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V. N. Minasyan, K. J. Touryan*

CHARGED SPINLESS QUASIPARTICLES AT THE INTERFACE BETWEEN VACUUM AND A LOW DENSITY GAS OF ELECTRONS

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*National Renewable Energy Laboratory, Golden, USA

1.Introduction.

The various models for explaining macroscopic properties and formation of high- T_c super-conducting phase as well as light transmission trough arrays of sub-wavelength sized holes in metal films have been invoked in recent years[1-5].

It has been known that plasmon field of metal may mediate an attractive electron-electron interaction. In 1983 Sham et. al.[6,7] had found that a plasmon field can induce an attractive electron-electron interaction in superconductivity. Using the Eliashberg equation they showed that exist an attractive forces between two electrons by action of plasmon field.

Kalio et al[8] had showed that the plasmon field in metallic lithium can create from two heavy fermion in the form of one boson having a size about $3\dot{A}$.

In 1957 Bardeen, Cooper and Schrieffer (BCS)[9] had proposed that the model of interacting Fermi gas leads to the creation of Cooper's pairs due to an electron-phonon-electron interaction near the Fermi surface. These pairs of electrons form a super-conducting phase in the ordinary superconductors. They obtained the size of pseudo-boson in order of $10^{-4}cm$.

In 1955 Schafroth[10] had investigated the model of ideal charged Bose-gas for ordinary superconductors, consisting of hypothetical charged spinless bosons with charge e_0 and mass m_0. He showed that the condensate charged bosons lead to the existence of super-conducting phase. Schafroth estimated a mass of hypothetical charged spinless boson having a mass $m_0 = 10^8 m_e$. In the theory of Schafroth the question about the formation mechanism of creation of charged spinless bosons is open.

In this paper, we estimate the significance of density electrons inside thin layer in vacuum which cames to view due to the Richardson-Dushman[11] effect of thermionic emission and investigate the action of the vibration of density electron in the system vacuum-conductor on the electron gas in thin layer of vacuum which leads to the appearance of a new state of matter in specific conditions of density electron of conductor.

To solve a problem of conductor which has a boundary with vacuum we will use the theory of of Zubarev[12] which is based on the method of "mixed" representation. According to prescription of Bohm and Pines[13], Zubarev had separated the motion of plasma electrons in the "collective" and "individual" components which correspond to vibrations of plasma density and to single particle motions. He had suggested that the separation of motion of Fermi-particles in the "collective" and "individual" components occurs simultaneously. It means that the every spatial coordinate of electron of plasma can simultaneously correspond to the "collective" and "individual" independent motions. In such situation, the number of electron degrees of freedom equal $2N$ (N is the total number of electrons of gas). However, the factor $2N$ is strived to infinity at approximation of thermodynamic limit $2N \to \infty$, consequently the electron degrees of freedom lose their meaning in the case of many bodies.

2. About the existence a new charged spinless quasi-particles.

We consider the model of a system consisting of conductor which has boundary with vacuum. Due to the Richardson-Dushman effect of thermionic emission, the n negatively charged electrons (where $N \gg n$) leave the volume V_m of the conductor and go into vacuum by the action of temperature. They are attracted by the positively charged lattice of conductor to the surface of vacuum-conductor by forming the thin layer of vacuum with volume V_v (where $V_m \gg V_v$) where are grouped evaporated electrons. The joint system of conductor and thin layer in vacuum consist of N electrons with the volume $V = V_m + V_v$ and create a system of electrically neutral in the background of the positively charged ions of conductor.

The conductor is modelled as a non- ideal Fermi gas with low density of $N - n$ electrons which have "individual" coordinates $\vec{R}_1\sigma_1, ..., \vec{R}_{N-n}\sigma_{N-n}$ ($\sigma = \frac{1}{2}$ is a spin of electron) and interact each other by the screening Coulomb potential. We will consider the densities of electrons in the systems of conductor and vacuum-conductor satisfying the following criterions:

$$\left(\frac{3V_m}{4\pi(N-n)}\right)^{\frac{1}{3}} \simeq \left(\frac{3V_m}{4\pi N}\right)^{\frac{1}{3}} \gg \frac{\hbar^2}{m_e e^2}$$

because within the Richardson-Dushman effect follows that $N \gg n$ and at

$V_m \gg V_v$

$$\left(\frac{3V}{4\pi N}\right)^{\frac{1}{3}} = \left(\frac{3(V_m + V_v)}{4\pi N}\right)^{\frac{1}{3}} \simeq \left(\frac{3V_m}{4\pi N}\right)^{\frac{1}{3}} \gg \frac{\hbar^2}{m_e e^2}$$

It is very important factor because within the given one we can describe the vibration of density electron as fully system conductor-vacuum.

