Hence, it follows that the dependence $\varphi^M(c)$ is curved more strongly at its minimum than the dependence $\varphi^A(c)$, provided the inequality (3) is satisfied.

LITERATURE CITED


DRAG THERMOELECTRIC POWER OF UNIAXIALLY DEFORMED n-TYPE Ge
IN QUANTIZING MAGNETIC FIELDS

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An investigation is made into the drag thermoelectric power of pure n-type Ge deformed strongly along [111] in quantizing magnetic fields for the phonon–phonon relaxation mechanisms of Herring and Simons. Calculations are made for a wide range of magnetic fields from classical strong fields to maximal quantizing fields, including the region of so-called weak quantization. An experiment is suggested that could indicate the mechanism of phonon–phonon relaxation.

Several studies, both theoretical and experimental (see the reviews [1, 2]), have been devoted to the drag thermoelectric power of anisotropic semiconductors in quantizing magnetic fields. However, the theoretical studies have been made in the region of limiting quantization $\gamma_0 = \hbar \Omega / 2kT \gg 1$ ($T$ is the temperature and $\Omega$ the cyclotron frequency) [1, 3], while the region $\gamma_0 \lesssim 1$ of intermediate fields has been hardly studied. In the present paper, we investigate this region of fields.

By the Onsager relation $\Pi_{\|\perp}(H) = T z_{\||\perp}(-H)$, the calculation of the tensor $z_{\||\perp}(H)$ of the thermoelectric power reduces formally to the finding of the Peltier tensor $\Pi_{\|\perp}(-H)$, which is found from the equation $\mathcal{W}_i = \Pi_{\|\perp}(H) J_{\|\perp}$, where $J_{\|\perp}$ are the components of the density of the electric current;

$$\mathcal{W}_i = \frac{1}{V} \sum_{\mathbf{q}} N_q \mathbf{E}_q \mathbf{S}_q \mathbf{j}_q / q$$

are the components of the heat flux density of the phonons due to their drag by the electrons; $N_q$ is the nonequilibrium correction to the distribution function of the phonons of polarization $\lambda$ and wave vector $\mathbf{q}$; $E_q = S_\lambda \cdot q$ is the energy of the phonons; $S_\lambda$ is the velocity of sound of the corresponding polarization; and $V$ is the volume of the crystal.

This method of finding the thermoelectric power (the so-called \( \Pi \) approach \([4]\)) makes it possible to consider an isothermal problem, which significantly simplifies the calculations in quantizing magnetic fields.

The nonequilibrium correction \( N_{q\lambda} \) due to the interaction of the phonons with electrons of a definite valley has the form \([3]\) (we assume that \( \kappa T/E_{q\lambda} \gg 1 \))

\[
N_{q\lambda} = -i\tau(q)|G_i(q)\|^2 \langle q_s - M_{1\lambda}/M_{3\lambda}q_\lambda \rangle \cdot F \cdot E_y/E_{q\lambda} \gamma_{1\lambda} m_c,
\]

where

\[
F = \int_{-\infty}^{+\infty} dt \cdot \cos (E_{q\lambda} t) \cdot S_0(t), \quad S_0(t) = \delta \cdot e^{-i\tau(q)e_{q\lambda}h_{\lambda}\gamma_{1\lambda} - iq_{\lambda}h_{\lambda}}.
\]

\( V \cdot n \cdot \exp \left\{ - (t^2/\beta - i\lambda) q_{\lambda}^2/2m_0 \right\} - Z_0 \left[ \cos \left( t - i\beta/2 \right) h_\lambda \right] \),

Here, \( \hat{H}_0 \) is the Hamilton operator of the electrons in the magnetic field; \( n \) is the concentration of the electrons of a definite valley; \( E \) is the electric field intensity; \( \tau(q) \) is the relaxation time of the long-wavelength acoustic phonons of polarization \( \lambda \) on the thermal phonons; \( \beta = 1/\kappa T \);

\[
Z_0 = \beta/4m_{1\lambda} \sin \tau_0 \cdot \Pi_{1\lambda} \cdot \left[ M_{3\lambda} (q_\lambda - M_{2\lambda}/M_{3\lambda}q_\lambda)^2 + (\Pi_{1\lambda}q_x + \Pi_{2\lambda}q_y + \Pi_{3\lambda}q_z)^2 \right],
\]

where \( \Pi_{1\lambda} = (1/m^*)_{1\lambda} \) are the components of the tensor of the reciprocal dimensionless effective electron mass; \( m_0, m_c, \) and \( m^* \) are the free-electron mass and cyclotron and effective masses along the field, respectively; \( M_{ik} \) is the cofactor of the element \( \Pi_{1\lambda} \) of the determinant formed from the components of the tensor of the reciprocal dimensionless effective electron mass;

\[
G_i(q) = i(2\beta VS_{q\lambda})^{-1/2} \sum_{ik} D_{ik} e_{q\lambda}^i e_{q\lambda}^k
\]
determines the electron-phonon interaction (\( \alpha \) is the density of the crystal); \( D_{ik} \) are the components of the deformation potential tensor; and \( e_{q\lambda}^j \) is the polarization unit vector of the phonons of mode \( \lambda \).

We consider \( n \)-type Ge deformed elastically along [111]. At sufficient compression, due to intervalley redistribution, all the electrons go over into the valley aligned along the [111] axis \([5]\). We investigate the drag thermoelectric power of such \( n \)-type Ge when the quantizing magnetic field is directed along the deformation axis. Then in the coordinate system associated with the principal axes of the tensor of the effective electron mass of the given valley, Eq. (1) takes the form

\[
N_{q\lambda} = -i\tau(q)|G_i(q)\|^2 \langle q_s - M_{1\lambda}/M_{3\lambda}q_\lambda \rangle \cdot F \cdot E_y/E_{q\lambda} \gamma_{1\lambda} m_{1\perp},
\]

where \( m_{1\perp} \) is the effective mass of an electron in the direction orthogonal to the magnetic field.

We use the relation

\[
\int_{-\infty}^{+\infty} dt \cdot \cos (E_{q\lambda} t) \cdot S_0(t) = i\beta/2 \int_{-\infty}^{+\infty} dt \cdot \cos (E_{q\lambda} t) \cdot S_0(t),
\]

whose validity (in the investigated approximation \( \kappa T/E_{q\lambda} \gg 1 \)) can be readily proved by going over to the new variable \( x = t - i\beta/2 \) and displacing the contour of integration. Then, going over to the Landau representation, we can write

\[
F = i\beta \sum_{xx} e^{-\beta E_x} |< x | e^{iq\hat{A}\gamma} | x > |^2 \delta \left[ E_x - E_s + E_{q\lambda} \right] + \delta \left( E_{q\lambda} - E_s - E_{q\lambda} \right),
\]

where \( x = n, p, s, q \) are the quantum numbers of an electron in the magnetic field, \( E_s \) is its energy, and \( < x | \hat{A} | x > \) is the matrix element of the operator \( \hat{A} \) calculated with Landau wave functions.

It is convenient to reduce Eq. (3) to the form

*In Eq. (2) of [3] a factor \( i \) has been omitted.