

Electronic Properties under the External Applied Magnetic Field in the Normal Metallic and Superconducting States

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Abstract

We discuss how the strength of the magnetic field are closely related to the electronic properties in the normal metallic states and the superconducting states. We formulate the electron–phonon coupling constants, which are very important physical parameters in the various research fields such as the normal metallic states and superconducting states, under the external applied magnetic field as well as under no external applied field. On the basis of these results, we compare the normal metallic states with the superconducting states. Furthermore, in this article, we elucidate the mechanism of the Faraday’s law in normal metallic states and the Meissner effects in superconductivity, on the basis of the theory suggested in our previous researches. Because of the very large stabilization energy of about 35–70 eV for the Bose–Einstein condensation, the Faraday’s law, Ampère’s law, and the Meissner effects can be observed.

Keywords: Normal Metal, Superconductor, Electron–Phonon Interactions, Electromotive Forces, Meissner effect.

1. Introduction

In modern physics and chemistry, the effect of electron–phonon interactions [1–7] in molecules and crystals has been an important topic. In the Bardeen–Cooper–Schrieffer (BCS) theory of superconductivity, electron–phonon coupling [1–7] is the consensus mechanism for attractive electron–electron interactions. On the other hand, room-temperature superconductivity has not yet been discovered even though many researchers have tried to realize the occurrence of high-temperature superconductivity for 100 years.

Related to seeking for the room-temperature superconductivity, in this article, we compare the normal metallic states with the superconducting states. In superconductivity, two electrons behave only as a Bose particle. On the other hand, in the normal metallic states, an electron behaves as bosonic as well as fermionic under the applied external magnetic or electric field.

The effect of vibronic interactions and electron–phonon interactions [1–7] in molecules and crystals is an important topic of discussion in modern physics. The vibronic and electron–phonon interactions play an essential role in various research fields such as the

decision of molecular structures, Jahn–Teller effects, Peierls distortions, spectroscopy, electrical conductivity, and superconductivity. We have investigated the electron–phonon interactions in various charged molecular crystals for more than ten years [1–8]. In particular, in 2002, we predicted the occurrence of superconductivity as a consequence of vibronic interactions in the negatively charged picene, phenanthrene, and coronene [8]. Recently, it was reported that these trianionic molecular crystals exhibit superconductivity [9].

Furthermore, in this article, we elucidate the mechanism of the Faraday’s law (experimental rule discovered in 1831) in normal metallic states [10] and the Meissner effects (discovered in 1933) in superconductivity, on the basis of the theory suggested in our previous researches [1–7].

2. Vibronic Stabilization Energies without Any External Applied Field in Molecules

In this section, we discuss the electron–phonon interactions without external applied magnetic field in molecules.

2.1 One-Electron Model

Let us consider an inert Fermi-sea, in which the electrons are treated as non-interacting [1–7]. To this Fermi-sea, one electron is added above the Fermi-surface. This one added electron does not interact with the inert Fermi-sea, as shown in Fig. 1. One electron occupies a plane-wave state $|k_{\text{one,av.}}\rangle$, in the absence of interactions, as shown in Fig. 2 (a),

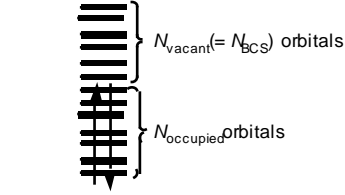
$$|k_{\text{one,av.}}\rangle = \sqrt{P_{k_{\text{ground}}}(T)} |k_{\text{ground}}\rangle + \sqrt{P_{k_{\text{excited}}}(T)} |k_{\text{excited}}\rangle, \quad (1)$$

where the $P_{k_{\text{ground}}}(T)$ and $P_{k_{\text{excited}}}(T)$ values denote the probability of the occurrence of the electronic states $|k_{\text{ground}}\rangle$ and $|k_{\text{excited}}\rangle$, respectively, which can be defined as

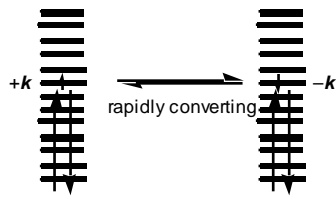
$$|k_{\text{ground}}\rangle = \frac{1}{\sqrt{2}}|+k \downarrow\rangle + \frac{1}{\sqrt{2}}|-k \uparrow\rangle, \quad (2)$$

$$|k_{\text{excited}}\rangle = \frac{1}{\sqrt{2}}|+k \uparrow\rangle + \frac{1}{\sqrt{2}}|-k \downarrow\rangle. \quad (3)$$

(a) ground state



(b) one-electron theory



(c) two-electrons BCS theory

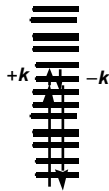


Fig. 1. Electronic states in the (a) ground state, (b) monoanionic state, and (c) dianionic state.

Here, the one extra electron in the absence of such a peculiar interaction is denoted by $|k_{\text{one,av}}\rangle$, and in the presence of the interaction by $|K_{\text{one,av}}\rangle$. Denoting the Hamiltonian of the system by

$$H = H_0 + V_{\text{eff}}, \quad (4)$$

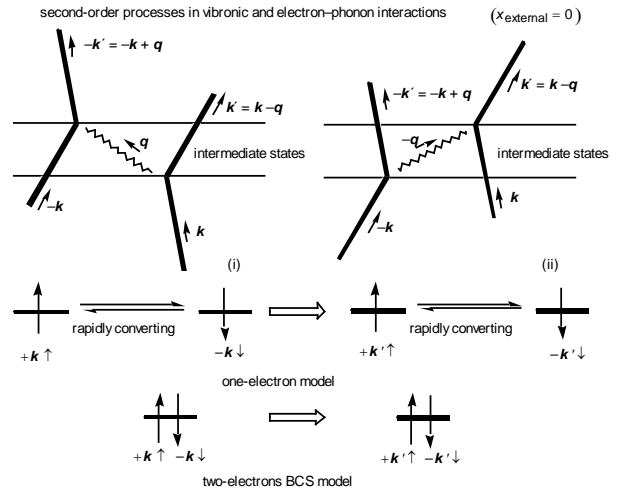
then

$$H_0|\pm k\rangle = \varepsilon_k|\pm k\rangle, \quad (5)$$

where ε_k denotes the single-particle energy of the non-interacting fermion system. Adding interactions, the exact Schrödinger equation for the one-particle problem defined above are given by

$$H|K_{\text{one,av}}\rangle = E_{\text{one},k}|K_{\text{one,av}}\rangle, \quad (6)$$

where $E_{\text{one},k}$ denotes the exact one-particle energy above the Fermi-surface, in the presence of vibronic interactions. Assuming that the states $|k_{\text{one,av}}\rangle$ form a complete set



(a) no external applied electric or magnetic field in one-electron model ($x_{\text{external}} = 0$)

$$\begin{aligned} & \begin{array}{c} \uparrow \\ +k \end{array} \rightleftharpoons \begin{array}{c} \downarrow \\ -k \end{array} \\ & \psi_{k,\text{one,av}}(x_{\text{external}}) = |k_{\text{one,av}}(x_{\text{external}})\rangle = c_{+,k\uparrow}(x_{\text{external}})|+k\rangle + c_{-,k\downarrow}(x_{\text{external}})|-k\rangle \\ & |c_{+,k\uparrow}(0)\rangle = |c_{-,k\downarrow}(0)\rangle = \frac{1}{\sqrt{2}} \\ & \psi_{k,\text{one,av}}(0) = |k_{\text{one,av}}(0)\rangle = \frac{1}{\sqrt{2}}|+k\rangle + \frac{1}{\sqrt{2}}|-k\rangle \\ & \frac{1}{2}(+k \uparrow) \leftarrow \bullet \quad \bullet \rightarrow \frac{1}{2}(-k \downarrow) \\ & k_{\text{one,av}}(0) = \left(+\frac{1}{2}k\right) + \left(-\frac{1}{2}k\right) = 0 \end{aligned}$$

the second-order processes in the vibronic and electron-phonon interactions can be applied

