$$\left(\frac{\partial \tilde{\varepsilon}_k}{\partial T}\right)_{\pm} = \pm \frac{g_9}{T_c}\left(\frac{4\mu}{3K_0+4\mu}\right)^2 (\lambda A)^{-\chi-1}\xi^{(\alpha-1)/\alpha}, \tag{8}$$

and for $\xi = 0$, $r \neq 0$:

$$\tilde{\varepsilon}_p = g_{10}(\lambda A)^{\alpha/(1-\alpha)}|r|^{-\alpha}, \left(\frac{\partial \tilde{\varepsilon}_v}{\partial T}\right) = \frac{g_{11}}{T_c}\left(\frac{4\mu}{3K_0+4\mu}\right)^2 (\lambda A)^{1/(1-\alpha)}\frac{|r|^{\alpha}}{r}. \tag{9}$$

It is clear from formulas (3) and (9) that in our case the thermodynamics differs appreciably from the classical one near the critical point of a liquid-gas system (4). For the MIM, in particular, c_p is proportional to $t^{-2/3}$ and not to t^{-1}.

The region of applicability of formulas (6) and (8) is bounded by the conditions $|t| \ll (\lambda b)^{1/\alpha}$ and $|\tau| \ll (\lambda A)^{1/\alpha}$ for the MIM and DIM, respectively. Such a strong dependence on λ ($1/\alpha \approx 8$ for the three-dimensional Ising model) makes it possible to observe experimentally the described effects only in substances with λb (or λA) sufficiently close to unity.

For a similar reason ($1/\varepsilon \approx 12$), the first-order transitions described in [1] are suppressed even by weak magnetic fields.

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HALL EFFECT IN SEMICONDUCTORS IN A STRONG ELECTRIC FIELD

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When a semiconductor is placed in crossed electric and magnetic fields then a current or a potential difference is produced in the third direction, depending on the boundary conditions. This is the well-known Hall effect. It is also known that in strong electric fields the Hall coefficient begins to depend on the field and can strongly deviate from the value in weak fields. Moreover, it was observed that in p-tellurium [1] the sign of the Hall constant is even reversed (the type of conductivity remaining the same). On the other hand, the current-voltage characteristics of crystals placed in a strong magnetic field have revealed not ordinary current saturation but the inverse effect, voltage saturation [2, 3]. Moreover, Moore has observed [3] a gradual transition from current saturation to voltage saturation with changing magnetic field. We shall show below that all these effects are of the same nature and are closely linked to phonon generation by supersonic carrier motion in a strong electric field [4].

When the carrier drift velocity in a semiconductor exceeds the phase velocity of the sound wave, then the spontaneous thermal lattice vibrations can become amplified [4]. The growing flux of acoustic phonons leads in turn to the occurrence of a so-called acoustoelectric force exerted by the lattice on the carriers (electrons or holes). The properties of this force were discussed in a review by one of the authors [3], and an exact expression is obtained by averaging the hydrodynamic equations over the fluctuations

$$e\mathbf{F} = \frac{e\langle n_\sim \mathbf{E}_\sim \rangle}{n_0}. \tag{1}$$

Here $e\vec{F}$ is the electroacoustic force, $n_\sim$ and $E_\sim$ are the fluctuating deviations of the carrier density and of the electric field from their mean values $n(\vec{r})$ and $\vec{E}(\vec{r})$, and n_0 is the equilibrium density. Under generation conditions, the force $e\vec{F}$ depends strongly on the coordinates (exponentially in the quasilinear approximation), and therefore all the quantities also depend on the coordinates. It can be shown that if the dimension of the inhomogeneity ℓ satisfies the conditions $\ell \gg r_D$ and $\ell \gg r_D(v_D/v_T)(\nu/\omega_0)$, then the electric field $\vec{E}(\vec{r})$, the current density $\vec{j}(\vec{r})$, and the drift velocity $\vec{v}_d(\vec{r})$, all averaged over the fluctuations, satisfy in the case $\vec{E} \perp \vec{B}$ the equations

$$\mathbf{j} = \frac{\sigma_0}{1+n^2}\{\mathbf{E}+\mathbf{F}+[\mathbf{E}+\mathbf{F}]\times\mathbf{h}\}; \quad \mathbf{v}_d = \frac{\mu}{1+h^2}\{\mathbf{E}+[\mathbf{E}\times\mathbf{h}]\};$$
$$\operatorname{div}\mathbf{j} = 0; \ \operatorname{curl}\mathbf{E} = 0, \tag{2}$$

where $r_0 = v_T/\omega_0$ is the Debye radius, $v_T = \sqrt{T_0/m}$ the thermal velocity of the carriers with effective mass m, $\omega_0 = (4\pi e^2 n_0/m\varepsilon_0)^{1/2}$ the plasma frequency, ε_0 the lattice dielectric constant, e the electron charge, $\sigma_0 = en_0\mu$ the static conductivity, $\mu = e/m\nu$ the mobility, ν the frequency of the collisions with the scattering centers, $\vec{h} = (\mu\vec{B}/c)$ the dimensionless magnetic field B, and c the speed of light. From the system (2) we easily obtain the general relation

$$\operatorname{curl}\mathbf{j} = \sigma_0 \operatorname{curl}\mathbf{F}, \tag{3}$$

from which it follows immediately that the action of the acoustoelectric force in a magnetic field leads to the occurrence of a rotational current component, so that the sample acquires a magnetic moment whose velocity is determined entirely by the acoustoelectric force.