However, at $N \gg n$ and $V_m \gg V_v$ we will suggest that the model of thin layer in vacuum can be considered as a non- ideal Fermi- gas with density of electrons satisfying condition $\frac{n}{V_v} \gg \frac{N}{V_m}$. In this case, the thin layer in vacuum consist of n electrons with "individual" coordinates $\vec{r}_1\sigma_1, ..., \vec{r}_n\sigma_n$ which interact each other by the screening Coulomb potential. The density of electrons in such system satisfies the following criteria

$$\frac{n}{V_v} \ll \frac{3}{4\pi}\left(\frac{m_e e^2}{\hbar^2}\right)^3$$

To describe the "collective" motion of electrons in the system conductor-vacuum we will introduce a spatial coordinates of N electrons $\vec{R}_1, ..., \vec{R}_N$ which coincide with a "individual" spatial coordinates of electrons which are into conductor and thin layer $\vec{r}_1\sigma_1, ..., \vec{r}_n\sigma_n, \vec{R}_1\sigma_1, ..., \vec{R_{N-n}}\sigma_{N-n}$. This approach will help us to describe the plasmon vibration density of electrons in the system conductor-vacuum.

The wave function of conductor-vacuum can be represented the following way:

$$\begin{aligned}\psi &= \psi_s(\vec{R}_1\sigma_1, ..., \vec{R}_{N-n}\sigma_{N-n}; t)\psi_c(\vec{R}_1, ..., \vec{R}_N; t) \cdot \\ &\quad \psi_s(\vec{r}_1\sigma_1, ..., \vec{r}_n\sigma_n; t) \qquad (1)\end{aligned}$$

where $\psi_s(\vec{R}_1\sigma_1, ..., \vec{R_{N-n}}\sigma_{N-n}; t)$ and $\psi_s(\vec{r}_1\sigma_1, ..., \vec{r}_n\sigma_n; t)$ are,respectively, the wave functions of the electrons performing in "individual" motions into conductor and thin layer of vacuum (the Slater determinants); $\psi_c(\vec{R}_1, ..., \vec{R}_N; t)$ is the wave function of the electrons performing in "collective" motions which is connected with describing of the vibration of density of electrons in the system vacuum-conductor.

As variables of wave function of the electrons of "collective" component in the system conductor-vacuum we take Fourier coefficients of the operator density of electrons $\varrho_{\vec{p}}$ with momentum $\vec{p}$:

$$\varrho_{\vec{p}} = \frac{1}{\sqrt{N}} \sum_{i=1}^{N} \exp\left(\frac{i\vec{p}\vec{R}_i}{\hbar}\right), \vec{p} \neq 0, \tag{2}$$

Then, the wave function of the electrons of "collective" component has the form:

$$\psi_c(\varrho_{\vec{p}_1} \cdots \varrho_{\vec{p}_i} \cdots ; t)$$

The Schrödinger equation for the system of conductor-vacuum has the form:

$$i\hbar \frac{d\psi}{dt} = \hat{H}\psi$$

where the Hamiltonian of system conductor-vacuum $\hat{H}$ is

$$\hat{H} = \hat{H}_m + \hat{H}_v + \hat{H}_c + \hat{H}_{m,v,c} + \hat{H}_{m,v} \tag{3}$$

where $\hat{H}_m$ is the Hamilton operator of conductor; $\hat{H}_v$ is the Hamilton operator of thin layer in vacuum; $\hat{H}_c$ is the Hamilton operator of "collective" component; $\hat{H}_{m,v,c}$ is the operator interaction between the electrons of conductor which take in place of "individual" motions and the electrons in thin layer of vacuum performing in "collective" motion in the system conductor-vacuum; $\hat{H}_{m,v}$ is the operator of interaction between the electrons of "individual" components in conductor and thin layer of vacuum:

