ON THE NATURE OF ELECTRICAL ACTIVITY IN SUPERFLUID HELIUM AT SECOND SOUND EXCITATION

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Polarization of superfluid helium (HeII) during the second sound excitation, which was observed by Rybalko (Fiz. Nizk. Temp. **30**, 1321 (2004)), has been explained as the inertial polarization of a dielectric medium $\mathbf{P} \approx -\kappa m_4 \dot{\mathbf{v}}/(4e)$, where κ is the polarizability of HeII, m_4 the atomic mass of ^{4}He, e the electron charge, and $\dot{\mathbf{v}}$ the mechanical acceleration. For the second sound waves, the acceleration is chosen as the time derivative of the relative velocity of the normal component with respect to the superfluid one. The ratio between the amplitudes of temperature and electrostatic potential oscillations in the second sound standing wave has been obtained: $\Delta T/\Delta\varphi = 2ef(T)/k_\mathrm{B}$, where $f(T) = \rho_n(T)/\sigma(T)$, $\rho_n(T)$ is the density of the normal component normalized to the total HeII density, k_B the Boltzmann constant, and $\sigma(T)$ the entropy per ^{4}He atom in units of k_B. The dimensionless parameter $f(T)$ is almost temperature-independent in the range 1.3 K $\le T \le$ 2 K, being close to unity, but it drops rapidly with the temperature decrease at $T <$ 1.3 K. Consequently, additional measurements in the low-temperature range have been proposed to elucidate the mechanism of HeII polarization in the second sound wave.

1. Introduction

The centenary of low-temperature physics—the branch of science started by Kamerlingh Onnes [1] by producing liquid helium (^{4}He) for the first time in August, 1908—and the 70-th anniversary of the discovery of superfluidity in liquid helium, made by Kapitsa [2] and Allen and Misener [3] in 1938, are almost synchronized with the 90-th anniversary of the National Academy of Sciences of Ukraine (NASU) and the 80-th anniversary of the Institute of Physics of the NASU. Plenty of new phenomena and unique properties have been revealed for a century of experimental and theoretical researches of normal (HeI) and superfluid (HeII) liquid helium, a quantum Bose liquid.

Recently, in work [4] by Rybalko, the electric activity of HeII has unexpectedly been found below the λ-point (T_λ = 2.18 K). Namely, when standing waves of the second sound were excited in a resonator, a time-dependent potential difference with the amplitude $\Delta\varphi \approx (10 \div 100)$ nV between the metal body of the resonator and an isolated electrode was observed. Temperature, T, and potential, φ, oscillations were cophased, and the ratio between their amplitudes (ΔT and $\Delta\varphi$, respectively) did not depend on T within the temperature interval 1.4 K $\le T \le$ 1.8 K, obeying—with a relative accuracy of 25%—the relation

$$\frac{\Delta T}{\Delta U} \cong \frac{2e}{k_\mathrm{B}} = 2.3188 \times 10^4 \text{ K/V}, \tag{1}$$

where e is the electron charge, and k_B the Boltzmann constant.

It should be noted that a possibility of static polarization of HeII was indicated for the first time in work [5], where the influence of polarization on the first sound velocity along and across the electric field direction was considered. It was found there that the motion of HeII in strong fields with the strength E of about 10^8 V/cm that occurred normally to the field direction gave rise to a superfluidity destruction.

The first attempt to explain the experimental data of work [4] was done by Kosevich [6]. He supposed that the quadrupole moments of ^{4}He atoms became macroscopically ordered in the superfluid state. However, the issues on the microscopic nature of such quadrupole moments and on the mechanism of their ordering remained unanswered.

