where $B^i_{o,2}(n)$ are the coefficients of magnetoelastic coupling of the n-th sublattice, $I_{5/2}$ the hyperbolic Bessel function, L^{-1} the inverse Langevin function, and m_n the temperature dependence of magnetization of the n-th sublattice.

The temperature dependence of the magnetization of the octahedral and tetrahedral sublattices of the lithium ferrite were measured by the neutron diffraction method between 4 and 904°K in [6], and used by us for the calculations. In the calculations we assumed that the elastic constants C_{11}, C_{12}, and C_{44} do not depend on the temperature. The coefficients of the magnetoelastic coupling were calculated from the values of the magnetostriction constants at two different temperatures. The obtained calculated dependences of λ_{100} and λ_{111} on the temperature are represented by the solid lines of Fig. 2. The agreement between calculation and experiment is good.

[1] I. Kanamori, Magnetism, vol. 1, Academic Press, 1963.

[2] P. B. Braun, Nature 170, 1123 (1952).

[3] G. A. Petrakovskii and Yu. N. Kotyukov, FTT 7, 2339 (1965), Soviet Phys. Solid State 7, 1892 (1966).

[4] R. L. Comstock, PEEE No. 10, 1698 (1965).

[5] E. R. Callen, A. E. Clark, B. De Savage, W. Coleman, and H. B. Callen, Phys. Rev. 130, 1735 (1963).

[6] E. Prince, J. de Phys. 25, 503 (1964).

NEGATIVE CONDUCTIVITY PRODUCED UNDER THE INFLUENCE OF HYPERSONIC FLUX

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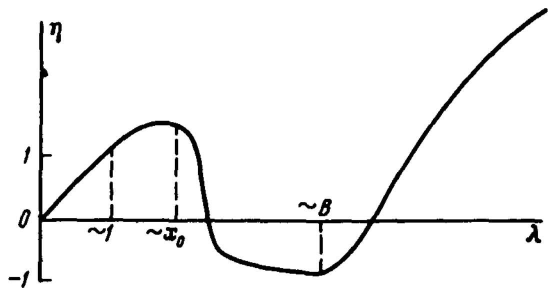
1. We wish to call attention in this note to the fact that negative differential conductivity is possible when a semiconductor is simultaneously under the influence of an electric field and a sound wave whose length lies in the quantum region ($q \gtrsim 1/\hbar\sqrt{mT}$, q - sound wave vector, m - electron effective mass, T - crystal temperature in energy units). Moreover, in the case of a sufficiently strong hypersound flux, the voltage-current characteristic can cross the abscissa axis when the electric field is increased, corresponding to a reversal in the sign of the current density.

From the energy and momentum conservation laws it follows that only electrons with momenta $p > \hbar q/2$ interact with the phonons. If the sound flux through the sample has a frequency so high that $\hbar q \gg \sqrt{mT}$, then there will be practically no sound absorption and the acoustoelectric current will be equal to zero. Let us apply to the crystal an electric field E such that the vectors eE and q are antiparallel. So long as the field is weak, it affects only the antisymmetrical part of the electron distribution function, so that the acoustoelectric current remains equal to zero, and the total current is proportional to the field. But when the energy eEl acquired by the electron on the free path l becomes comparable with $(ms^2T)^{1/2}$ (s - speed of sound), the average electron energy begins to increase [1]. In a sufficiently strong electric field, the thermal de Broglie wavelength of the electron becomes smaller than the wavelength of the sound, as a result of which a non-zero acoustoelectric current appears, in a direction opposite to the current due to the applied electric field. If the sound flux is sufficiently strong (and this is the most interesting case, which is considered here), then the total current in the electric-field direction will decrease with increasing average electron energy and reverse sign.



2. The foregoing is confirmed by direct calculation carried out in the electron-temperature approximation [2-4].

Starting from the kinetic equation for the electrons interacting with the electric field $\vec{E}$, the hypersound flux W, and the thermal phonons (or impurities), we obtain for the case $e(\vec{E}\cdot\vec{W}) = -|eEW|$ the following equations for the current density j and the electron temperature T_e:

$$\eta = \frac{1}{\Gamma(5/2)}\left[\gamma\left(\frac{5}{2}+a, \frac{x_0}{\xi}\right)\lambda\xi^a - \Gamma\left(\frac{5}{2}, \frac{x_0}{\xi}\right)\right] + O(B^{-1}), \tag{1}$$

$$\xi - 1 = \frac{A}{\Gamma(5/2)}\left[\gamma\left(\frac{5}{2}+a, \frac{x_0}{\xi}\right)\lambda^2\xi^{a+b} + \Gamma\left(\frac{5}{2}-a, \frac{x_0}{\xi}\right)\xi^{b-a}\right] + O(B^{-1}). \tag{2}$$