$$\hat{H}_m = -\frac{\hbar^2}{2m_e} \sum_{i=1}^{N-n} \Delta_{\vec{R}_{i,\sigma}} + \frac{1}{2} \sum_{i \neq j} U(\vec{R}_{i,\sigma} - \vec{R}_{j,\sigma}) \tag{4}$$

$$\hat{H}_v = -\frac{\hbar^2}{2m_e} \sum_{i=1}^{n} \Delta_{\vec{r}_{i,\sigma}} + \frac{1}{2} \sum_{i \neq j} U(\vec{r}_{i,\sigma} - \vec{r}_{j,\sigma}) \tag{5}$$

$$\begin{aligned} \hat{H}_c = & \frac{1}{\sqrt{N}} \sum_{p_1 \neq 0, p_2 \neq 0} \frac{\vec{p}_1 \vec{p}_2}{2m_e} \varrho_{\vec{p}_1 + \vec{p}_2} \frac{d^2}{d\varrho_{\vec{p}_1} d\varrho_{\vec{p}_2}} + \sum_{p \neq 0} \frac{p^2}{2m_e} \varrho_{\vec{p}} \frac{d}{d\varrho_{\vec{p}}} + \\ + & \frac{N}{2V} \sum_{p \neq 0} U_{\vec{p}} \varrho_{\vec{p}} \varrho_{-\vec{p}} + \frac{1}{2m_e\sqrt{N}} \sum_{i, \vec{p} \neq 0} \vec{p}\vec{p}_i \exp\left(-\frac{i\vec{p}\vec{R}_i}{\hbar}\right) \frac{d}{d\varrho_{\vec{p}}} - \\ - & \frac{N}{2V} \sum_{\vec{p} \neq 0} U_{\vec{p}} + \frac{U_0 N^2}{2V} \end{aligned} \tag{6}$$

where $\vec{p_i}$ is the momentum of i-th electron;

$$\hat{H}_{m,v,c} = \frac{1}{2}\sum_{i \neq j} U(\vec{R_i} - \vec{R}_{j,\sigma}) + \frac{1}{2}\sum_{i \neq j} U(\vec{R_i} - \vec{r}_{j,\sigma}) \tag{7}$$

$$\hat{H}_{m,v} = \frac{1}{2}\sum_{i \neq j} U(\vec{r}_{i,\sigma} - \vec{R}_{j,\sigma}) \tag{8}$$

where $U(\vec{r}_{i,\sigma} - \vec{r}_{j,\sigma})$ and $U(\vec{R}_{i,\sigma} - \vec{R}_{j,\sigma})$ are the screening Coulomb potentials of interactions between the electrons inside thin layer and the electrons inside conductor;

$$U_{\vec{p}} = \frac{4\pi\hbar^2 e^2}{p^2 \epsilon(p)} \tag{9}$$

is the Fourier transform of the screening Coulomb interaction in the system of conductor-vacuum; $\epsilon(p)$ is the dielectric response of electron system on the statical potential of interaction (the formulae of Lindhard):

$$\epsilon(p) = 1 + \frac{\hbar^2}{2\Lambda^2 p^2}\left(1 + \frac{1-\tau^2}{2\tau} ln|\frac{1+\tau}{1-\tau}|\right)$$

where $\tau = \frac{p}{2p_f}$ (p_f is the Fermi momentum of the system conductor-vacuum); Λ is the screening length of Thomas-Fermi for the system conductor-vacuum:

$$\Lambda^2 = \frac{\hbar^2}{4m_e e^2}\left(\frac{V}{N}\right)^{\frac{1}{3}} \simeq \frac{\hbar^2}{4m_e e^2}\left(\frac{V_m}{N}\right)^{\frac{1}{3}}$$

The screening Coulomb interaction of Thomas-Fermi is determined within expression for $\epsilon(p)$ at $p \ll p_f$. However, $p_f \ll \frac{\hbar}{\Lambda}$ which is realized at above-mentioned criteria for system conductor-vacuum $\left(\frac{3V_m}{4\pi N}\right)^{\frac{1}{3}} \gg \frac{\hbar^2}{m_e e^2}$ with using the zero approximation into the Eq.(9). Then, we obtain the following form for $U_{\vec{p}}$

$$U_{\vec{p}} \simeq 4\pi e^2 \Lambda^2 = \frac{\pi\hbar^2}{m_e}\left(\frac{V_m}{N}\right)^{\frac{1}{3}}$$