In work [7] by Melnikovsky, an assumption was put forward that the electric polarization of HeII in the second-sound standing wave is associated with a general inertial mechanism of atom polarization in dielectric media, being similar to the Stewart–Tolman effect in metals [8]. In that theory, the vector of macroscopic polarization was determined, by the order of magnitude, as

$$\mathbf{P} \approx -\frac{\kappa M}{2Ze}\dot{\mathbf{v}}, \tag{2}$$

where $\kappa = (\varepsilon - 1)/(4\pi)$ is the polarizability of a medium with the dielectric permittivity ε, M the mass of an atom, Z the total number of electrons in its electron shell, and $\dot{\mathbf{v}}$ the mechanical acceleration ($\mathbf{v}$ is the velocity, and the dot means a time derivative). For liquid ^{4}He, the parameters are $\kappa \approx 4.5 \times 10^{-3}$, $M = m_4 \approx 6.68 \times 10^{-24}$ g, and $Z = 2$.

In work [7], the quantity $\mathbf{P}$ for HeII was calculated by analogy with a procedure for normal liquid [9], i.e. by averaging over thermal fluctuations, the role of which is determined by thermodynamic equilibrium phonons. As a result, on the basis of the virial theorem on the equality between the average values of the kinetic and potential energies of phonons, the following expression was obtained for $\mathbf{P}$:

$$\mathbf{P} = \frac{\kappa m_4}{4e}\left[\frac{1}{\rho}\left(1 - \frac{\delta W}{c_1^2}\right)\nabla p - \frac{1}{3}C(T)\nabla T\right], \tag{3}$$

where p and ρ are the pressure and the density of HeII, respectively; c_1 is the velocity of the first (hydrodynamic) sound in liquid heliums ($c_1 \approx 236$ m/s); and δW and $C(T)$ are the enthalpy and the specific heat, respectively, of the equilibrium Bose gas of phonons, so that $C(T) \sim T^3$ (see works [10, 11]).

When second sound waves propagate in liquid helium, then, owing to an anomalously low coefficient of thermal expansion of HeII, the relation $\nabla p = 0$ holds true with a high accuracy [12]. For this case, the following expression was obtained for the potential difference U between the opposite walls of a half-wave resonator [7]:

$$\Delta U \approx 4\pi \int \mathbf{P} dx \approx -\frac{(\varepsilon - 1) m_4}{12e} C(T)\Delta T. \tag{4}$$

Expression (4) does not agree with empirical relation (1) by both the order of magnitude and the temperature dependence. Moreover, relation (3) cannot be applied in the temperature interval of measurements reported in work [4], because the basic contribution to the thermodynamic properties of HeII at $T > 1$ K is given by the Boltzmann gas of thermally excited rotons rather than by phonons [10, 11]. Therefore, the consideration carried out in work [7] can be applied only to a range of rather low temperatures, $T < 1$ K.

In work [13], the macroscopic polarization of HeII in the second sound wave was associated with the inertial separation of charges belonging to two boson condensates: a negatively charged electron one, which consists of strongly correlated singlet electron pairs in the filled shells of ^{4}He atoms, and a positively charged nuclear one consisting of heavy nuclei with zero spins (α-particles). In the framework of this approach, taking a large difference between the electron and nuclear masses into account and supposing that the polarization of HeII in the second sound wave is a bulk effect rather than a surface one and the electric field is potential – i.e.

$$\mathbf{P} = \kappa \mathbf{E} = -\kappa \nabla \varphi, \tag{5}$$

where $\mathbf{E}$ is the strength of the induced field, and φ its potential – the following ratio between ΔT- and $\Delta\varphi$-amplitudes was obtained:

$$\frac{\Delta T}{\Delta \varphi} = \frac{4e}{\sigma(T)}. \tag{6}$$

Here, $\sigma(T)$ is the entropy of HeII per ^{4}He atom (its dimension coincides with that of the Boltzmann constant k_B). In work [13], to put Eqs. (6) and (1) into agreement, an assumption was made that the entropy of HeII includes a constant component $\sigma_0 = 2k_\mathrm{B}$, which is independent of T. However, such an assumption does not agree with conventional ideas concerning the zero entropy of the superfluid component. It also contradicts the temperature dependence of the second sound velocity [12].

Recently, another hypothetical mechanism of the HeII polarization in the second sound wave has been proposed [14]. It is based on an assumption that there are microscopic quantum vortex rings in HeII. But such rings are possible only if a strongly developed vortex turbulence takes place in HeII. However, there are no reasons at the excitation and propagation of second sound waves with a small amplitude for such a turbulence to emerge.