(b) no external applied electric or magnetic field in two-electrons BCS model ($x_{\text{external}} = 0$)

$$\begin{aligned} & \begin{array}{c} \uparrow \downarrow \\ +k \uparrow \quad -k \downarrow \end{array} \\ & \psi_{k,\text{two,av}}(x_{\text{external}}) = |k,-k\rangle \\ & \begin{array}{c} \leftarrow \bullet \quad \bullet \rightarrow \\ +k \uparrow \quad -k \downarrow \end{array} \\ & k_{\text{two,av}}(0) = (+k) + (-k) = 0 \end{aligned}$$

the second-order processes in the vibronic and electron-phonon interactions can be applied

Fig. 2. Electron-phonon interactions without any external magnetic field.

such that the exact one-particle eigenstate can be expanded in this basis, then

$$\begin{aligned} |K_{\text{one,av}}\rangle &= \sum_k a_k |k_{\text{one,av}}\rangle \\ &= \sum_k a_k \left\{ \sqrt{P_{k_{\text{ground}}}(T)} |k_{\text{ground}}\rangle + \sqrt{P_{k_{\text{excited}}}(T)} |k_{\text{excited}}\rangle \right\} \end{aligned}$$

$$\begin{aligned}
 &= \sum_k \left\{ a_k \sqrt{P_{k_{\text{ground}}}(T)} \frac{|+k \downarrow\rangle + |-k \uparrow\rangle}{\sqrt{2}} \right. \\
 &\quad \left. + a_k \sqrt{P_{k_{\text{excited}}}(T)} \frac{|+k \uparrow\rangle + |-k \downarrow\rangle}{\sqrt{2}} \right\} \\
 &= \sum_k b_k (|+k\rangle + |-k\rangle). \tag{7}
 \end{aligned}$$

Inserting Eq. (7) into Eq. (6), and then we obtain

$$(H_0 + V_{\text{eff}}) \sum_k b_k (|+k\rangle + |-k\rangle) = E_{\text{one}} \sum_k b_k (|+k\rangle + |-k\rangle). \tag{8}$$

Considering the above orthogonality relation $\langle k' | k \rangle = \delta_{k,k'}$, we thus find

$$\sum_{k'} b_{k'} (\langle +k' | + \langle -k' |) H_0 (|+k\rangle + |-k\rangle) = 2b_k \varepsilon_k, \tag{9}$$

$$\sum_{k'} b_{k'} (\langle +k' | + \langle -k' |) E_{\text{one}} (|+k\rangle + |-k\rangle) = 2b_k E_{\text{one}}. \tag{10}$$

The quantity $\langle k' | V_{\text{eff}} | k \rangle$ denotes a one-electron scattering matrix element from a one-particle state $|k\rangle$ to a one-particle state $|k'\rangle$.

We now consider that the electronic states k can be stabilized by V_{one} only when the scattering within the same electronic states k occurs. That is, we have

$$\begin{aligned}
 \langle +k' | V_{\text{eff}} | +k \rangle &= \langle +k' | V_{\text{eff}} | -k \rangle = \langle -k' | V_{\text{eff}} | +k \rangle \\
 &= \langle -k' | V_{\text{eff}} | -k \rangle = -V_{\text{one},k} \delta_{k,k'}, \tag{11}
 \end{aligned}$$

$$\begin{aligned}
 &\sum_{k'} b_{k'} (\langle +k' | + \langle -k' |) V_{\text{eff}} (|+k\rangle + |-k\rangle) \\
 &= -4V_{\text{one}} \sum_{k'} b_{k'} \delta_{k,k'}. \tag{12}
 \end{aligned}$$

Thus, Eq. (8) takes the form

$$2b_k (\varepsilon_k - E_{\text{one}}) = 4V_{\text{one}} b_k. \tag{13}$$

Then the energy difference between the states of one non-interacting particle on the Fermi-surface (ε_k), and the exact energy eigenvalue (E_{one}), is introduced, i.e., $\Delta_{\text{vib,one}} = \varepsilon_k - E_{\text{one}}$. The $\Delta_{\text{vib,one}}$ denotes the stabilization energy of independent one electron as a consequence of the electron-phonon interactions.

$$\Delta_{\text{vib,one}} = 2V_{\text{one}}. \tag{14}$$

2.2 Conventional Two-Electrons BCS Model

Let us consider added two electrons above the Fermi-surface, as shown in Fig. 1 (c). We now consider that the electronic states k can be stabilized by V_{one} only when the scattering within the same electronic states k occurs. Here, the two-particle state in the absence of such a peculiar interaction is denoted by $|+k, -k\rangle$, as shown in Figs. 1 (c) and 2 (b), and in the presence of the interaction by $|K_1, K_2\rangle$.

$$H_0 | +k, -k \rangle = 2\varepsilon_k | +k, -k \rangle, \tag{15}$$

where ε_k denotes the single-particle energy of the non-interacting fermion system. We must have $2\varepsilon_k > 2\varepsilon_F$ in the presence of the inert Fermi-sea, due to the Pauli principle. Adding interactions, the exact Schrödinger equation for the two-particle problem defined above is given by

$$H | K_1, K_2 \rangle = E_{\text{two}} | K_1, K_2 \rangle, \tag{16}$$

where E_{two} denotes the exact two-particle energy of the two electrons above the Fermi-surface, in the presence of an attractive interaction. Assuming that the states $|+k, -k\rangle$ form a complete set such that the exact two-particle eigenstate can be expanded in this basis, then

$$\begin{aligned}
 |K_1, K_2\rangle &= \sum_k a_k \left\{ \sqrt{P_{k_{\text{ground}}}(T)} | +k \downarrow, -k \uparrow \rangle \right. \\
 &\quad \left. + \sqrt{P_{k_{\text{excited}}}(T)} | +k \uparrow, -k \downarrow \rangle \right\} \\
 &= \sum_k \left\{ a_k \sqrt{P_{k_{\text{ground}}}(T)} | +k \downarrow, -k \uparrow \rangle \right. \\
 &\quad \left. + a_k \sqrt{P_{k_{\text{excited}}}(T)} | +k \uparrow, -k \downarrow \rangle \right\} \\
 &= \sum_k \{ c_k | +k, -k \rangle \}. \tag{17}
 \end{aligned}$$

Inserting Eq. (17) into Eq. (16), and then we obtain,

$$(H_0 + V_{\text{eff}}) \sum_k c_k | +k, -k \rangle = E_{\text{two}} \sum_k c_k | +k, -k \rangle. \tag{18}$$

Considering the above orthogonality relation $\langle +k', -k' | +k, -k \rangle = \delta_{k,k'}$, we thus find

$$\sum_{k'} c_{k'} \langle +k', -k' | H_0 | +k, -k \rangle = 2c_k \varepsilon_k, \tag{19}$$

$$\sum_{k'} c_{k'} \langle +k', -k' | E_{\text{two}} | +k, -k \rangle = c_k E_{\text{two}}, \quad (20)$$

and thus

$$c_k (2\varepsilon_k - E_{\text{two}}) = - \sum_{k'} c_{k'} \langle +k', -k' | V_{\text{eff}} | +k, -k \rangle. \quad (21)$$

The quantity $\langle +k', -k' | V_{\text{eff}} | +k, -k \rangle$ denotes a two-particle scattering matrix element for particles on opposite sides of the Fermi surface, from a two-particle state $|+k, -k\rangle$ to a two-particle state $\langle +k', -k'|$. This scattering matrix element is attractive (V_{two}) within the same electronic states k , and zero elsewhere [1–6]. That is, we have

$$\langle +k', -k' | V_{\text{eff}} | +k, -k \rangle = -V_{\text{two}} \delta_{k,k'}, \quad (22)$$

$$\sum_{k'} c_{k'} \langle +k', -k' | V_{\text{eff}} | +k, -k \rangle = -V_{\text{two}} \sum_{k'} c_{k'} \delta_{k,k'}. \quad (23)$$