In our situation the potentials of interactions can present as

$$U(\vec{r}_{i,\sigma} - \vec{r}_{j,\sigma}) = \frac{\pi\hbar^2}{m_e}\left(\frac{V_v}{n}\right)^{\frac{1}{3}} \delta(r)$$

$$U(\vec{R}_{i,\sigma} - \vec{R}_{j,\sigma}) = \frac{\pi\hbar^2}{m_e}\left(\frac{V_m}{N}\right)^{\frac{1}{3}}\delta(R)$$

where $r = |\vec{r}_{i,\sigma} - \vec{r}_{j,\sigma}|$ and $R = |\vec{R}_{i,\sigma} - \vec{R}_{j,\sigma}|$ are the distances between the electrons insides of thin layer and conductor; $\delta(r)$ is the delta function.

At the condition $\frac{n}{V_v} \gg \frac{N}{V_m}$ we can neglect $U(\vec{r}_{i,\sigma} - \vec{r}_{j,\sigma})$ in respect to $U(\vec{R}_{i,\sigma} - \vec{R}_{j,\sigma})$.

The Hamilton operator in Eq.(6) is a non-Hermitian because there is not a canonical transformation for the transition of variables $\vec{R}_i$ to $\varrho_{\vec{p}}$. To make the operator of Hamilton in Eq.(6) to Hermitian, we use the random - phase approximation[13]

$$\varrho_{\vec{p1}+\vec{p2}} \approx \sqrt{N}\delta_{0,\vec{p1}+\vec{p2}}; \vec{p1} \neq 0, \vec{p2} \neq 0$$

Then, from Eq.(6) we can neglect a first and a third terms. At this case, we will introduce the wave function of Zubarev in the following form:

$$\Psi = \psi \exp\left(-\frac{1}{4}\sum_{\vec{p}} \varrho_{\vec{p}}\varrho_{-\vec{p}}\right),$$

Then, we obey the Hamilton operator of "collective" component $\hat{H}_c$ in representation of Zubarev's wave function Ψ:

$$\begin{aligned}\hat{H}_c &= \frac{1}{2}\sum_{\vec{p}\neq 0}\frac{p^2}{m_e}\left(-\frac{d^2}{d\varrho_{\vec{p}}d\varrho_{-\vec{p}}} + \frac{1}{4}\varrho_{\vec{p}}\varrho_{-\vec{p}} - \frac{1}{2}\right) + \frac{N}{2V}\sum_{\vec{p}\neq 0} U_{\vec{p}}\varrho_{\vec{p}}\varrho_{-\vec{p}} - \\ &- \frac{N}{2V}\sum_{\vec{p}\neq 0} U_{\vec{p}} + \frac{U_0 N^2}{2V} \end{aligned} \tag{10}$$

We introduce Zubarev's Bose-operators of "creation" $\hat{b}^+_{\vec{p}}$ and "annihilation" $\hat{b}_{\vec{p}}$ of a plasmon with momentum $\vec{p}$ for the gas of electrons with low density:

$$\left.\begin{aligned} \hat{b}_{\vec{p}} &= \lambda_{\vec{p}}\frac{d}{d\varrho_{-\vec{p}}} + \frac{1}{2\lambda_{\vec{p}}}\varrho_{\vec{p}} \\ \hat{b}^+_{\vec{p}} &= -\lambda_{\vec{p}}\frac{d}{d\varrho_{\vec{p}}} + \frac{1}{2\lambda_{\vec{p}}}\varrho_{-\vec{p}} \end{aligned}\right\} \tag{11}$$

where $\lambda_{\vec{p}}$ is a real symmetrical function of momentum $\vec{p}$.