Here $x_0 = \hbar^2 q^2/8mT$, $\xi = T_e/T$, $\eta = j/ens$, $\lambda = eE\tau_i(T)/ms$, $B = \pi^2\hbar^4 qW/8m^2sT^3 \gg 1$, n is the electron density, and $\tau(\epsilon)$ is the electron momentum relaxation time; a and b are determined by the expressions for the electron momentum and energy relaxiation times: $\tau_i(\epsilon) = \tau_i(T)/(\epsilon/T)^a$, $\tau_e(\epsilon) = \tau_e(T)(\epsilon/T)^b$; $A = [\tau_e(T)/\tau_i(T)](ms^2/T)$, $\gamma(c, z) = \Gamma(c) - \Gamma(c, z) = \int_0^z e^{-x}x^{c-1}dx$. Equations (1) and (2) pertain to the case $B \gg \lambda$ and $B \gg x_0$; the direction of the electric field is taken as positive in (1).

In the quantum frequency region ($x_0 \gg 1$) and in a weak electric field ($\lambda \ll 1$) we have $\xi - 1 \sim \lambda^2$ and $\eta \sim \lambda$ (cf. [2]). In the case of a strong electric field ($\lambda \gg x_0$) with $a > b - 1$ we get

$$\xi = \left[\frac{A}{\left(\frac{5}{2}+a\right)\Gamma\left(\frac{5}{2}\right)}\right]^{2/(7-2b)} x_0^{(5+2a)/(7-2b)}\lambda^{4/(7-2b)}, \tag{3}$$

$$\eta = -1 + \left[\left(\frac{5}{2}+a\right)\Gamma\left(\frac{5}{2}\right)\right]^{-1}\xi^{-5/2}\lambda. \tag{4}$$

Finally, when $\lambda \gg B \gg x_0$ the principal role is assumed by the electric field, and the voltage-current characteristic should have the same form as in the absence of the sound flux. Thus, the general appearance of the voltage-current characteristic should be such as shown in the figure.

The presence of a descending section on the voltage-current characteristic can lead to development of domain instability [5,6].

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[1] B. I. Davydov, JETP 7, 1069 (1937).
[2] W. Shockley, Bell Syst. Techn. J. 30, 990 (1951).
[3] H. Frohlich and B. V. Paranjape, Proc. Phys. Soc. B69, 21 (1956).
[4] I. M. Dykman and P. M. Tomchuk, FTT 2, 2228 (1960), Soviet Phys. Solid State 2, 1988 (1961).
[5] B. K. Ridley, Proc. Phys. Soc. 82, 954 (1963).
[6] V. L. Bonch-Bruevich and Sh. M. Kogan, FTT 7, 23 (1965), Soviet Phys. Solid State 7, 15 (1965).

COLLECTIVE PROPERTIES OF LARGE-RADIUS EXCITONS

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In certain semiconductors (Ge, CdS. GaAs) the Bohr radius of the exciton becomes quite large, $a_0 = \hbar^2\epsilon/me_0^2 \sim 10^{-6}$ cm. Excitons with such a radius begin to "touch" at relatively low densities $n \sim a_0^{-3} \sim 10^{18}$ cm^{-3}, which are perfectly attainable by modern experimental means. It is clear that when $na_0^3 \sim 1$ the excitons influence one another greatly and, in particular, the Bohr level of the exciton $E_0 = -me_0^4/2\hbar^2\epsilon^2 \sim -10^{-2}$ eV should, in general, change by an amount equal to its own value. It is obvious that when $na_0^3 \gtrsim 1$ the exciton is not a good quasiparticle [1] and the model of non-ideal Bose gas of excitons is just as poor as the model of a non-ideal Bose gas of Cooper pairs for a superconductor. The limiting case $na_0^3 \gg 1$ was considered earlier [2,3]. In this article we report results pertaining to the opposite case, $na_0^3 \ll 1$. We shall show that in this limit the excitons cannot be regarded rigorously as Bose particles when speaking of collective effects. The reason is that the properties of the electrons and holes forming the excitons become renormalized as functions of n. Allowance for this fact introduces in all the formulas contributions of the same order as allowance for the non-ideal nature of the exciton gas. A rigorous investigation of this question is especially interesting in connection with the fact that many workers [4-6] have predicted Bose-condensation of excitons on the basis of the concept of excitons as Bose particles.