Thus, Eq. (21) takes the form

$$c_k (2\varepsilon_k - E_{\text{two}}) = V_{\text{two}} c_k. \quad (24)$$

Then the energy difference between the states of two non-interacting particles on the Fermi-surface, and the exact energy eigenvalue E_{two} , is introduced, i.e., $\Delta_{\text{vib,two}} = 2\varepsilon_F - E_{\text{two}}$. In terms of this variable, Eq. (24) may be written

$$\Delta_{\text{vib,two}} = V_{\text{two}}. \quad (25)$$

2.3 Comparison of the One-Electron Theory with the Conventional Two-Electrons BCS Theory

Let us next investigate the relationships between our new theory of one-electron model and the conventional BCS theory of two-electrons model in electron pairing processes. As discussed in the previous section, the vibronic stabilization energies are derived as Eqs. (14) and (25) in our new theory of independent one-electron model and the conventional theory of bound state two-electrons model, respectively. The vibronic stabilization energies for the opened-shell one electron systems in the various research fields such as the decision of molecular structures, Jahn–Teller effects, Peierls distortions, spectroscopy, electrical conductivity, and superconductivity can be estimated by our one-electron model. On the other hand, since an electron pair must be finally formed from two electrons, we must here consider the stabilization energy of two electrons as a consequence

of the vibronic interactions in order to estimate stabilization energies for electron pairing. Vibronic stabilization energy of independent two electrons in the one-electron theory ($\Delta_{\text{vib,pair,one}}$) is denoted as

$$\Delta_{\text{vib,pair,one}} = 2\Delta_{\text{vib,one}} = 4V_{\text{one}}. \quad (26)$$

Vibronic stabilization energy of bound state two electrons in the two-electrons BCS theory ($\Delta_{\text{vib,pair,two}}$) is denoted as

$$\Delta_{\text{vib,pair,two}} = \Delta_{\text{vib,two}} = V_{\text{two}}. \quad (27)$$

$$V_{k \rightarrow k',m} = \hbar v_{k \rightarrow k',m} g_{k \rightarrow k',m}^2, \quad (28)$$

$$V_{k \rightarrow k'} = \sum_m V_{k \rightarrow k',m}, \quad (29)$$

where $g_{k \rightarrow k',m}$ is the dimensionless vibronic coupling constant for the m th mode, which denotes the slope in the original point on the potential energy surface along each vibrational mode m , and which is proportional to the number of electrons above the Fermi level under consideration [1–7], as shown in Fig. 3. However, in Eq. (14), only independent one electron has been considered and two electrons have not been treated. That is, vibronic stabilization energies for the opened-shell electronic states have been calculated by many researchers, without definite reason, on the basis of the second-order processes in the electron–phonon interactions in quantum field theory, in which the phonon exchanges between two electrons should be considered.

Let us look into the electron–phonon interactions for the independent one-electron model V_{one} . The V_{one} value can be expressed as

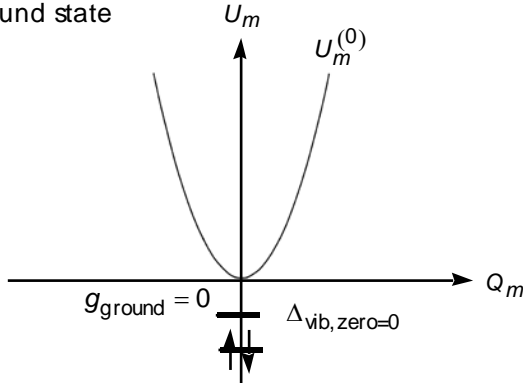
$$V_{\text{one}} = \sum_m g_{k \rightarrow k',m}^2 \hbar v_m, \quad (30)$$

where $g_{k \rightarrow k',m}$ is the vibronic coupling constant between the electronic states originating from an electron promotion from the orbital k to the orbital k' and the vibrational mode m , and the v_m is the frequency for the vibrational mode m , as shown in Fig. 3 (b).

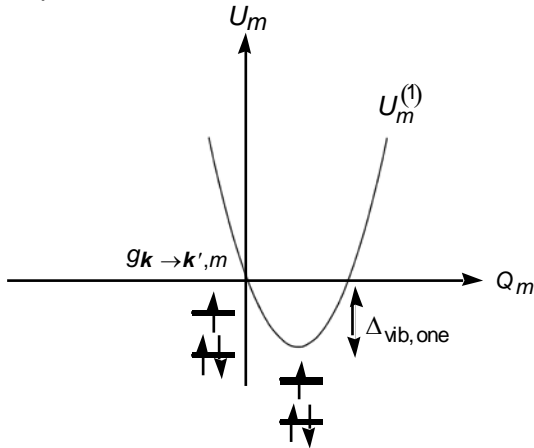
Let us next look into the bound state two-electrons model. In a similar way, by considering that the dimensionless vibronic coupling constants are proportional to the number of electrons above the Fermi level under consideration (i.e., $g_{+k,-k \rightarrow +k',-k',m} = 2g_{k \rightarrow k',m}$), the electron–phonon

coupling constant V_{two} for the two-electrons model can be defined as

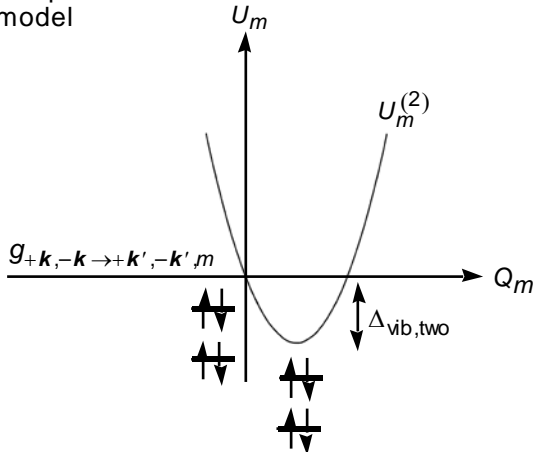
(a) ground state



(b) second-order processes in the vibronic and electron-phonon interactions in one-electron model



(c) second-order processes in the vibronic and electron-phonon interactions in two-electrons BCS model



$$g_{+k,-k \to +k',-k',m} = 2g_{k \to k',m}$$

$$V_{two} = 4V_{one}$$

Fig. 3. Vibronic stabilization energy for (a) ground state, (b) monoanionic state, and (c) dianionic state.

$$V_{two} = \sum_m g_{+k,-k \to +k',-k',m}^2 \hbar \nu_m = \sum_m (2g_{k \to k',m})^2 \hbar \nu_m$$

$$= 4 \sum_m g_{k \to k',m}^2 \hbar \nu_m = 4V_{one}, \quad (31)$$

where $g_{+k,-k \to +k',-k',m}$ is the vibronic coupling constant between the electronic states originating from two electrons promotion from the orbital $(+k, -k)$ to the orbital $(+k', -k')$ and the vibrational mode m .

Let us next discuss the vibronic stabilization energies estimated by the one- and two-electrons theory. From Eqs. (14), (25), and (31), the relationships between the $\Delta_{vib,pair,one}$ and $\Delta_{vib,pair,two}$ values can be expressed as

$$\Delta_{vib,pair,one} = 2\Delta_{vib,one} = \Delta_{vib,two} = \Delta_{vib,pair,two}. \quad (32)$$

Therefore, the vibronic stabilization energies derived from the one-electron theory ($\Delta_{vib,pair,one}$) are exactly the same with those derived from the conventional two-electrons BCS theory ($\Delta_{vib,pair,two}$).

3. Vibronic Stabilization Energies under the External Applied Magnetic Field in Molecules

In this section, we discuss the electron-phonon interactions under external applied magnetic field in molecules.

