PINCH EFFECT IN SEMICONDUCTORS IN THE CASE OF BIMOLECULAR RECOMBINATION

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When a strong current flows through a semiconductor with bipolar conductivity, the spatial distribution of the carriers becomes inhomogeneous - a pinch effect is produced in the electron-hole plasma. The detailed picture of the deviation of the spatial distribution from equilibrium depends strongly on the conditions of volume and surface generation-recombination of the carriers. In those cases when the time of volume recombination of the carriers decreases monotonically with increasing carrier density (for example, bimolecular recombination), the current-voltage characteristic of the crystal is sublinear in the region of strong fields; under definite conditions, drooping characteristics are obtained. We confine ourselves here to a consideration of those cases when the rate of carrier generation is independent of the current and of the carrier density.

If the role of the surface processes is negligible, under conditions of linear (monomolecular) volume recombination the carrier density averaged over the crystal is independent in the pinch effect of the current flowing through the crystal. The current-voltage characteristic is practically linear in this case, since the magnetoresistance is usually small in the pinch effect. The influence of the surface recombination-generation in this case is discussed in [1].

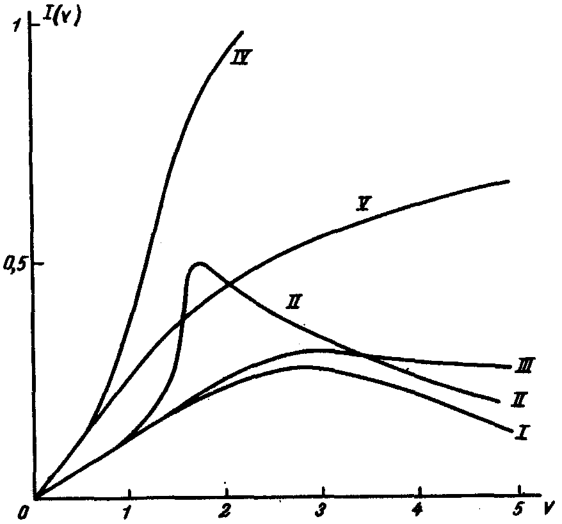
At sufficiently large deviations of the carrier density from the equilibrium value, a very typical case is that of quadratic (bimolecular) recombination. In this case, the average carrier density N in the pinch effect may decrease with increasing drift velocity v of the carriers. If the surface-recombination rate s is equal to zero, then $dN/dv < 0$ for all v. When s differs from zero, $dN/dv < 0$ only in the region of a strong drawing electric field E, when the flux of the carriers generated on the surface is close to saturation.

The form of the function N(v) in the region of large v is determined also by the geometry of the crystal and by the degree of carrier degeneracy. By large v we mean here those values of the drift velocity at which the bulk of the carriers is concentrated in a region whose transverse dimensions are smaller than the bibolar diffusion length L.

In the absence of degeneracy, the asymptotic form of the solution for a crystal in the form of an infinitesimally thin plate is of the form $N(v) \sim v^{-2/3}$, and for an infinitesimally thin cylinder $N(v) \sim v^{-2}$.

If the carriers are strongly degenerate (degeneracy of the carriers with the higher mobility is sufficient), the asumptotic form is $N(v) \sim v^{-6/11}$ in the plate and $N(v) \sim v^{-6/5}$ in the cylinder.

The total current flowing through the crystal is proportional to vN(v). The connection



Current-voltage characteristic I(v) = vN(v) in bimolecular recombination: I, III, V - Φ = 0; II - Φ = 5: IV - Φ = 7.

between the drift velocity v and the field E may be nonlinear if the carrier mobility depends on E. We shall henceforth define the current-voltage characteristic as the function I(v) = vN(v); when v ∿ E, this characteristic is the usual current-voltage characteristic. It is seen from the presented expressions that for a crystal in the form of a plate the function I(v) is sublinear for large v, and for a crystal in the form of a cylinder the characteristic has a negative slope. Thus, in the case of bimolecular recombination, the occurrence of the pinch can be detected by the start of the drooping of the current-voltage characteristic. This feature was observed experimentally by A. P. Shotov.

The figure shows typical current-voltage characteristics. Curves I, II, and III pertain to a cylindrical crystal geometry, and curves IV and V to a planar geometry. Curves I, II, and IV represent a nondegenerate plasma, and curves III and V a degenerate one. Here $\Phi = sr/d$, where r is the recombination time in a weakly-nonequilibrium plasma and d is the half-thickness of the plate (radius of the cylinder). The figure was drawn for the case L >> d with arbitrary scales for v and I; the ordinate scales are different for the plate and for the cylinder.

The main features of the current-voltage characteristics should be realized at an average current density in the crystal of about 10^5 A/cm^2.

[1] I. I. Boiko, ZhETF Pis. Red. 5, 421 (1967) [JETP Lett. 5, 343 (1967)]; Fiz. Tverd. Tela 9, 2929 (1967) [Sov. Phys.-Solid State 9, 2303 (1968)].

SCREENING OF SHOCK-WAVE RADIATION BY A GAS NOT IN THERMODYNAMIC EQUILIBRIUM AHEAD OF THE FRONT

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Experiment [1-3] and theory [4,5] show that the brightness temperature of the front of a strong shock wave is lower than the gas temperature behind the front. The gas ahead of the front is heated by the short-wave radiation and loses its transparency to the long-wave radiation of the front, as a result of which the brightness temperature corresponding to this radiation drops. Quantitative estimates of the phenomenon, obtained by Raizer [5] for a shock wave in air assuming thermodynamic equilibrium of the gas in the screening layer, are in satisfactory agreement with the experimental results [2, 3]. However, similar estimates for shock waves in argon and xenon do not agree with experiment [3]. The possible cause of the