The behavior and the connection between the current and the voltage depend strongly on the boundary conditions. We shall therefore consider two limiting cases.

1. Sample with open Hall circuit. It is convenient to divide the current density into two components, potential and rotational, $\vec{j} = \vec{j}^p + \vec{j}^r$. According to (3), $\vec{j}^r = \sigma_0\vec{F}^r$ and $\vec{j}^p = \vec{j} - \vec{j}^r$ ($\vec{F}^r$ is the rotational component of the force). We can then impose the following conditions: $J_y^p = j_z^p = 0$, $\int_0^{L_x} E_x dx = V$, $h \parallel z$, where L_x, L_y, and L_z are the sample dimensions along the corresponding axes and V is the potential difference. By defining the Hall coefficient as the ratio of the Hall emf $_H(x) = (1/L_y)\int_0^{L_y} E_y dy$ to the average current density $I_x/L_yL_z = (1/L_y)\int_0^{L_y} j_x(x,y)dy$, we readily obtain

$$R_H(x) = R_H^0 - \frac{L_z}{BI_x}\int_0^{L_y} F_y^p\,dy\,, \tag{5}$$

where $R_H^0 = (1/en_0c)$ is the value of the coefficient in weak fields $F_y^p = F_y - F_y^r$ is the potential part of the force component F_y, and

$$I_x/L_yL_z = \sigma_0\left(\frac{V}{L_x} + \frac{1}{L_xL_y}\int_0^{L_x}dx\int_0^{L_y}dyF_x\right).$$

An analysis shows that $F_y^p > 0$ when $F_x < 0$ and that F_y^p also increases with increasing electric field. The current I_x then saturates. It can be shown that in the saturation region, where $I_x \simeq L_yL_zen_0v_s$ (v_s is the speed of sound) the ratio R_H/R_H^0 satisfies the inequality

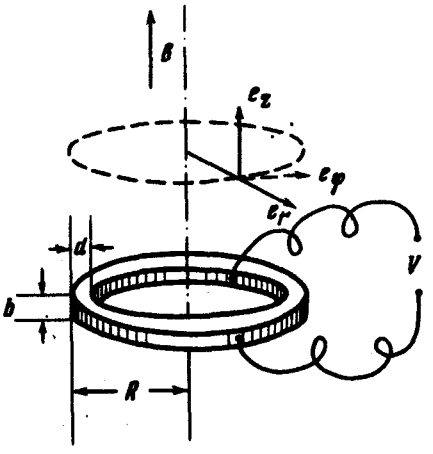
$$\frac{|R_H|}{R_H^0} \geqslant \frac{V}{L_x}\frac{\mu}{v_s}\Big/(1+h^2) - 1\,. \tag{6}$$

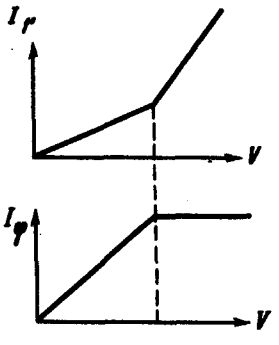
The sufficient condition for the reversal of the sign in the current-saturation region is $(V/L_x)(\mu/v_s) \simeq 1 + h^2$. Experiments [1][1)] yielded $1 + h^2 \simeq 10$ at the criterion (6) was indeed satisfied. The sign reversal occurred at $(V/L_x)(\mu/v_s) \simeq 4$, which agrees with our estimate $(V/L_x)(\mu/v_s) \simeq 10$. The analysis described above was based on the assumption that the directions of the force $e\vec{E}$ and $\vec{v}_d$ are antiparallel. This is indeed the case in isotropic crystals or in substances having a single anisotropy axis that coincides in our coordinate system with the x axis. This is indeed how the experiment on p-Te was performed [1]. A case is also possible wherein the natural anisotropy of the crystal (connected, for example, with the anisotropy of the constants of the electron-phonon interaction) at not too high drift velocities (but larger than the speed of sound) turns out to be dominant and will determine the sign of the force component eF_y^p. In a suitable geometry this can lead to a growth of the Hall coefficient on the initial section (beyond the phonon-generation threshold). With further increase of the field, on the other hand, the decisive role is assumed by the anisotropy connected with the drift velocity, and the Hall coefficient begins to decrease. Thus, the coefficient should have a maximum as a function of the field. This effect was apparently observed by Zucker in p-Ge [5]. Finally, in very strong fields we have $F \to 0$ and the Hall coefficient should reverse sign again. In addition, it is easy to show that $F_y = 0$ and $R_H = R_H^0$ when $x = 0$. Thus, the Hall coefficient and its sign should depend on the coordinate x.