3.1 One-Electron Model

Let us consider an inert Fermi-sea, in which the electrons are treated as non-interacting [1-7]. To this Fermi-sea, one electron is added above the Fermi-surface. This one added electron does not interact with the inert Fermi-sea, as shown in Fig. 1. One electron occupies a plane-wave state $|k_{one,av.}(c_{k\uparrow}, c_{k\downarrow})\rangle$, in the absence of interactions, as shown in Fig. 2 (a),

$$|k_{one,av.}(c_{k\uparrow}, c_{k\downarrow})\rangle = \sqrt{P_{k_{ground}}(T)} |k_{ground}(c_{k\uparrow}, c_{k\downarrow})\rangle$$

$$+ \sqrt{P_{k_{excited}}(T)} |k_{excited}(c_{k\uparrow}, c_{k\downarrow})\rangle, \quad (33)$$

where

$$|k_{ground}(c_{k\uparrow}, c_{k\downarrow})\rangle = c_{k\downarrow} | +k \downarrow \rangle + c_{k\uparrow} | -k \uparrow \rangle, \quad (34)$$

$$|k_{excited}(c_{k\uparrow}, c_{k\downarrow})\rangle = c_{k\uparrow} | +k \uparrow \rangle + c_{k\downarrow} | -k \downarrow \rangle. \quad (35)$$

$$\langle k_{ground}(c_{k\uparrow}, c_{k\downarrow}) | k_{ground}(c_{k\uparrow}, c_{k\downarrow}) \rangle$$

$$\begin{aligned}
 &= \langle \mathbf{k}_{\text{excited}}(c_{k\uparrow}, c_{k\downarrow}) | \mathbf{k}_{\text{excited}}(c_{k\uparrow}, c_{k\downarrow}) \rangle \\
 &= c_{k\downarrow}^2 + c_{k\uparrow}^2 = 1, \tag{36}
 \end{aligned}$$

$$\begin{aligned}
 &\langle \mathbf{k}_{\text{one.av.}}(c_{k\uparrow}, c_{k\downarrow}) | \mathbf{k}_{\text{one.av.}}(c_{k\uparrow}, c_{k\downarrow}) \rangle \\
 &= P_{k_{\text{ground}}}(T) \langle \mathbf{k}_{\text{ground}}(c_{k\uparrow}, c_{k\downarrow}) | \mathbf{k}_{\text{ground}}(c_{k\uparrow}, c_{k\downarrow}) \rangle \\
 &+ P_{k_{\text{excited}}}(T) \langle \mathbf{k}_{\text{excited}}(c_{k\uparrow}, c_{k\downarrow}) | \mathbf{k}_{\text{excited}}(c_{k\uparrow}, c_{k\downarrow}) \rangle = 1. \tag{37}
 \end{aligned}$$

Here, the one extra electron in the absence of such a peculiar interaction is denoted by $|\mathbf{k}_{\text{one.av.}}(c_{k\uparrow}, c_{k\downarrow})\rangle$, and in the presence of the interaction by $|\mathbf{K}_{\text{one.av.}}(c_{k\uparrow}, c_{k\downarrow})\rangle$. Denoting the Hamiltonian of the system by

$$H = H_0 + V_{\text{eff}}, \tag{38}$$

then

$$H_0|\pm k\rangle = \varepsilon_k|\pm k\rangle, \tag{39}$$

where ε_k denotes the single-particle energy of the non-interacting fermion system. Adding interactions, the exact Schrödinger equation for the one-particle problem defined above are given by

$$\begin{aligned}
 &H|\mathbf{K}_{\text{one.av.}}(c_{k\uparrow}, c_{k\downarrow})\rangle \\
 &= E_{\text{one}}(c_{k\uparrow}, c_{k\downarrow})|\mathbf{K}_{\text{one.av.}}(c_{k\uparrow}, c_{k\downarrow})\rangle, \tag{40}
 \end{aligned}$$

where $E_{\text{one}}(c_{k\uparrow}, c_{k\downarrow})$ denotes the exact one-particle energy above the Fermi-surface, in the presence of vibronic interactions. Assuming that the states $\mathbf{k}_{\text{one.av.}}(c_{k\uparrow}, c_{k\downarrow})$ form a complete set such that the exact one-particle eigenstate can be expanded in this basis, then

$$\begin{aligned}
 |\mathbf{K}_{\text{one.av.}}(c_{k\uparrow}, c_{k\downarrow})\rangle &= \sum_k a_k |\mathbf{k}_{\text{one.av.}}(c_{k\uparrow}, c_{k\downarrow})\rangle \\
 &= \sum_k a_k \left\{ \sqrt{P_{k_{\text{ground}}}(T)} |\mathbf{k}_{\text{ground}}(c_{k\uparrow}, c_{k\downarrow})\rangle \right. \\
 &\quad \left. + a_k \sqrt{P_{k_{\text{excited}}}(T)} |\mathbf{k}_{\text{excited}}(c_{k\uparrow}, c_{k\downarrow})\rangle \right\} \\
 &= \sum_k \left\{ a_k \sqrt{P_{k_{\text{ground}}}(T)} (c_{k\downarrow}|+k\downarrow\rangle + c_{k\uparrow}|-k\uparrow\rangle) \right. \\
 &\quad \left. + a_k \sqrt{P_{k_{\text{excited}}}(T)} (c_{k\uparrow}|+k\uparrow\rangle + c_{k\downarrow}|-k\downarrow\rangle) \right\}
 \end{aligned}$$

$$= \sum_k b_k (c_{k\uparrow}|k\uparrow\rangle + c_{k\downarrow}|k\downarrow\rangle) \tag{41}$$

Inserting Eq. (41) into Eq. (40), and then we obtain

$$\begin{aligned}
 &(H_0 + V_{\text{eff}}) \sum_k a_k |\mathbf{k}_{\text{one.av.}}(c_{k\uparrow}, c_{k\downarrow})\rangle \\
 &= E_{\text{one}}(c_{k\uparrow}, c_{k\downarrow}) \sum_k a_k |\mathbf{k}_{\text{one.av.}}(c_{k\uparrow}, c_{k\downarrow})\rangle. \tag{42}
 \end{aligned}$$

Considering the above orthogonality relation $\langle \mathbf{k}' | \mathbf{k} \rangle = \delta_{\mathbf{k}, \mathbf{k}'}$, we thus find

$$\begin{aligned}
 &\sum_{k'} b_{k'} (c_{k'\uparrow} \langle k'\uparrow | + c_{k'\downarrow} \langle k'\downarrow |) H_0 (c_{k\uparrow} |k\uparrow\rangle + c_{k\downarrow} |k\downarrow\rangle) \\
 &= b_k \varepsilon_k, \tag{43}
 \end{aligned}$$

$$\begin{aligned}
 &\sum_{k'} b_{k'} (c_{k'\uparrow} \langle k'\uparrow | + c_{k'\downarrow} \langle k'\downarrow |) E_{\text{one}}(c_{k\uparrow} |k\uparrow\rangle + c_{k\downarrow} |k\downarrow\rangle) \\
 &= b_k E_{\text{one}}, \tag{44}
 \end{aligned}$$

and thus

$$\begin{aligned}
 &b_k (\varepsilon_k - E_{\text{one}}(c_{k\uparrow}, c_{k\downarrow})) \\
 &= - \sum_{k'} b_{k'} (c_{k'\uparrow} \langle k'\uparrow | + c_{k'\downarrow} \langle k'\downarrow |) \\
 &\quad \times |V_{\text{eff}}|(c_{k\uparrow} |k\uparrow\rangle + c_{k\downarrow} |k\downarrow\rangle) \tag{45}
 \end{aligned}$$

The quantity $\langle \mathbf{k}' | V_{\text{eff}} | \mathbf{k} \rangle$ denotes a one-electron scattering matrix element from a one-particle state $|\mathbf{k}\rangle$ to a one-particle state $|\mathbf{k}'\rangle$ (Fig. 2).