After a some calculations with taking into consideration the Fourier transformations for the potentials of interactions $U(\vec{R}_i - \vec{r}_{j,\sigma})$ and $U(\vec{R}_i - \vec{R}_{j,\sigma})$ and Eq.(2), Eq.(11), we get to the following form for $\hat{H}$:

$$\begin{aligned}\hat{H} &= \sum_{\vec{p}\neq 0} \varepsilon_{\vec{p}} \hat{b}^+_{\vec{p}} \hat{b}_{\vec{p}} + \frac{\sqrt{N}}{2V} \sum_{j,\vec{p}\neq 0} U_{\vec{p}} \lambda_{\vec{p}} \Big(\hat{b}^+_{-\vec{p}} + \hat{b}_{\vec{p}}\Big) \Big[\exp - \Big(\frac{i\vec{p}\vec{R}_{j,\sigma}}{\hbar}\Big) + \\ &+ \exp - \Big(\frac{i\vec{p}\vec{r}_{j,\sigma}}{\hbar}\Big)\Big] - \frac{\hbar^2}{2m_e} \sum_{i=1}^{N-n} \Delta_{\vec{R}_{i,\sigma}} - \frac{\hbar^2}{2m_e} \sum_{i=1}^{n} \Delta_{\vec{r}_{i,\sigma}} + \\ &+ \frac{1}{2} \sum_{i\neq j} U(\vec{R}_{i,\sigma} - \vec{r}_{j,\sigma}) + \frac{1}{2} \sum_{i\neq j} U(\vec{R}_{i,\sigma} - \vec{R}_{j,\sigma}) + \hat{H}_0 \end{aligned} \tag{12}$$

where $\varepsilon_{\vec{p}}$ is the energy of plasmon with momentum $\vec{p}$ for the gas of electrons with low density:

$$\varepsilon_{\vec{p}} = \left[\left(\frac{p^2}{2m}\right)^2 + \frac{p^2 U_{\vec{p}} N}{m_e V}\right]^{1/2} \tag{13}$$

In other hand, we have

$$\varepsilon_{\vec{p}} = \frac{p^2}{2m_e \lambda^2_{\vec{p}}} \tag{14}$$

$$\hat{H}_0 = \frac{1}{2} \sum_{\vec{p}\neq 0} \left(\varepsilon_{\vec{p}} - \frac{p^2}{2m_e} - \frac{NU_{\vec{p}}}{V}\right) + \frac{U_0 N^2}{2V} \tag{15}$$

We want to use a canonical transformation for the operator $\hat{H}$ in Eq.(12) which could expel a terms of interaction plasmon field with "individual" particles. Letting that the operator $\hat{S}$ satisfies the condition $\hat{S}^+ = -\hat{S}$.

In this case, the new operator $\tilde{H}$ is represented as:

$$\tilde{H} = \exp\Big(\hat{S}^+\Big) \hat{H} \exp\Big(\hat{S}\Big) = \hat{H} - [\hat{S}, \hat{H}] + \frac{1}{2}[\hat{S}, [\hat{S}, \hat{H}]] - \cdots \tag{16}$$

where we can take into account that $\hat{S} = \sum_{\vec{p}} \hat{S}_{\vec{p}}$
and

$$\hat{S}_{\vec{p}} = \alpha^+_{\vec{p}} \hat{b}^+_{\vec{p}} - \alpha_{\vec{p}} \hat{b}_{\vec{p}} + \gamma^+_{\vec{p}} \hat{b}^+_{\vec{p}} - \gamma_{\vec{p}} \hat{b}_{\vec{p}} \tag{17}$$

We note that the operators $\alpha_{\vec{p}}$ and $\gamma_{\vec{p}}$ are unknown. Then, using the form of operator $\hat{H}$ from Eq.(12) to the formula Eq.(16) and make a some calculations we find the following form for the operator $\tilde{H}$:

