

$$h\nu_{\text{red}} = (\epsilon_{V_1 0} - \epsilon_{V_2 0}) + \frac{\pi^2 \hbar^2}{2m_{p_2} d^2} \quad (3)$$

and for $d < d_0$

$$h\nu_{\text{red}} = (\epsilon_{c0} - \epsilon_{V_2 0}) + \frac{\pi^2 \hbar^2}{2d^2} \left(\frac{1}{m_e} + \frac{1}{m_{p_2}} \right). \quad (3a)$$

Qualitatively, the form of $h\nu_{\text{red}}(1/d^2)$ remains the same as in Fig. 2, but ϵ' and ϵ'' are now defined as $\epsilon' = \epsilon_{c0} - \epsilon_{V_2 0}$ and $\epsilon'' = \epsilon_{V_1 0} - \epsilon_{V_2 0}$, i.e., we determine, besides the forbidden band of the bulk samples, also the distance between the valence band maxima at different values of \vec{k} . At the point $d = d_0$, in analogy with the preceding case, we determine the value of m_e . We note finally that, in the thickness range in question, singularities should also be observed for the transitions from the V_2 band to the conduction band.

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1) I am deeply grateful to V. B. Sandomirskii who expressed this opinion.

TRANSITION OF SEMICONDUCTORS TO A SUPERCONDUCTING STATE UNDER THE INFLUENCE OF THE FIELD EFFECT

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In superconducting semiconductors the transition to the superconducting state sets in at a carrier density small compared with that in metals, and the transition temperature T_c depends on the carrier density. In p-type GeTe, T_c changes from 0.1 to 0.3°K as the hole density is changed from 8.5×10^{20} to $1.5 \times 10^{21} \text{ cm}^{-3}$ [1]. In n-type SrTiO₃, T_c changes from 0.1 to 1.0°K as the density of the normal electron is changed from 10^{18} to 10^{21} cm^{-3} , going through a maximum at $T_c \approx 0.5^\circ\text{K}$ and at $n \approx 10^{20} \text{ cm}^{-3}$ [2]. In either n- or p-type PbTe, $T_c \approx 5^\circ\text{K}$ at an excess of Pb (n-type) density or Tl (p-type) impurity density $\sim 1 \text{ wt.}\%$ [3]. Such carrier densities can be produced in a narrow region near the surface of a superconductor by means of the field effect. To avoid misunderstanding we emphasize that we are referring here not to the surface superconductivity considered by V. L. Ginzburg and D. L. Kirzhnits [4], but to superconductivity in a space-charge layer near the surface.

Let us make a few estimates for a semiconductor having the parameters of SrTiO₃. Assume that a degenerate layer of such a superconductor serves as one electrode of a capacitor in which the dielectric is a ferroelectric material. (It is obvious that to increase the capac-

itance it is always desirable to use in the capacitor a dielectric with large dielectric constant; in the case of SrTiO_3 this is especially important because of its large dielectric constant $\epsilon \approx 10^4$). Then (for a sample which is thick compared with the screening length) the ratio of the electron density n_0 in the conduction band of the semiconductor near the surface to the electron density n_∞ deep in the layer, in the absence of a surface charge, is equal to

$$\frac{n_0}{n_\infty} = \left(1 + \frac{5}{16\pi\epsilon\mu_\infty n_\infty} D_n^2\right)^{3/5}, \quad (1)$$

where μ_∞ is the chemical potential of the electrons measured from the edge of the conduction band, and D_n is the normal component of the dielectric induction in the ferroelectric of the capacitor near the boundary with the sample in question.

We put $n_\infty = 10^{17} \text{ cm}^{-3}$, obtaining $\mu_\infty = 3 \times 10^{-5} \text{ eV}$ for SrTiO_3 with $m^* = 10m_0$ [5] at $T = 1^\circ\text{K}$; assume that $D_n = 5 \times 10^8 \text{ V/cm}$. If the dielectric constant of the ferroelectric of the capacitor is $\epsilon \approx 10^4$, then the assumed value of D_n corresponds to an electric field intensity in the capacitor $E_c \approx 5 \times 10^4 \text{ V/cm}$. At the chosen values of the parameters, Eq. (1) yields $n_0/n_\infty \approx 10^4$, i.e., $n_0 \approx 10^{21} \text{ cm}^{-3}$. This density decreases to $n/n_\infty = 10$ ($n = 10^{18} \text{ cm}^{-3}$) over a distance on the order of the screening length $l = (\epsilon\mu_\infty/4\pi q^2 n_\infty)^{1/2} \approx 2 \times 10^{-7} \text{ cm}$. For a nondegenerate semiconductor, the estimates remain practically the same.