The quantity $\langle \mathbf{k}' | V_{\text{eff}} | \mathbf{k} \rangle$ denotes a one-electron scattering matrix element from a one-particle state $|\mathbf{k}\rangle$ to a one-particle state $|\mathbf{k}'\rangle$. That is, we have

$$\begin{aligned}
 \langle k'\uparrow | V_{\text{eff}} | k\uparrow \rangle &= \langle k'\uparrow | V_{\text{eff}} | k\downarrow \rangle = \langle k'\downarrow | V_{\text{eff}} | k\uparrow \rangle \\
 &= \langle k'\downarrow | V_{\text{eff}} | k\downarrow \rangle = -V_{\text{one}} \delta_{\mathbf{k}, \mathbf{k}'}, \tag{46}
 \end{aligned}$$

$$\begin{aligned}
 &\sum_{k'} b_{k'} (c_{k'\downarrow} \langle +k'\downarrow | + c_{k'\uparrow} \langle -k'\uparrow |) V_{\text{eff}} | \\
 &\quad \times (c_{k\downarrow} |+k\downarrow\rangle + c_{k\uparrow} |-k\uparrow\rangle) \\
 &= -V_{\text{one}} \sum_{k'} b_{k'} (c_{k'\downarrow} c_{k\downarrow} + c_{k'\downarrow} c_{k\uparrow} + c_{k'\uparrow} c_{k\downarrow} + c_{k'\uparrow} c_{k\uparrow}) \\
 &\quad \times \delta_{\mathbf{k}, \mathbf{k}'}
 \end{aligned}$$

$$\begin{aligned}
 &= -V_{\text{one}} \sum_{k'} b_{k'} (1 + 2c_{k'\uparrow}c_{k'\downarrow}) \delta_{k,k'} \\
 &= -2V_{\text{one}} \sum_{k'} b_{k'} \left(\frac{1}{2} + c_{k'\uparrow}c_{k'\downarrow} \right) \delta_{k,k'} \\
 &= -2V_{\text{one}} f_{\text{Bose}}(c_{k\uparrow}, c_{k\downarrow}) \sum_{k'} b_{k'} \delta_{k,k'} \\
 &= -2b_k V_{\text{one}} f_{\text{Bose}}(c_{k\uparrow}, c_{k\downarrow}) \quad (47)
 \end{aligned}$$

where

$$f_{\text{Bose}}(c_{k\uparrow}, c_{k\downarrow}) = \frac{1}{2} + c_{k\uparrow}c_{k\downarrow} = \frac{1}{2} + c_{k\downarrow} \sqrt{1 - c_{k\downarrow}^2} \quad (48)$$

Thus, Eq. (42) takes the form

$$b_k (\varepsilon_k - E_{\text{one}}(c_{k\uparrow}, c_{k\downarrow})) = 2b_k V_{\text{one}} f_{\text{Bose}}(c_{k\uparrow}, c_{k\downarrow}) \quad (49)$$

Then the energy difference between the states of one non-interacting particle on the Fermi-surface (ε_F), and the exact energy eigenvalue ($E_{\text{one}}(c_{k\uparrow}, c_{k\downarrow})$), is introduced, i.e., $\Delta_{\text{vib,one}}(c_{k\uparrow}, c_{k\downarrow}) = \varepsilon_F - E_{\text{one}}(c_{k\uparrow}, c_{k\downarrow})$. In terms of this variable, Eq. (49) may be written

$$\Delta_{\text{vib,one}}(c_{k\uparrow}, c_{k\downarrow}) = 2V_{\text{one}} f_{\text{Bose}}(c_{k\uparrow}, c_{k\downarrow}) \quad (50)$$

The $\Delta_{\text{vib,one}}(c_{k\uparrow}, c_{k\downarrow})$ denotes the stabilization energy of independent one electron as a consequence of the electron-phonon interactions under the external applied magnetic field.

3.2 Comparison of the One-Electron Theory with the Conventional Two-Electrons BCS Theory under the Applied Magnetic Field in Molecules

Let us next discuss the vibronic stabilization energy of independent two electrons in the one-electron theory ($\Delta_{\text{vib,pair,one}}(c_{k\uparrow}, c_{k\downarrow})$).

When the magnetic field penetrates into the specimen ($\Delta B_{\text{in}} \neq 0$), the $\Delta_{\text{vib,pair,two}}(c_{k\uparrow}, c_{k\downarrow})$ value can be defined as

$$\begin{aligned}
 \Delta_{\text{vib,pair,two}}(c_{k\uparrow}, c_{k\downarrow}) &= 2\Delta_{\text{vib,one}}(c_{k\uparrow}, c_{k\downarrow}) \\
 &= 4V_{\text{one}} f_{\text{Bose}}(c_{k\uparrow}, c_{k\downarrow}) \quad (51)
 \end{aligned}$$

On the other hand, when the magnetic field is expelled from the specimen as a consequence of the Meissner effect

($\Delta B_{\text{in}} = 0$), the $\Delta_{\text{vib,pair,two}}(c_{k\uparrow}, c_{k\downarrow})$ value can be defined as

$$\begin{aligned}
 \Delta_{\text{vib,pair,two}}(c_{k\uparrow}, c_{k\downarrow}) &= 2\Delta_{\text{vib,one}}(c_{k\uparrow}, c_{k\downarrow}) \\
 &= 4V_{\text{one}} - 4V_{\text{one}} (1 - f_{\text{Bose}}(c_{k\uparrow}, c_{k\downarrow})) \\
 &= 4V_{\text{one}} f_{\text{Bose}}(c_{k\uparrow}, c_{k\downarrow}) \quad (52)
 \end{aligned}$$

The total electronic energy for the electronic state with $\Delta B_{\text{in}} \neq 0$ is the same with that for the electronic state with $\Delta B_{\text{in}} = 0$. On the other hand, the kinds of energies are different. The electronic energy level itself for the electronic state with $\Delta B_{\text{in}} \neq 0$ is stabilized by $4V_{\text{one}} f_{\text{Bose}}(c_{k\uparrow}, c_{k\downarrow})$ with zero kinetic energy for the supercurrent, while those for the electronic state with $\Delta B_{\text{in}} = 0$ is $4V_{\text{one}}$ with the kinetic energy of supercurrent $4V_{\text{one}} (1 - f_{\text{Bose}}(c_{k\uparrow}, c_{k\downarrow}))$.

4. The Origin of the Faraday's Law

4.1 Theoretical Background

In this article, we consider the molecular systems for mathematical simplicity. On the other hand, we can easily apply this discussion to the case in the solids.

The wave function for an electron occupying the highest occupied crystal orbital (HOCO) in a material under the external applied field ($x_{\text{in}} = B_{\text{in}}$ or E_{in}) can be expressed as

$$\begin{aligned}
 &|k_{\text{HOCO}}(T)((B_{\text{out}}, B_{\text{in}}), (E_{\text{out}}, E_{\text{in}}), B_{k_{\text{HOCO}}}, I_{k_{\text{HOCO}}}) \rangle \\
 &= \sqrt{P_{\text{ground}}(T)} |k_{\text{HOCO,ground},0}(x_{\text{in}}) \rangle \\
 &+ \sqrt{P_{\text{excited}}(T)} |k_{\text{HOCO,excited},0}(x_{\text{in}}) \rangle, \quad (53)
 \end{aligned}$$

where

$$\begin{aligned}
 &|k_{\text{HOCO,excited},0}(x_{\text{in}}) \rangle \\
 &= c_{+k_{\text{HOCO}}\uparrow,0}(x_{\text{in}}) |k_{\text{HOCO}}\uparrow \rangle \\
 &+ c_{-k_{\text{HOCO}}\downarrow,0}(x_{\text{in}}) |k_{\text{HOCO}}\downarrow \rangle, \quad (54)
 \end{aligned}$$

$$\begin{aligned}
 &|k_{\text{HOCO,ground},0}(x_{\text{in}}) \rangle \\
 &= c_{-k_{\text{HOCO}}\uparrow,0}(x_{\text{in}}) |k_{\text{HOCO}}\uparrow \rangle \\
 &+ c_{+k_{\text{HOCO}}\downarrow,0}(x_{\text{in}}) |k_{\text{HOCO}}\downarrow \rangle, \quad (55)
 \end{aligned}$$

$$P_{\text{ground}}(T) + P_{\text{excited}}(T) = 1, \quad (56)$$

$$c_{+k_{\text{HOCO}} \downarrow, 0}^2(x_{\text{in}}) + c_{-k_{\text{HOCO}} \uparrow, 0}^2(x_{\text{in}}) = 1, \quad (57)$$

$$c_{-k_{\text{HOCO}} \downarrow, 0}^2(x_{\text{in}}) + c_{+k_{\text{HOCO}} \uparrow, 0}^2(x_{\text{in}}) = 1. \quad (58)$$