$$\begin{aligned}\tilde{H} &= \sum_{\vec{p}\neq 0}\varepsilon_{\vec{p}}\hat{b}^{+}_{\vec{p}}\hat{b}_{\vec{p}} - \sum_{\vec{p}\neq 0}\varepsilon_{\vec{p}}\hat{\alpha}^{+}_{\vec{p}}\hat{\alpha}_{\vec{p}} - \sum_{\vec{p}\neq 0}\varepsilon_{\vec{p}}\hat{\gamma}^{+}_{\vec{p}}\hat{\gamma}_{\vec{p}} - 2\sum_{\vec{p}\neq 0}\varepsilon_{\vec{p}}\hat{\alpha}^{+}_{\vec{p}}\hat{\gamma}_{\vec{p}} - \\ &- \frac{\hbar^2}{2m_e}\sum_{i=1}^{N-n}\Delta_{\vec{R}_{i,\sigma}} - \frac{\hbar^2}{2m_e}\sum_{i=1}^{n}\Delta_{\vec{r}_{i,\sigma}} + \frac{1}{2}\sum_{i\neq j}U(\vec{R}_{i,\sigma}-\vec{R}_{j,\sigma}) + \\ &+ \frac{1}{2}\sum_{i\neq j}U(\vec{R}_{i,\sigma}-\vec{r}_{j,\sigma}) + \hat{H}_0 \end{aligned} \tag{18}$$

where

$$\alpha_{\vec{p}} = \frac{\sqrt{N}}{V\varepsilon_{\vec{p}}}U_{\vec{p}}\lambda_{\vec{p}}\sum_{i=1}^{N-n}\exp\left(-\frac{i\vec{p}\vec{R}_{i,\sigma}}{\hbar}\right) \tag{19}$$

$$\gamma_{\vec{p}} = \frac{\sqrt{N}}{V\varepsilon_{\vec{p}}}U_{\vec{p}}\lambda_{\vec{p}}\sum_{i=1}^{n}\exp\left(-\frac{i\vec{p}\vec{r}_{i,\sigma}}{\hbar}\right) \tag{20}$$

Then

$$\begin{aligned}\tilde{H} &= \sum_{\vec{p}\neq 0}\varepsilon_{\vec{p}}\hat{b}^{+}_{\vec{p}}\hat{b}_{\vec{p}} + \frac{1}{2}\sum_{i\neq j}\Phi(\vec{R}_{i,\sigma}-\vec{R}_{j,\sigma}) + \frac{1}{2}\sum_{i\neq j}\Phi(\vec{r}_{i,\sigma}-\vec{r}_{j,\sigma}) - \\ &- \frac{\hbar^2}{2m_e}\sum_{i=1}^{N-n}\Delta_{\vec{R}_{i,\sigma}} - \frac{\hbar^2}{2m_e}\sum_{i=1}^{n}\Delta_{\vec{r}_{i,\sigma}} + \sum_{i\neq j}\Phi(\vec{r}_{i,\sigma}-\vec{R}_{j,\sigma}) + \\ &+ \frac{1}{2}\sum_{i\neq j}U(\vec{R}_{i,\sigma}-\vec{r}_{j,\sigma}) + \frac{1}{2}\sum_{i\neq j}U(\vec{R}_{i,\sigma}-\vec{R}_{j,\sigma}) + \hat{H}_0 \end{aligned} \tag{21}$$

Thus, we find the attractive potential between the electrons inside of thin layer in vacuum which has the form:

$$\Phi(\vec{r}_{i,\sigma}-\vec{r}_{j,\sigma}) = -2\frac{N}{V^2}\sum_{\vec{p}}\frac{U^2_{\vec{p}}\lambda^2_{\vec{p}}\exp\left(\frac{i\vec{p}\vec{R}}{\hbar}\right)}{\varepsilon_{\vec{p}}} = -\frac{a}{r}\exp(-br) \tag{22}$$

where

$$a = \frac{4mNU_{\vec{p}}^2}{V\hbar^2} \simeq \frac{4\pi^2\hbar^2}{m_e}\left(\frac{N}{V_m}\right)^{\frac{1}{3}}$$

$$b = \left(\frac{16\pi mNU_{\vec{p}}}{V\hbar^2}\right)^{\frac{1}{2}} \simeq 4\pi\left(\frac{N}{V_m}\right)^{\frac{1}{3}}$$

The average distant between the electrons inside of thin layer in vacuum satisfies the following condition $\left(\frac{3V_v}{4\pi n}\right)^{\frac{1}{3}} \ll \frac{1}{b}$ because the condition $\frac{n}{V_v} \gg \frac{N}{V_m}$. Consequently at $r \ll \frac{1}{b}$, the attractive potential form between the electrons inside of thin layer in vacuum has the form

$$\Phi(\vec{r}_{i,\sigma} - \vec{r}_{j,\sigma}) = -\frac{a}{r}$$

where the parameter $a = \frac{4\pi^2\hbar^2}{m_e}\left(\frac{N}{V_m}\right)^{\frac{1}{3}}$ can be considered as a charge. It has been known that the minimal significant of charge is a charge of electron e, therefore we will consider the density of electrons for conductor such which satisfies the condition of $\frac{N}{V_m} \simeq 2 \cdot 10^{-5}\left(\frac{m_e e^2}{\hbar^2}\right)^3$. It is realized at $a \simeq e$. Such density of electrons can have semiconductors at room temperature.