In this work, we show that, in the framework of the phenomenological approach, the inertial polarization of the normal and superfluid components of HeII in a second-sound standing wave is governed by the relative acceleration of those components $\dot{\mathbf{w}} = (\dot{\mathbf{v}}_n - \dot{\mathbf{v}}_s)$ and characterized by the following ratio between the amplitudes of temperature and electric potential oscillations:

$$\frac{\Delta T}{\Delta \varphi} = \frac{2e\rho_n(T)}{m_4 S(T)} = \frac{2e}{\sigma(T)}\frac{\rho_n(T)}{\rho}, \tag{7}$$

where $S(T)$ is the entropy per unit volume, and $\rho_n(T)$ the density of the normal component of HeII.

The temperature dependence of the right-hand side of relation (7) is characterized by an almost constant value close to $2e$ with an accuracy of 25% in the interval 1.3 K $\leq T \leq T_\lambda$, which agrees with experimental data [4]. However, at $T < 1.3$ K, the right-hand side of relation (7) drops rapidly as the temperature decreases, down to zero at $T \to 0$. Therefore, to elucidate the issue concerning the mechanism of the HeII polarization, when the second sound waves are excited, it is necessary to measure this effect in the low-temperature range.

2. Inertial Polarization of HeII at Second Sound Wave Excitation

In the framework of the macroscopical approach, the property of HeII are described by the equations of two-liquid hydrodynamics [11, 15]

$$\frac{\partial \rho}{\partial t} + \mathrm{div}\left(\rho_n \dot{\mathbf{v}}_n + \rho_s \dot{\mathbf{v}}_s\right) = 0; \tag{8}$$

$$\frac{\partial S}{\partial t} + \mathrm{div}\left(S \mathbf{v}_n\right) = 0; \tag{9}$$

$$\frac{d\mathbf{v}_s}{dt} = \frac{\partial \mathbf{v}_s}{\partial t} + \left(\mathbf{v}_s \nabla\right) \mathbf{v}_s = -\nabla \mu; \tag{10}$$

$$\rho_n \frac{d\mathbf{v}_n}{dt} + \rho_s \frac{d\mathbf{v}_s}{dt} + \mathbf{v}_n \frac{\partial \rho_n}{\partial t} + \mathbf{v}_s \frac{\partial \rho_s}{\partial t} + \mathbf{v}_n \nabla\left(\rho_n \mathbf{v}_n\right) +$$

$$+\mathbf{v}_s \nabla\left(\rho_s \mathbf{v}_s\right) = -\nabla p, \tag{11}$$

where ρ_n and ρ_s are the partial densities of the normal and superfluid components, respectively; $\mathbf{v}_n$ and $\mathbf{v}_s$ are the corresponding hydrodynamic velocities; $\rho = \rho_n + \rho_s$ is the total density of HeII; S the entropy per unit volume; and μ the chemical potential, the gradient of which equals

$$\nabla \mu = \frac{1}{\rho} \nabla p - \frac{S}{\rho} \nabla T - \frac{\rho_n}{2\rho} \nabla \left(\mathbf{v}_n - \mathbf{v}_s\right)^2. \tag{12}$$

From Eqs. (8) and (12), it follows that the characteristic velocities for HeII are the hydrodynamic mean-mass velocity

$$\mathbf{v} = \frac{1}{\rho}\left(\rho_n \mathbf{v}_n + \rho_s \mathbf{v}_s\right), \tag{13}$$

and the relative velocity between the normal and superfluid components

$$\mathbf{w} = \left(\mathbf{v}_n - \mathbf{v}_s\right). \tag{14}$$

The constant velocity $\mathbf{v}$ is related to the mass transfer, $\mathbf{j} = \rho \mathbf{v}$, and it can be excluded by changing over to the coordinate system that moves together with HeII. The relative speed $\mathbf{w}$, on the contrary, is associated with the convective heat transfer in HeII by counter fluxes of the normal and superfluid components. Therefore, it cannot be zeroed by means of the Galilean transformation, being, actually, an additional thermodynamic parameter of the system (together with p and T).