The magnetic field ($B_{k_{\text{HOCO}}}(x_{\text{out}}, x_{\text{in}})(=B_{\text{in}})$) at the condition of the external applied field x_{out} and the field felt by an electron x_{in} can be expressed as

$$B_{k_{\text{HOCO}}}(x_{\text{out}}, x_{\text{in}}) = B_{k_{\text{HOCO}} \uparrow}(x_{\text{out}}, x_{\text{in}}) - B_{k_{\text{HOCO}} \downarrow}(x_{\text{out}}, x_{\text{in}}), \quad (59)$$

where

$$B_{k_{\text{HOCO}} \uparrow}(x_{\text{out}}, x_{\text{in}}) = P_{\text{excited}}(T)c_{+k_{\text{HOCO}} \uparrow, x_{\text{in}}}^2(x_{\text{out}} - x_{\text{in}}) + P_{\text{ground}}(T)c_{-k_{\text{HOCO}} \uparrow, x_{\text{in}}}^2(x_{\text{out}} - x_{\text{in}}), \quad (60)$$

$$B_{k_{\text{HOCO}} \downarrow}(x_{\text{out}}, x_{\text{in}}) = P_{\text{excited}}(T)c_{-k_{\text{HOCO}} \downarrow, x_{\text{in}}}^2(x_{\text{out}} - x_{\text{in}}) + P_{\text{ground}}(T)c_{+k_{\text{HOCO}} \downarrow, x_{\text{in}}}^2(x_{\text{out}} - x_{\text{in}}). \quad (61)$$

The electric field ($I_{k_{\text{HOCO}}}(x_{\text{out}}, x_{\text{in}})(=E_{\text{in}})$) at the condition of the external applied field x_{out} and the field felt by an electron x_{in} can be expressed as

$$I_{k_{\text{HOCO}}}(x_{\text{out}}, x_{\text{in}}) = I_{+k_{\text{HOCO}}}(x_{\text{out}}, x_{\text{in}}) - I_{-k_{\text{HOCO}}}(x_{\text{out}}, x_{\text{in}}), \quad (62)$$

$$I_{+k_{\text{HOCO}}}(x_{\text{out}}, x_{\text{in}}) = P_{\text{excited}}(T)c_{+k_{\text{HOCO}} \uparrow, x_{\text{in}}}^2(x_{\text{out}} - x_{\text{in}}) + P_{\text{ground}}(T)c_{+k_{\text{HOCO}} \downarrow, x_{\text{in}}}^2(x_{\text{out}} - x_{\text{in}}), \quad (63)$$

$$I_{-k_{\text{HOCO}}}(x_{\text{out}}, x_{\text{in}}) = P_{\text{excited}}(T)c_{-k_{\text{HOCO}} \downarrow, x_{\text{in}}}^2(x_{\text{out}} - x_{\text{in}}) + P_{\text{ground}}(T)c_{-k_{\text{HOCO}} \uparrow, x_{\text{in}}}^2(x_{\text{out}} - x_{\text{in}}). \quad (64)$$

Let us look into the energy levels for various electronic states when the applied field increases from 0 to x_{out} at 0 K in superconductor, in which the HOCO is partially occupied by an electron. The stabilization energy as a consequence of the electron-phonon interactions can be expressed as

$$E_{\text{SC, electronic}}(x_{\text{out}}, x_{\text{in}}) - E_{\text{NM, electronic}}(0, 0) = -2V_{\text{one}, f \text{ Bose}, 0}(x_{\text{in}}), \quad (65)$$

where the $-2V_{\text{one}}$ denotes the stabilization energy for the electron-phonon interactions between an electron occupying the HOCO and the vibronically active modes [1-7] (Fig. 4).

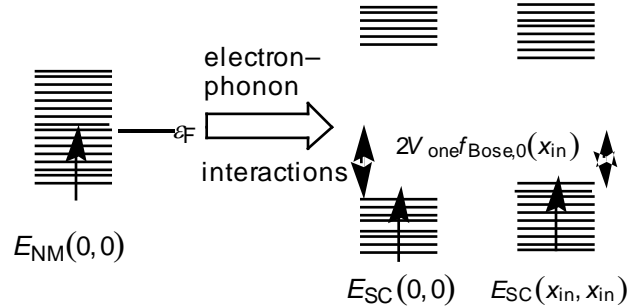


Fig. 4. Stabilization energy as a consequence of the electron-phonon interactions as a function of the external applied field.

The ($f_{\text{Bose}, 0}(E_{\text{in}})$) denotes the ratio of the bosonic property under the internal field x_{in} ($c_{+k_{\text{HOCO}} \downarrow, 0}(x_{\text{in}}) = c_{+k_{\text{HOCO}} \uparrow, 0}(x_{\text{in}}) = c_{+k_{\text{HOCO}}, 0}(x_{\text{in}})$ and $c_{-k_{\text{HOCO}} \uparrow, 0}(x_{\text{in}}) = c_{-k_{\text{HOCO}} \downarrow, 0}(x_{\text{in}}) = c_{-k_{\text{HOCO}}, 0}(x_{\text{in}})$), and can be estimated as

$$f_{\text{Bose}, 0}(x_{\text{in}}) = f_{\text{Bose}, x_{\text{in}}}(0) = \frac{1}{2} + c_{-k_{\text{HOCO}}, 0}(x_{\text{in}}) \sqrt{1 - c_{-k_{\text{HOCO}}, 0}^2(x_{\text{in}})}. \quad (66)$$

The $f_{\text{Bose}, B_{\text{in}}}(0)(=f_{\text{Bose}, 0}(B_{\text{in}}))$ denotes the ratio of the bosonic property under the internal field x_{in} ($c_{+k_{\text{HOCO}} \uparrow, 0}(x_{\text{in}}) = c_{-k_{\text{HOCO}} \uparrow, 0}(x_{\text{in}}) = c_{k_{\text{HOCO}} \uparrow, 0}(x_{\text{in}})$ and $c_{+k_{\text{HOCO}} \downarrow, 0}(x_{\text{in}}) = c_{-k_{\text{HOCO}} \downarrow, 0}(x_{\text{in}}) = c_{k_{\text{HOCO}} \downarrow, 0}(x_{\text{in}})$), and can be estimated as

$$f_{\text{Bose}, 0}(x_{\text{in}}) = f_{\text{Bose}, x_{\text{in}}}(0) = \frac{1}{2} + c_{k_{\text{HOCO}} \downarrow, 0}(x_{\text{in}}) \sqrt{1 - c_{k_{\text{HOCO}} \downarrow, 0}^2(x_{\text{in}})}. \quad (67)$$