Then, the attractive potentials between the electrons in the system vacuum-conductor and conductor,respectively are given as

$$\Phi(\vec{R}_{i,\sigma} - \vec{r}_{j,\sigma}) \simeq -\frac{e}{R_r}\exp(-bR_r) \tag{23}$$

$$\Phi(\vec{R}_{i,\sigma} - \vec{R}_{j,\sigma}) \simeq -\frac{e}{R}\exp(-bR) \tag{24}$$

where $R_r = |\vec{R}_{i,\sigma} - \vec{r}_{j,\sigma}|$ is the distant between the electrons inside of system conductor-vacuum.

Thus, the Hamiltonian of system conductor-vacuum gains the form:

$$\begin{aligned}\tilde{H} &= -\frac{\hbar^2}{2m_e}\sum_{i=1}^{N-n}\Delta_{\vec{R}_{i,\sigma}} - \frac{\hbar^2}{2m_e}\sum_{i=1}^{n}\Delta_{\vec{r}_{i,\sigma}} + \frac{1}{2}\sum_{i\neq j}V(\vec{R}_{i,\sigma} - \vec{r}_{j,\sigma}) + \\ &+ \frac{1}{2}\sum_{i\neq j}\Phi(\vec{r}_{i,\sigma} - \vec{r}_{j,\sigma}) + \frac{1}{2}\sum_{i\neq j}V(\vec{R}_{i,\sigma} - \vec{R}_{j,\sigma}) + \hat{H}_q\end{aligned} \tag{25}$$

where the effective interactions between the electrons of systems of conductor and conductor- vacuum are

$$V(\vec{R}_{i,\sigma} - \vec{R}_{j,\sigma}) = \frac{\pi\hbar^2}{m_e}\left(\frac{V_m}{N}\right)^{\frac{1}{3}}\delta(R) - \frac{2a}{R}\exp(-bR)$$

$$V(\vec{R}_{i,\sigma} - \vec{r}_{j,\sigma}) = \frac{\pi\hbar^2}{m_e}\left(\frac{V_m}{N}\right)^{\frac{1}{3}}\delta(R_r) - \frac{2a}{R_r}\exp(-bR_r)$$

and

$$\hat{H}_q = \sum_{\vec{p}\neq 0} \varepsilon_{\vec{p}} \hat{b}^+_{\vec{p}} \hat{b}_{\vec{p}} + \hat{H}_0 \tag{26}$$

We see that the average distances between the electrons insides conductor and vacuum-conductor satisfy the conditions $\left(\frac{3V_m}{4\pi(N-n)}\right)^{\frac{1}{3}} \gg \frac{1}{b}$ and $\left(\frac{3V}{4\pi N}\right)^{\frac{1}{3}} \gg \frac{1}{b}$ because $\left(\frac{3V_m}{4\pi N}\right)^{\frac{1}{3}} \gg \frac{\hbar^2}{m_e e^2}$. It means that $bR_r \gg 1$ and $bR \gg 1$ and then, we can neglect the effective potentials of interactions $V(\vec{R}_{i,\sigma} - \vec{r}_{j,\sigma})$ and $V(\vec{R}_{i,\sigma} - \vec{R}_{j,\sigma})$ in respect to the potential of interaction $\Phi(\vec{r}_{i,\sigma} - \vec{r}_{j,\sigma})$.

