gas are embedded in a medium with a low conductivity, agreed with the existing values of h/ie^2. The manifestation of QHE in the bulk of InSe cannot be understood on the basis of the band structure, confirmed by cyclotron resonance data[6] and photoemission studies,[8] according to which the lowest conduction band and the top of the valence band lie in InSe and GaSe at $\mathbf{k} = 0$ and are virtually isotropic.[3] It must be assumed that in InSe at low temperatures electrons are localized on plane, interlayer defects, forming regions of 2D gas, responsible for the two-dimensional behavior of one of the cyclotron resonance lines[6] and QHE. As the temperature is raised the electrons are excited into isotropic states, determining the character of the exciton gas for $\mathbf{k} = 0$ in InSe and GaSe.[3,9] The properties of these crystals at high optical excitation densities, however, cannot be described based on the existence of only such (with $\mathbf{k} = 0$) an exciton gas. As the excitation density increases, new wide lines appear in the luminescence spectra of InSe, GaSe, and GaS; the energy position of the lines and the dependence of their intensity and width on the temperature and excitation density indicate that an EHL formed in the system of excitons.[5] In all three crystals such a transition is possible only in a system of indirect excitons, created as a result of excitation of electrons into a state with symmetry M_3^+ at the boundary of a hexagonal Brillouin zone, which is the bottom of the conduction band of GaS, but in InSe and GaSe lies somewhat above the three-dimensional electron band with $\mathbf{k} = 0$.

Atomic orbitals localized in a separate layer make a significant contribution to the electron density responsible for the M_3^+ band, as a result of which the M_3^+ state is more

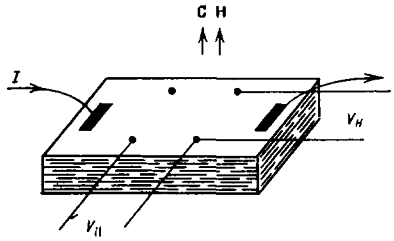

FIG. 1. InSe sample with contacts for measuring the dependences $\rho_{xx}(\mathbf{H})$ and $\rho_{xy}(\mathbf{H})$.

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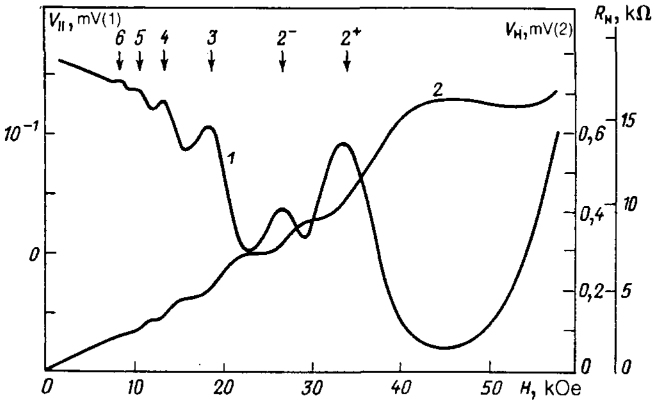

FIG. 2. Magnetic field dependence of the quantities $\rho_{xx} \sim V_{\parallel}$ and $\rho_{xy} \sim V_H$ for the sample shown in Fig. 1. In determining the values of $R_H = V_H/I_{2D}$ the two-dimensional current I_{2D} was evaluated in the linear region of the dependence $V_H(H)$ from the formula $V_H = (H/ec)I_{2D}/N_{2D}$; 2^+, 2^-, and 3 . . . denote the Landau levels.

anisotropic than the bottom of the conduction band with $k = 0$. This fact, the existence of three valleys, and the size of the effective masses of the electrons give rise[10,11] to a high equilibrium particle density in the EHL ($n_0 \approx 10^{20}$ cm^{-3} for GaS) and high critical temperatures—40 K in InSe, 90 K in GaSe, and 130 K in GaS.

Thus in a layered semiconductor plane structural defects lead to the formation of low-temperature macroscopic regions of a two-dimensional gas of carriers responsible for the QHE, and under conditions when the effects of the interparticle interaction are significant the existence of anisotropic states gives rise to restructuring of the electron spectrum.

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