4.2 New Interpretation of the Faraday's Law in the Normal Metallic States

Let us next apply the Higgs mechanism to the Faraday's law in the normal metallic states. Let us next consider the superconductor, the critical magnetic field of which is B_c . Below T_c , the bosonic Cooper pairs are in

the superconducting states. We consider the case where the HOCO is partially occupied by an electron. We consider that the magnetic field is quantized by $\Delta B_{\text{unit}} (= B_c / n_c)$. The n_c value is very large and the quantization value of B_c / n_c is very small ($B_c / n_c \approx 0$) (Fig. 5). That is, the j th quantized magnetic field B_j with respect to the zero magnetic field can be defined as

$$B_j = j\Delta B_{\text{unit}}. \tag{68}$$

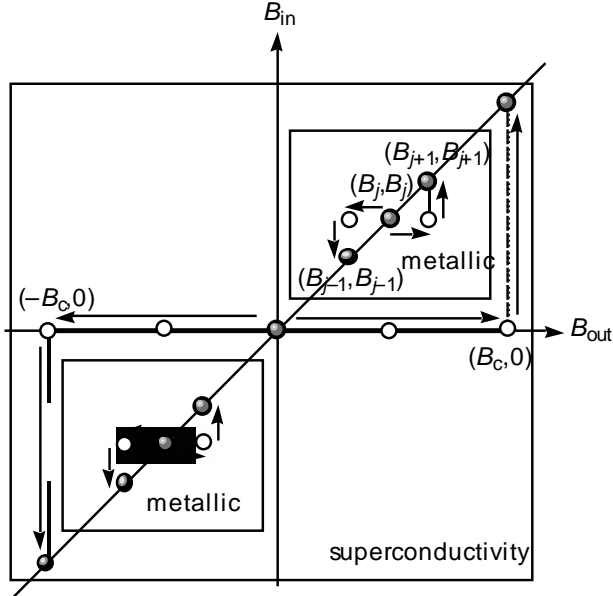


Fig. 5. B_{out} versus B_{in} in the normal metallic and superconducting states.

The ratio of the bosonic property under the internal magnetic field B_{excited} with respect to the ground state for the magnetic field B_γ ($B_{\text{in}} = B_\gamma + B_{\text{excited}}$) can be denoted as $f_{\text{Bose}, B_\gamma}(B_{\text{excited}})$. In particular, the ratio of the bosonic property under the internal magnetic field B_{in} with respect to the ground state for the zero magnetic field can be denoted as $f_{\text{Bose}, 0}(B_{\text{in}})$. We define the electronic

$|k_{\text{HOCO}}(T)((B_{\text{out}}, B_{\text{in}}), (E_{\text{out}}, E_{\text{in}}), B_{k_{\text{HOCO}}}; I_{k_{\text{HOCO}}})$ state, where the E_{out} denotes the induced electric field applied to the specimen, the E_{in} the induced electric field felt by the electron, the $B_{k_{\text{HOCO}}}$ the induced magnetic moment from the electron (the induced magnetic field $B_{\text{induced}, k_{\text{HOCO}}}$ or the change of the spin magnetic moment of an electron $\sigma_{\text{spin}, k_{\text{HOCO}}}$ from the each ground state), and the $I_{k_{\text{HOCO}}}$ the induced electric moment of an

electron (canonical electric momentum $p_{\text{canonical}, k_{\text{HOCO}}}$ or the electric momentum of an electron $v_{\text{em}, k_{\text{HOCO}}}$).

Without any external applied magnetic field ($j=0$; $B_{\text{out}} = B_{\text{in}} = 0$), the ratio of the bosonic property under the internal magnetic field 0 can be estimated to be $f_{\text{Bose}, 0}(0) = 1$. Therefore, the electronic state pairing of an electron behaves as a boson,

$$f_{\text{Bose}, 0}(0) = 1. \tag{69}$$

In such a case ($c_{+k_{\text{HOCO}} \uparrow, 0}(0) = c_{-k_{\text{HOCO}} \uparrow, 0}(0) = c_{+k_{\text{HOCO}} \downarrow, 0}(0) = c_{-k_{\text{HOCO}} \downarrow, 0}(0) = 1/\sqrt{2}$), there is no induced current and the magnetic fields, as expected,

$$\begin{aligned} B_{k_{\text{HOCO}}}(0, 0) &= B_{k_{\text{HOCO}} \uparrow}(0, 0) - B_{k_{\text{HOCO}} \downarrow}(0, 0) \\ &= \left\{ P_{\text{excited}}(T) c_{+k_{\text{HOCO}} \uparrow, 0}^2(0) + P_{\text{ground}}(T) c_{-k_{\text{HOCO}} \uparrow, 0}^2(0) \right\} \\ &\quad - \left\{ P_{\text{excited}}(T) c_{-k_{\text{HOCO}} \downarrow, 0}^2(0) + P_{\text{ground}}(T) c_{+k_{\text{HOCO}} \downarrow, 0}^2(0) \right\} \\ &= 0, \end{aligned} \tag{70}$$

$$\begin{aligned} I_{k_{\text{HOCO}}}(0, 0) &= I_{+k_{\text{HOCO}}}(0, 0) - I_{-k_{\text{HOCO}}}(0, 0) \\ &= \left\{ P_{\text{excited}}(T) c_{+k_{\text{HOCO}} \uparrow, 0}^2(0) + P_{\text{ground}}(T) c_{+k_{\text{HOCO}} \downarrow, 0}^2(0) \right\} \\ &\quad - \left\{ P_{\text{excited}}(T) c_{-k_{\text{HOCO}} \downarrow, 0}^2(0) + P_{\text{ground}}(T) c_{-k_{\text{HOCO}} \uparrow, 0}^2(0) \right\} \\ &= 0. \end{aligned} \tag{71}$$

This can be in agreement with the fact that charges at rest feel no magnetic forces and create no magnetic fields. This is the bosonic ground normal metallic state for $j=0$ ($|k_{\text{HOCO}}(T)((0, 0); (0, 0); 0; 0)\rangle$) (Figs. 6 and 7 (a)). It should be noted that the electronic states are in the ground normal metallic states when all the $p_{\text{canonical}}$, v_{em} , σ_{spin} , and B_{induced} values are 0 ($p_{\text{canonical}} = 0$, $v_{\text{em}} = 0$, $\sigma_{\text{spin}} = 0$, and $B_{\text{induced}} = 0$), and are in the excited normal metallic states when the $p_{\text{canonical}}$, v_{em} , σ_{spin} , or B_{induced} values are not 0 ($p_{\text{canonical}} \neq 0$, $v_{\text{em}} \neq 0$, $\sigma_{\text{spin}} \neq 0$, or $B_{\text{induced}} \neq 0$).

Let us next consider the case where the applied magnetic field (B_{out}) increases from 0 to ΔB_{unit} (Fig. 6). Soon after the external magnetic field is applied, the momentum of the electronic state pairing of an electron cannot be changed but the electromotive force can be induced, because of the Nambu–Goldstone boson formed by the fluctuation of the bosonic electronic state pairing of an electron $|k_{\text{HOCO}}(T)((0, 0); (0, 0); 0; 0)\rangle$. In such a

case, the $B_{k_{\text{HOCO}}}(\Delta B_{\text{unit}}, 0)$ and $I_{k_{\text{HOCO}}}(\Delta B_{\text{unit}}, 0)$ values for the $|k_{\text{HOCO}}(T)(\Delta B_{\text{unit}}, 0); (\Delta E_{\text{unit}}, 0); 0; 0\rangle$ state can be estimated as

$$B_{k_{\text{HOCO}}}(\Delta B_{\text{unit}}, 0) = \left\{ P_{\text{excited}}(T) c_{+k_{\text{HOCO}} \uparrow, 0}^2(\Delta B_{\text{unit}}) + P_{\text{ground}}(T) c_{-k_{\text{HOCO}} \uparrow, 0}^2(\Delta B_{\text{unit}}) - \left\{ P_{\text{excited}}(T) c_{-k_{\text{HOCO}} \downarrow, 0}^2(\Delta B_{\text{unit}}) + P_{\text{ground}}(T) c_{+k_{\text{HOCO}} \downarrow, 0}^2(\Delta B_{\text{unit}}) \right\} \right\} = 0, \quad (72)$$

and thus

$$I_{k_{\text{HOCO}}}(\Delta B_{\text{unit}}, 0) = \left\{ P_{\text{excited}}(T) c_{+k_{\text{HOCO}} \uparrow, 0}^2(\Delta B_{\text{unit}}) + P_{\text{ground}}(T) c_{+k_{\text{HOCO}} \downarrow, 0}^2(\Delta B_{\text{unit}}) - \left\{ P_{\text{excited}}(T) c_{-k_{\text{HOCO}} \downarrow, 0}^2(\Delta B_{\text{unit}}) + P_{\text{ground}}(T) c_{-k_{\text{HOCO}} \uparrow, 0}^2(\Delta B_{\text{unit}}) \right\} \right\} = 2 P_{\text{excited}}(T) \left\{ c_{+k_{\text{HOCO}} \uparrow, 0}^2(\Delta B_{\text{unit}}) - c_{-k_{\text{HOCO}} \downarrow, 0}^2(\Delta B_{\text{unit}}) \right\} = I_{k_{\text{HOCO}}, \text{emf}}(\Delta B_{\text{unit}}, 0) = \Delta E_{\text{unit}} \cdot (73)$$