Within our approximations, the Hamiltonian of system conductor- vacuum gains the form:

$$\tilde{H} = -\frac{\hbar^2}{2m_e}\sum_{i=1}^{N-n}\Delta_{\vec{R}_{i,\sigma}} - \frac{\hbar^2}{2m_e}\sum_{i=1}^{n}\Delta_{\vec{r}_{i,\sigma}} + \frac{1}{2}\sum_{i\neq j}\Phi(\vec{r}_{i,\sigma} - \vec{r}_{j,\sigma}) + \hat{H}_q \tag{27}$$

So the system of $\frac{n}{2}$ electrons inside of thin layer in vacuum are linked to the $\frac{n}{2}$ electrons the same medium. In this case, are formed spinless electrons pairs by action of centrally-symmetric field $\Phi(\vec{r}) \simeq -\frac{e^2}{r}$.

In perfect analogously to the hydrogen atom, the energy spectrum has the form:

$$E_n \simeq -\frac{m_e e^4}{4\hbar^2 n^2} \tag{28}$$

where $n = 1, 2, 3, \ldots$.

Consequently, two electrons are combined and form an one spinless boson inside of thin layer in vacuum. These bosons have a charge $e_0 = 2e$, a mass $m = 2m_e$ and a radius

$$d \simeq \frac{\hbar^2}{m_e e^2} = 0.53\dot{A} \tag{29}$$

Thus, a new Hamiltonian of system conductor-vacuum $\tilde{H}$ is divided on the Hamilton operator $\hat{H}_n$ for a new medium which is an ideal Bose gas and the Hamilton operator of the conductor $\hat{H}_p$ which is an ideal Fermi gas of electrons:

$$\tilde{H} = \hat{H}_n + \hat{H}_p + \hat{H}_q \tag{30}$$

$$\hat{H}_n = -\frac{\hbar^2}{2m} \sum_{i=1}^{\frac{n}{2}} \Delta_{\vec{r}_i} \tag{31}$$

$$\hat{H}_p = -\frac{\hbar^2}{2m_e} \sum_{i=1}^{N-n} \Delta_{\vec{R}_i} \tag{32}$$

3. Conclusion.

As we see, the action of the vibration of all electrons of the system conductor-vacuum on the thin layer with density of electrons $10^{23}cm^{-3} \gg \frac{n}{V_v} \gg \frac{N}{V_m}$ leads to the appearance of a new state of matter which consisting of charged spinless quasi-particles. This substance of matter is a skin of conductor which has the density of electrons in order of $\frac{N}{V_m} \simeq 1.6 \cdot 10^{20}cm^{-3}$. We showed that the given theory can find the application for investigation of semiconductors which can be considered as a good high T_c superconductors. The expected results of research may not only be of a fundamental interest but also have a significant practical output, in particular for the solution of the problem theoretical explanation of the experimental data related to the unusual optical properties of metallic films with nanoholes because the holes with nanometer-sizes represent as a thin layer in vacuum involving a new bosons with a charge $e_0 = 2e$, a mass $m = 2m_e$ and a radius $d \simeq 0.53\dot{A}$.

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Минасян В. Н., Турян К. В. E17-2002-96

Бесспиновые заряженные бозоны на поверхности раздела между вакуумом и электронным газом низкой плотности

Показано, что на поверхности раздела вакуум и проводник, который рассматривается как электронный газ низкой плотности, вследствие плазменных колебаний плотности электронов внутри тонкого слоя в системе вакуум-проводник формируются заряженные бесспиновые квазичастицы с массой $m = 2m_e$, зарядом $e_0 = 2e$ и радиусом $d \cong 0{,}02$ Å (где e и m_e — заряд и масса электрона соответственно).

Работа выполнена в Научном центре прикладных исследований ОИЯИ и в Национальной лаборатории возобновляемых источников энергии (Голден, США).

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Minasyan V. N., Touryan K. J. E17-2002-96

Charged Spinless Quasiparticles at the Interface between Vacuum and a Low Density Gas of Electrons

We predicted that at the interface between vacuum and conductor, which is considered as a low density gas of electrons, charged spinless quasiparticles with a mass $m = 2m_e$, a charge $e_0 = 2e$ and a radius $d \cong 0.02$ Å (where e and m_e are a charge and a mass of electron, respectively) are formed inside a thin layer in vacuum due to the plasmon vibrations of density of electrons in the system vacuum-conductor.

The investigation has been performed at the Scientific Center of Applied Research, JINR and at the National Renewable Energy Laboratory (Golden, USA).

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