Suppose that there are no stationary fluxes of mass and heat transfer in HeII in the equilibrium state, so that $\mathbf{v}_0 = \mathbf{w}_0 = 0$, i.e. $\mathbf{v}_{n0} = \mathbf{v}_{s0} = 0$, in the zeroth-order approximation. Then, if the waves of the first and the second sound with small amplitudes are excited, Eqs. (8)–(11) considered in the linear approximation are reduced—making use of Eqs. (12) and (13)—to the following ones:

$$\dot{\rho}' + \mathrm{div}\left(\rho_{n0} \mathbf{v}'_n + \rho_{s0} \mathbf{v}'_s\right) = 0; \tag{15}$$

$$\dot{S}' + \mathrm{div}\left(S_0 \mathbf{v}'_n\right) = 0; \tag{16}$$

$$\dot{\mathbf{v}}'_s = -\frac{1}{\rho_0} \nabla p' + \frac{S_0}{\rho_0} \nabla T'; \tag{17}$$

$$\dot{\mathbf{v}}' = \frac{1}{\rho_0}\left(\rho_{n0} \dot{\mathbf{v}}'_n + \rho_{s0} \dot{\mathbf{v}}'_s\right) = -\frac{1}{\rho_0} \nabla p', \tag{18}$$

where the primes denote small perturbations, and zero subscripts denote unperturbed values of the corresponding quantities.

Expression (3) for the vector of macroscopic polarization in HeII that arises under the action of inertial forces due to the excitation of the first and the second sound waves can be transformed with the help of Eqs. (17) and (18) to the following form [8]:

$$\mathbf{P} = -\frac{\kappa m_4}{4e}\left[\left(1 - \frac{\delta W_0}{c_1^2}\right) \dot{\mathbf{v}}' - \frac{\rho_{n0}(T)\, C_0(T)}{3\rho_0 S_0(T)} \dot{\mathbf{w}}'\right], \tag{19}$$

where δW_0, $C_0(T)$, and $S_0(T)$ are the unperturbed values of the enthalpy, specific heat, and entropy of HeII, respectively. Since the condition $\nabla p' = 0$ is obeyed for the second sound waves—so that, according to Eq. (18), $\dot{\mathbf{v}}' = 0$—the perturbation of the relative acceleration of the normal and superfluid components, according to expressions (17) and (18), is equal to

$$\dot{\mathbf{w}}' = \left(\dot{\mathbf{v}}'_n - \dot{\mathbf{v}}'_s\right) = -\frac{S_0(T)}{\rho_{n0}(T)} \nabla T'. \tag{20}$$

In work [7], expression (19) was obtained taking only the phonon contribution to the HeII polarization into account. Therefore, the specific heat capacity and the entropy are coupled by the relation $C_0(T) = 3S_0(T)$, which is typical of an equilibrium Bose gas of phonons with the acoustic spectrum $\varepsilon(p) = pc_1$, where p is the phonon momentum (see works [10,11]). As a result, we obtain in this case that

$$\mathbf{P} = -\frac{\kappa m_4}{4e}\frac{S_{\rm ph}(T)}{\rho_0}\nabla T', \qquad (21)$$

where $S_{\rm ph}(T)$ is the phonon entropy ($S_{\rm ph} \sim T^3$). Whence – with regard for expression (5) modified for the case of a plane wave $\sim \exp(ikx - i\omega t)$, where k is the wave vector, and ω the second sound frequency – a relation analogous to Eq. (6), but with $\sigma(T)$ substituted by $\sigma_{\rm ph}(T) = m_4 S_{\rm ph}(T)/\rho_0$, follows.

It should be noted once again that expression (21) describes only the polarization of the normal component in HeII at low temperatures $T < 1$ K, when the dominant contribution to the entropy is given by equilibrium phonons.

