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**Abstract**

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# DEGENERATE PINCH IN InSb

*(Presented by Academician M. A. Leontovich, 23 X 1964)*

In many experiments (see, for example, ([1], [2])) it has been found that in an electron–hole plasma of InSb conditions are realized under which the phenomenon of current breakdown exists (the so-called pinch effect). In ([2]) the radii of pinch channels were determined for 8 different InSb samples; moreover, the dependence was shown of the ratio of the pinch radius $r$ to the current $I$ in the plasma on the supplied power $W$ inside the plasma. The values of $r$ calculated from the experimental data vary within the range $(1.6 \div 4) \cdot 10^{-3}$ cm. In ([2]) the particle density reaches $10^{19}$ cm$^{-3}$, and the plasma temperature is of the order of $10^3$ °K. Under these conditions there is strong degeneracy of the electron-hole plasma of InSb, and one should use the formulas of the quantum statistics of a degenerate Fermi gas, rather than the classical formulas used by the author of ([2]). In the present work, under very simplified assumptions (the model of a free electron–hole gas), a formula is obtained expressing the relation between the radius and the current in the pinch.

**Fig. 1.** Theoretical curve of the dependence of $r$ on $I$ according to formula (5) (for $\alpha$ of order unity) on a double logarithmic scale. Points are experimental data from ([2]). The numbers at the points are the numbers of the pinch channels (see ([2])).

Applying the plasma equilibrium equation

$$\nabla p = \frac{1}{c}[\mathbf{jH}] \tag{1}$$

and the equation

$$j = \frac{c}{4\pi} \operatorname{rot} \mathbf{H} \tag{2}$$

to a cylindrical pinch, we obtain

$$2\pi c^2 r^2 (P_e + P) = I^2, \tag{3}$$

where $P_e$ and $P$ are the electron and hole pressures averaged over the cross section of the plasma cord; $I$ is the current in the cord. The pressures of electrons $P_e$ and holes $P$ are determined by the formulas (see, for example, ([3]))

$$P_{e,} = {}^1/_5 (3\pi^2)^{2/3} \frac{\hbar^2}{m^*_{e,}} n_{e,}^{5/3}. \tag{4}$$

Eliminating $n$ by the formula $n = I/e\pi r^2 v_D$, where $v_D$ is the electron drift velocity, we obtain the desired dependence between the radius and the current in the pinch

$$r = aI^{-1/4}, \tag{5}$$

$$a = (0.4)^{3/4}(3\pi)^{1/2}(c\hbar)^{3/2}(ev_D)^{-5/4} m_e^{*-3/4}. \tag{6}$$

For InSb, $m_e^* = 0.013m$, $m_h^* = 0.18m$; $m$ is the mass of a free electron.

To compare the result obtained with the experimental data [(2)], it is necessary to determine the magnitude of the electron drift velocity $v_D$. For this purpose we use the results of Ref. [(4)], where it is shown that in semiconductors the current reaches saturation when the electron drift velocity $v_D$ reaches the speed of sound $v_S$, i.e., the value $(2 \div 5) \cdot 10^5$ cm/sec. In order for our formulas (5) and (6) to agree with experiment [(2)], it is necessary to put in (6) $v_D \simeq 10 v_S$; in this case $a$ turns out to be of order unity (see Fig. 1).

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*Note: Figure translations are in progress. See original paper for figures.*