These estimates show that with the aid of the field effect it is apparently possible to transform into the superconducting state a surface layer of a sample which would be in the normal state at the given temperature in the absence of charging.

Experiments aimed at changing T_c of metallic films by charging in the field effect have already been carried out [6]. (A value $\Delta T_c = 0.0013^\circ\text{K}$ was obtained in Sn films with ferroelectric triglycine sulfate in the capacitor). In the case of semiconductors, it is apparently possible to control the superconducting state.

In addition to the field effect, a considerable increase in the density in regions of small dimensions can also be obtained by using chemisorption, contact fields, and electric injection. This pertains, of course, both to electron and hole conductivity. Of special interest is the possibility in principle of producing and controlling with the aid of the field effect electron or hole superconductivity in the same sample.

In conclusion we note that measurements of the field effect in superconducting semiconductors make it possible to investigate experimentally screening in the superconducting state.

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ELECTRON HEATING IN THE TN-1 INSTALLATION

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Turbulent heating of a plasma by means of a high-frequency shock circuit has been the subject of many papers [1-5]. It is shown in them that when certain conditions are satisfied (in particular, $a = u_a/4v$ and $\tilde{H} = H_0$) it is possible to heat a plasma to temperatures $(T_e + T_i) = \xi \tilde{H}^2/8\pi nK$, where ξ reaches a value 0.3. Here a is the radius of the plasma column, u_a the Alfvén velocity, v the frequency of the circuit, and \tilde{H} the amplitude of the alternating magnetic field. The TN-1 installation, a diagram of which is shown in Fig. 1, was constructed to

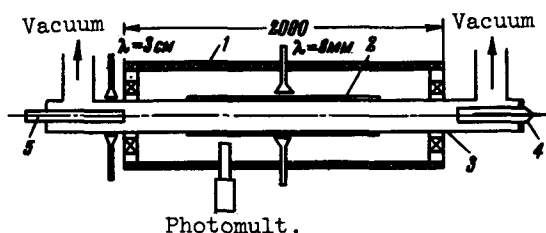


Fig. 1. Diagram of TN-1 installation. 1 - Solenoid, 2 - high-frequency shock circuit, 3 - vacuum glass chamber, 4 - plasma injector, 5 - grid probe or x-ray detector.

heat the electronic component of a plasma by this method. The quasistatic field H_0 reached a maximum within 5 μ sec, after which it decreased with a 20 msec time constant. The mirror ratio was 2, the maximum value of the field H_0 in the center of the trap was 8 kOe. The plasma was injected in the trap by a coaxial injector with electrodes made of deuterium-impregnated titanium. By varying the injector voltage it was possible to vary the plasma density from $n_e > 2 \times 10^{13} \text{ cm}^{-3}$ to $n_e < 10^{11} \text{ cm}^{-3}$. A single-turn loop with frequency $\nu = 3.5 \text{ Mc}$ at a voltage $u_c = 120 \text{ kV}$ on a capacitor $C_c = 3 \times 10^{-8} \text{ F}$ produced a field of $H = 900 \text{ Oe}$. By varying the time interval between the operation of the high-frequency loop and the application of the magnetic field, it was possible to study the heating of the electrons at different \tilde{H}/H_0 . It was expected that the electrons with $n_e = 2 \times 10^{12} \text{ cm}^{-3}$ would be heated to $T_e = 3 \text{ keV}$, and that further adiabatic compression would raise the temperature to $\sim 30 \text{ keV}$.

The experiment has shown that the cold plasma filling the trap chamber decayed as a result of recombination with a time constant $\tau_c = 300 \mu\text{sec}$. When the circuit was closed, a radial magnetohydrodynamic wave propagated in the plasma. From the readings of a magnetic probe mounted on the chamber axis, it is seen (Fig. 2) that for a compression wave (i.e., when the variable magnetic field is added to the quasistatic field), the wave front increases by 2 - 4 times steeper than the wave in vacuum. (The increase in slope of the combined wave was first observed in [6].) After the termination of the discharge in the circuit, the electron density increased by several times, and then decreased with a time constant $\tau_e = (0.25 - 0.5)\tau_c$. The average electron energy, determined from grid-probe data [7], is $\sim 200 \text{ eV}$ at $\tilde{H} = H_0$, corresponding to $nT \leq 10^{15} \text{ eV/cm}^3$. Consequently, not more than 10% of the high-frequency field energy goes into plasma heating, i.e., $\xi \leq 0.1$. Measurements of the logarithmic damping