On the other hand, relation (6) obtained in work [13] corresponds, in effect, to the polarization of the superfluid component only. Therefore, if $\nabla p' = 0$, then, according to Eq. (17), we obtain

$$\mathbf{P} = -\frac{\kappa m_4}{4e}\dot{\mathbf{v}}'_s = -\frac{\kappa m_4}{4e}\frac{S_0(T)}{\rho_0}\nabla T', \qquad (22)$$

where $S_0(T)$ is the total entropy of HeII at any $T \le T_\lambda$. According to conventional concepts [10,11,15], the latter is determined by the entropy of the normal component with regard for the contributions of equilibrium phonons and rotons. However, owing to a strong temperature dependence $S_0(T)$, relation (6) does not agree with empirical one (1).

The complete microscopic calculation of the inertial polarization in HeII with a consecutive account of contributions of all quasiparticle types to the thermodynamic property of HeII is impossible now, because of the lack of a rigorous microscopic theory for superfluidity in the quantum Bose liquid ^{4}He. In this connection, remaining within the scope of the phenomenological approach, let us determine the momentum of a unit volume of HeII that passes per unit time through a surface element dS:

$$K_i = \Pi_{ij} dS_j, \qquad (23)$$

where Π_{ij} is the stress tensor [15],

$$\Pi_{ij} = \rho_n v_{ni} v_{nj} + \rho_s v_{si} v_{sj} + p\delta_{ij}. \qquad (24)$$

In the absence of a macroscopic mass transfer flux in HeII, i.e. when $\mathbf{j} = \rho_n \mathbf{v}_n + \rho_s \mathbf{v}_s = 0$, Eq. (23) reads

$$\mathbf{K} = \rho_n(\mathbf{v}_n - \mathbf{v}_s)(\mathbf{v}_n \cdot d\mathbf{S}). \qquad (25)$$

Such a momentum of the heat flux, which is caused by the presence of two fields of velocities, $\mathbf{v}_n$ and $\mathbf{v}_s$, in HeII, was observed in experiments by Hall (see work [15]). In particular, a recoil force acting on a surface that radiated heat into HeII was revealed.

In the second sound wave with small amplitude, the velocities $\mathbf{v}_n$ and $\mathbf{v}_s$ oscillate harmonically and in antiphase. Therefore, the sole factor of the inertial polarization in HeII is, in this case, the relative acceleration between the normal and superfluid components $\dot{\mathbf{w}} = (\dot{\mathbf{v}}_n - \dot{\mathbf{v}}_s) \neq 0$. Accordingly, for the second sound waves, instead of Eq. (19) or (22), it is necessary to put

$$\mathbf{P} = -\frac{\kappa m_4}{4e}(\dot{\mathbf{v}}_n - \dot{\mathbf{v}}_s). \qquad (26)$$

Taking expression (20) into account, relation (26) reads (cf. with Eq. (21))

$$\mathbf{P} = \frac{\kappa m_4}{4e}\frac{S_0(T)}{\rho_{n0}(T)}\nabla T' \equiv \frac{\kappa}{4e}\frac{\rho_0\sigma_0(T)}{\rho_{n0}(T)}\nabla T', \qquad (27)$$

where $\sigma_0(T)$ is the entropy per ^{4}He atom, and it has the dimension of $k_{\rm B}$. Then, for a standing half-wave of the second sound with maximal amplitudes of temperature oscillations $\pm\Delta T$ with different signs at the opposite walls of a plane resonator (so that the total temperature variation along the resonator length is equal to $2\Delta T$) and taking Eq. (5) into account, we obtain the following relation (cf. with Eq. (6)):

$$\frac{\Delta T}{\Delta\varphi} = \frac{2e}{\sigma_0(T)}\frac{\rho_{n0}(T)}{\rho_0} \equiv \frac{2e}{k_{\rm B}}f(T). \qquad (28)$$