2. Sample with closed Hall circuit. Such conditions are easiest to realize in the geometry of a Corbino ring, with the electrodes placed on the cylindrical surfaces (see the figure) and the magnetic field is perpendicular to its plane. The boundary conditions are then

[1)] The authors are grateful to Professor S. Tanaka (Tokyo University) for a preprint of his paper.

$$\int_{R-d}^{R} E_r\,dr = V, \quad E_\phi = 0, \quad i_z = 0, \quad h \parallel z. \tag{7}$$





Using (7) we obtain for the currents I_r in the source circuit and I_ϕ in the ring itself, respectively,

$$I_r = 2\pi b \ln\left(\frac{R}{R-d}\right) \frac{\sigma_0}{1+h^2}\left\{V - \int_{R-d}^{R} (hF_\phi - F_r)\,dr\right\}, \tag{8}$$

$$I_\phi = \frac{b\sigma_0}{1+h^2}\left\{hV + \int_{R-d}^{R} (F_\phi + hF_r)\,dr\right\}. \tag{9}$$

It is seen from (8) that the sign of the increment to the ohmic current depends on the sign of the difference $hF_\phi - F_r$. It can be shown that $F_\phi < 0$ and $F_r < 0$ when $v_{dr} > 0$. In sufficiently strong magnetic fields ($h \gg 1$) the electron drift is principally tangential to the ring and $|hF_\phi| > |F_r|$, so that the increment of the ohmic current will be positive. Moreover, it can be shown that $F_r/F_\phi \approx v_{dr}/v_{d\phi} = 1/h$. The current I_r satisfies therefore the relation

$$I_r = 2\pi b \ln\left(\frac{R}{R-d}\right) \frac{\sigma_0}{1+h^2}\left\{V + \frac{h^2-1}{h}\int_{R-d}^{R} |F_\phi|\,dr\right\}. \tag{10}$$

It is seen from (10) that with increasing magnetic field there should occur a smooth transition from current saturation to voltage saturation. This transition occurs at $h = 1$. Physically this is connected with the fact that in crossed field the force $e\vec{F}$ leads to a decrease of the length of the current vector (tendency to saturation) and to its rotation about the vector $\vec{B}$ (tendency to increase the current projection I_r). As a result the projection on the direction E_r may either increase or decrease, depending on which of the tendencies predominates. It is clear that in strong magnetic field even a slight rotation of the current vector leads to a sharp increase of the projection. On the other hand, in strong electric fields the deflection of the currents, produced by the force, is so strong that further rotation of the current cannot compensate for the decrease of the length of the current vector, i.e., saturation should be observed. In still stronger fields, when $F \to 0$, the current-voltage characteristic should have the same slope as in the initial section in subcritical fields. This is precisely the type of current-voltage characteristic observed by Moore in CdS [3].

We note finally that the phonon flux generated in the ring, under conditions when the phonon-phonon collisions are significant, transports momentum and a kinematic effect should therefore be observed, wherein the ring is rotated in a direction opposite to that of the flux.

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FEASIBILITY OF AN ADSORPTION-GASDYNAMIC LASER

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The operation of the gasdynamic laser [1 - 4] is based on processes of vibrational relaxation of polyatomic molecules, which result from paired collisions of the molecules in the volume of the gas.

The purpose of the present article is to show that non-equilibrium expansion of a two-phase gas-aerosol system in a supersonic nozzle can be accompanied by inversion of the population of the vibrational levels of polyatomic anisotropic molecules, as a result of vibrational relaxation of the molecules in the adsorbed state on the surface of the aerosol particles. The surface relaxation greatly increases the number of molecular gases in which population inversion can be obtained by the gasdynamic method.

We assume that the adsorption has a dynamic character, i.e., within the time scale characteristic of the problem, the molecule is in the adsorbed state many times, and that physical adsorption on the surface occurs at a temperature higher than the critical two-dimensional-condensation temperature [5].

The dependence of the average lifetime of the molecule in a two-phase gas-aerosol system on the type of vibrational level of the molecule is due to the joint action of three factors: 1) the adsorbed molecule is oriented in a definite manner relative to the surface of the adsorbent; 2) the damping of different vibrational modes of the molecule depends on its orientation in the adsorbed state; 3) the time of stay on the surface also depends on the orientation of the molecule. For clarity, we shall consider the CO_2 molecule, and to simplify the calculations we assume that the rotational motion of the molecule in the adsorbed state is suppressed and that the molecule can be oriented either parallel or perpendicular to the surface.

Let us determine the dependence of the time of stay of the molecule in the adsorbed state on its orientation. The density of the fluctuating electromagnetic fields, which exists near the surface of the adsorbent, decreases like $1/r^3$ with increasing distance r from the surface. The energy of interaction of the molecule with this field gives the dispersion component of the Van-der-Waals forces. If we assume that the main cause of the difference between the absorption energies for two orientations is the change of the distance between the center of the molecule and the surface of the absorbent, then

$$\gamma = E_{\perp}/E_{\parallel} = (b/a)^3,$$

where a and b are the dimensions of the electron cloud of the molecule parallel and perpendicular to the molecule axis. Taking b/a = 0.7 for the CO_2 molecule,