I. M. Tsidil'kovskiĭ. *Gapless semiconductors: A new class of substances.* The possibility in principle that a gapless electron energy spectrum might exist was predicted in 1934 by S. P. Shubin and S. V. Vonsovskiĭ. It was established in 1955 that HgTe is a gapless semiconductor. The gapless state in crystals of HgTe and HgSe and solid solutions based on them is a result of degeneration of the electron and valence bands at the center of the Brillouin zone Γ. This degeneration is due to the cubic symmetry of the crystal and can be lifted only by a disturbance of lower symmetry—a magnetic field or a uniaxial stress. The most important parameter of electron structure—the energy gap ε_g between the neighboring Γ_6 (s-type) and Γ_8 (p-type) zones—depends on the pressure P, the temperature T, and the content x of the element in $Hg_{1-x}A_xS$ crystals (A is a group II element or other atom with an isoelectronic valence shell, S, Se, Te). Under these external disturbances, the electron spectrum undergoes significant changes, all the way up to inversion of the Γ_6 and Γ_8 zones, which corresponds to transition from a gapless (GL) to an ordinary semiconductor. Lifting the degeneracy of the Γ_8 zones, a quantizing magnetic field opens a gap $\delta(H)$, i.e., it also causes the GL-to-semiconductor transition. The value of $\delta(H)$ may become large at small $|\varepsilon_g|$. With an appropriate combination of external disturbances (P, x, H), therefore, experimental conditions can be produced such that it is possible to investigate the physical effects governed by restructuring of the electron spectrum. Transport phenomena were used as a research tool. Below we summarize the most significant results obtained in the Institute of Metal Physics (IFN) Semiconductor Laboratory in 1978–1981 on electron transitions in GL semiconductors.

1. The GL-to-semiconductor transition is accompanied in a magnetic field by freezing-out of conduction-band electrons to impurity levels or to the valence band. The exponential inccrease in the longitudinal reluctance ρ_{zz} that results from freezing-out was investigated in HgTe, $Hg_{0.9}Cd_{0.1}Te$, and $Hg_{0.85}Cd_{0.15}Te$. The possible types of freezing-out effects were classified and conditions under which band parameters can be determined from the exponential curve of $\rho_{zz}(H)$ were stated.

2. It was shown that the traditional Hall-effect method of studying electron concentration is inadequate in GL semiconductors because transport phenomena are determined by the contributions of two or three carrier types with markedly differing mobilities. Competition between the contributions of highly mobile conduction-band electrons and much less mobile carriers of the valence or acceptor bands produces anomalies in the temperature and magnetic-field curves of conductivity and the Hall effect (for example, double inversion of the Hall coefficient in p-HgCdTe). A sharp increase in conductivity was observed at $T < 5$ K owing to the decrease in the number of scattering charged acceptors, which form quasineutral complexes with donors as the temperature drops.

3. At the GL-to-semiconductor transition associated with variation of the Cd content in HgCdTe, there is a significant change in the electronic g-factor and, consequently, in the quantum-oscillation picture. It was shown that in semiconductors where there are electrons in the Γ_6 band, the g-factor is determined by interaction with the adjacent Γ_7 and Γ_8 bands, whereas distant bands make a significant contribution to the electron g-factor of the Γ_8 band in GL semiconductors.

4. A second exponential increase of $\rho_{zz}(H)$ and $\rho_{xx}(H)$ was observed in strong magnetic fields at low temperatures, $\delta(H) \gg kT$. It corresponds to the transition from impurity-band metallic conductivity to hopping conductivity. This is essentially an inverse Mott transition induced by the magnetic field, which compresses the wave functions of electrons bound to impurities and reduces the two-center overlap integral. Hopping-conductivity behavior in GL semiconductors was investigated on HgCdTe and HgMnTe crystals.

5. A qualitatively new type of electron transition occurs in HgMnTe GL semiconductors that contain magnetic substitutional atoms. The exchange interaction of band electrons with the d-electrons of Mn results in an upward shift δ_{exch} of the valence band in proportion to the magnetic moment of the d-electron system. For HgMnTe, the increment δ_{exch} is proportional to the Brillouin function, i.e., it is linear in weak fields and tends to saturation in strong ones.

In a magnetic field, therefore, the valence band first overlaps the conduction band (GL-to-semimetal transition) and this overlap is then lifted in strong fields $\delta(H) \geqslant \delta_{exch}$, with the resulting semimetal-semiconductor transition. The electron transitions described here were investigated for $Hg_{1-x}Mn_xTe$ with $0.02 \leqslant x \leqslant 0.07$.

Thus, new types of electron transitions and kinetic-effect anomalies associated with the gapless state were detected and investigated.

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