In Fig. 1, the temperature dependence of the dimensionless factor $f(T)$ from Eq. (28) is shown. It was calculated on the basis of the known formulas for the entropy and density of the normal component of HeII, in which the contributions of equilibrium phonons and rotons are taken into account (see works [10,11]):

$$\frac{\sigma_0(T)}{k_{\rm B}} = \frac{2\pi^2}{45n}\left(\frac{k_{\rm B}T}{\hbar c_1}\right)^3 +$$

$$+\frac{2p_0^2\sqrt{m_2^* k_{\rm B}T}}{(2\pi)^{3/2}\hbar^3 n}\left[\frac{\Delta(T)}{k_{\rm B}T} + \frac{3}{2}\right]\exp\left\{-\frac{\Delta(T)}{k_{\rm B}T}\right\}; \qquad (29)$$

$$\frac{\rho_{n0}\left(T\right)}{\rho_0} = \frac{2\pi^2}{45}\left(\frac{k_{\rm B}T}{\hbar c_1}\right)^3\frac{k_{\rm B}T}{c_1^2} +$$

$$+\frac{2p_0^4\sqrt{m_2^*}}{3\left(2\pi\right)^{3/2}\sqrt{k_{\rm B}T}\hbar^3}\exp\left\{-\frac{\Delta\left(T\right)}{k_BT}\right\}; \qquad (30)$$

where n is the concentration of ^{4}He atoms in HeII ($n = 2.19\times10^2$ cm^{-3}), $\hbar$ Planck's constant, p_0 the position of the roton minimum in the elementary excitation spectrum ($p_0/\hbar\approx 1.92\times10^8$ cm^{-1}), m^* the effective roton mass, and $\Delta\left(T\right)$ the temperature dependence of the roton gap (as the temperature grows, it diminishes from $\Delta\left(0\right) = k_{\rm B}\times 8.65$ K at $T\to 0$ to $\Delta\left(T_\lambda\right) = k_{\rm B}\times 5.53$ K at $T\to T_\lambda = 2.18$ K).

One can see that, in the range $0.6\leq\tau\leq 0.9$, i.e. in the temperature interval 1.3 K $\leq T\leq$ 2 K, the factor $f\left(T\right)$ is almost independent of T, being close to unity (with an accuracy of 25%). This fact agrees with experimental data of work [4] which were obtained in the temperature interval 1.4 K $\leq T\leq$ 1.8 K. However, in the interval $T<1.3$ K, the factor $f\left(T\right)$ quickly drops with the decreasing T and tends to zero at $T\to 0$. Therefore, to elucidate whether the phenomenological model of the inertial mechanism of the HeII polarization in a second sound standing wave, which was considered above, is valid, additional measurements of this effect in the low-temperature region are needed.

At the same time, in the case of first sound waves in HeII, when the excited normal and superfluid components oscillate in phase, so that $\mathbf{v}_n = \mathbf{v}_s = \mathbf{v}$, the polarization vector, according to Eq. (18), equals, in the linear approximation,

$$\mathbf{P} = -\frac{\kappa m_4}{4e}\dot{\mathbf{v}}' = \frac{\kappa m_4}{4e\rho_0}\nabla p'. \qquad (31)$$

For a first sound standing wave, from relation (31) and making allowance for Eq. (5), we obtain the following relations between the amplitudes of density, temperature, and potential oscillations:

$$\frac{\Delta\rho}{\rho_0} = \frac{2e\Delta\varphi}{m_4c_1^2}. \qquad (32)$$

Whence it follows that the electric signal of the order of $\Delta\varphi\approx\left(10\div 100\right)$ nV in the first sound wave can be reached at a relative amplitude of density oscillations $\Delta\rho/\rho_0\approx 10^{-5}\div 10^{-4}$, which means a rather strong power of acoustic oscillations. Such a power was probably not achieved in experiments [4], which was the reason why the HeII polarization was not observed, if the first sound wave was excited.

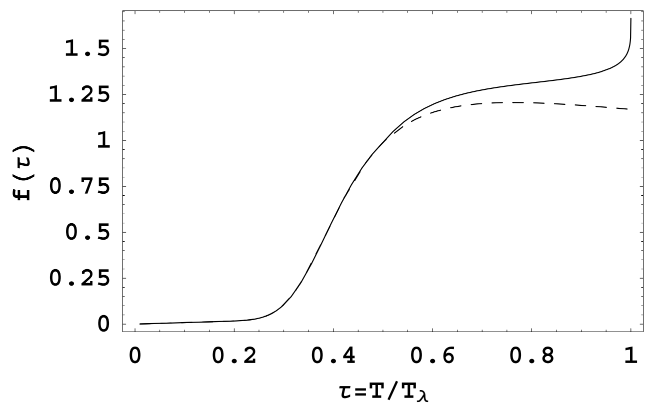

Fig. 1. Dependence of the factor $f\left(\tau\right) = \rho_n\left(\tau\right)k_{\rm B}/(\rho_0\sigma_0(\tau))$ on the dimensionless temperature $\tau = T/T_\lambda$ for a second sound standing wave at the constant roton gap $\Delta\left(0\right) = k_{\rm B}\times 8.65$ K (dashed curve) and taking the temperature dependence of the roton gap $\Delta\left(\tau\right)$ into account (solid curve)

3. Conclusions

To summarize, we have proposed a probable scenario of the inertial mechanism of the HeII polarization in a second sound standing wave due to the relative acceleration between the normal and superfluid components $\dot{\mathbf{w}} = (\dot{\mathbf{v}}_n - \dot{\mathbf{v}}_s)$. The scenario allows a rather satisfactory agreement with the experiment by Rybalko [4] to be obtained in the measurement temperature interval 1.4 K $\leq T\leq$ 1.8 K. At the same time, in the low-temperature region $T\leq 1.3$ K, the ratio between the amplitudes of the temperature, ΔT, and induced electric potential, $\Delta\varphi$, oscillations in a second sound wave quickly drops with decrease in the temperature and vanishes at $T\to 0$ (Fig. 1). Whence it follows that, to make a more reliable comparison between theoretical results and experimental data and to elucidate the issue whether the mechanism of the helium polarization considered in this work is applicable at the second sound wave excitation, it is necessary to carry out additional measurements of this effect in the low-temperature region, as well as in the vicinity of the λ-point, where the theoretical model predicts a certain growth of the ratio $\Delta T/\Delta\varphi$, provided that the temperature dependence of the roton gap is taken into account (see the solid curve in Fig. 1).

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ПРО ПРИРОДУ ЕЛЕКТРИЧНОЇ АКТИВНОСТІ НАДПЛИННОГО ГЕЛІЮ ПРИ ЗБУДЖЕННІ ХВИЛЬ ДРУГОГО ЗВУКУ

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Р е з ю м е

В даній роботі ефект поляризації надплинного гелію (HeII) під час збудження стоячих хвиль другого звуку, який спостерігали в роботі [4], пояснюється на основі механізму інерційної поляризації діелектричного середовища $\mathbf{P} \approx -\kappa m_4 \dot{\mathbf{v}}/(4e)$, де κ – поляризовність HeII, m_4 – маса атома ^{4}He, e – заряд електрона, $\dot{\mathbf{v}}$ – механічне прискорення. В ролі такого прискорення для хвиль другого звуку використовується похідна за часом від відносної швидкості нормальної та надплинної компонент. Отримано співвідношення між амплітудами коливань температури ΔT та електричного потенціалу $\Delta\varphi$ у стоячій хвилі другого звуку у вигляді $\Delta T/\Delta\varphi = 2ef(T)/k_{\rm B}$, де $f(T) = \rho_n(T)/\sigma(T)$, $\rho_n(T)$ – густина нормальної компоненти, нормована на повну густину HeII, $k_{\rm B}$ – стала Больцмана, а $\sigma(T)$ – ентропія в розрахунку на один атом ^{4}He в одиницях $k_{\rm B}$. Температурно залежний безрозмірний фактор $f(T)$ в діапазоні $1,3$ K $\leq T \leq 2$ K майже не залежить від T і є близьким до одиниці, що задовільно узгоджується з експериментальними даними, але в діапазоні $T < 1,3$ K фактор $f(T)$ швидко зменшується при зниженні температури. У зв'язку з цим для з'ясування питання про механізм поляризації HeII у хвилі другого звуку запропоновано проведення додаткових експериментів в низькотемпературному діапазоні.