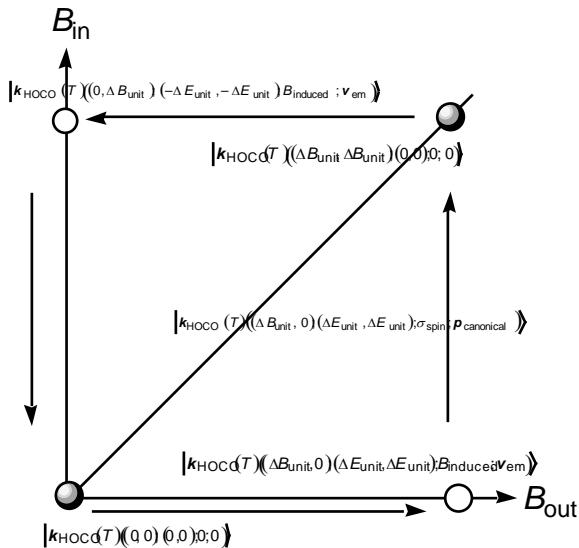


Fig. 6. The B_{in} versus B_{out} between $\gamma=0$ and $\gamma=1$.

Large Bose-Einstein condensation energy ($V_{\text{kin, Fermi}} k_{\text{HOCO}} \sigma(0) \approx 35 \text{ eV}$) may be related to the

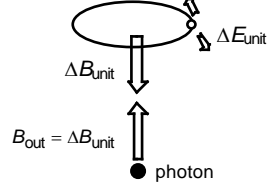
(a) ground bosonic normal metallic state for $j=0$

$$|k_{\text{HOCO}}(T)(0,0)(0,0); 0; 0\rangle$$

$$B_{k_{\text{HOCO}}}(0,0)=0$$

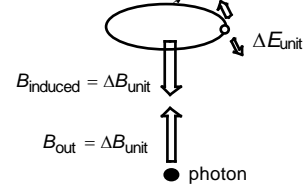
(b) excited bosonic normal metallic state for $j=0$

$$|k_{\text{HOCO}}(T)(\Delta B_{\text{unit}}, 0)(\Delta E_{\text{unit}}, 0); 0; 0\rangle$$



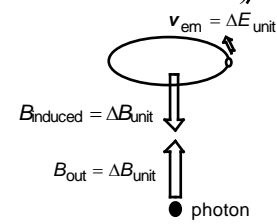
(c) excited bosonic normal metallic state for $j=0$

$$|k_{\text{HOCO}}(T)(\Delta B_{\text{unit}}, 0)(\Delta E_{\text{unit}}, 0); B_{\text{induced}}; 0\rangle$$



(d) excited bosonic normal metallic state for $j=0$

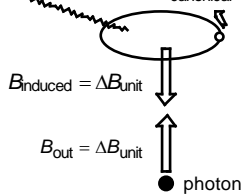
$$|k_{\text{HOCO}}(T)(\Delta B_{\text{unit}}, 0)(\Delta E_{\text{unit}}, \Delta E_{\text{unit}}); B_{\text{induced}}; v_{\text{em}}\rangle$$



(e) excited fermionic normal metallic state for $j=0$

$$|k_{\text{HOCO}}(T)(\Delta B_{\text{unit}}, 0)(\Delta E_{\text{unit}}, \Delta E_{\text{unit}}); \sigma_{\text{spin}}; p_{\text{canonical}}\rangle$$

photon emission (electrical resistivity) $p_{\text{canonical}} = \Delta E_{\text{unit}}$



(f) ground bosonic normal metallic state for $j=1$

$$|k_{\text{HOCO}}(T)(\Delta B_{\text{unit}}, \Delta B_{\text{unit}})(0,0); 0; 0\rangle$$

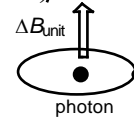


Fig. 7. The electronic states between $j=0$ and $j=1$ in normal metallic states.

Newton's third law and the conventional principle that "nature does not like the immediate change".

When the electromotive force ($I_{k_{\text{HOCO}}}(\Delta B_{\text{unit}}, 0) = \Delta E_{\text{unit}}$) is induced, a Nambu-Goldstone boson formed by the fluctuation of the

electronic state pairing of an electron $|k_{\text{HOCO}}(T)((\Delta B_{\text{unit}}, 0), (\Delta E_{\text{unit}}, 0); 0; 0)\rangle$ is absorbed by a photon (electric field) (Fig. 7 (b)). Therefore, a photon (electric field) has finite mass as a consequence of interaction with the Nambu–Goldstone boson formed by the fluctuation of the bosonic electronic state pairing of an electron. Soon after the electromotive force is induced, the momentum of the bosonic electronic state pairing of an electron cannot be changed but the magnetic field can be induced. In such a case, the $I_{k_{\text{HOCO}}}(\Delta E_{\text{unit}}, 0)$ and $B_{k_{\text{HOCO}}}(\Delta E_{\text{unit}}, 0)$ values for the $|k_{\text{HOCO}}(T)((\Delta B_{\text{unit}}, 0), (\Delta E_{\text{unit}}, 0), B_{\text{induced}}; 0)\rangle$ state (Fig. 7 (c)) can be estimated as

$$\begin{aligned}
 I_{k_{\text{HOCO}}}(\Delta E_{\text{unit}}, 0) &= \left\{ P_{\text{excited}}(T)c_{+k_{\text{HOCO}}\uparrow,0}^2(\Delta E_{\text{unit}}) \right. \\
 &\quad \left. + P_{\text{ground}}(T)c_{+k_{\text{HOCO}}\downarrow,0}^2(\Delta E_{\text{unit}}) \right\} \\
 &\quad - \left\{ P_{\text{excited}}(T)c_{-k_{\text{HOCO}}\downarrow,0}^2(\Delta E_{\text{unit}}) \right. \\
 &\quad \left. + P_{\text{ground}}(T)c_{-k_{\text{HOCO}}\uparrow,0}^2(\Delta E_{\text{unit}}) \right\} \\
 &= 0, \tag{74}
 \end{aligned}$$

and thus

$$\begin{aligned}
 B_{k_{\text{HOCO}}}(\Delta E_{\text{unit}}, 0) &= \left\{ P_{\text{excited}}(T)c_{+k_{\text{HOCO}}\uparrow,0}^2(\Delta E_{\text{unit}}) \right. \\
 &\quad \left. + P_{\text{ground}}(T)c_{-k_{\text{HOCO}}\uparrow,0}^2(\Delta E_{\text{unit}}) \right\} \\
 &\quad - \left\{ P_{\text{excited}}(T)c_{-k_{\text{HOCO}}\downarrow,0}^2(\Delta E_{\text{unit}}) \right. \\
 &\quad \left. + P_{\text{ground}}(T)c_{+k_{\text{HOCO}}\downarrow,0}^2(\Delta E_{\text{unit}}) \right\} \\
 &= 2P_{\text{excited}}(T) \left\{ c_{+k_{\text{HOCO}}\uparrow,0}^2(\Delta E_{\text{unit}}) \right. \\
 &\quad \left. - c_{-k_{\text{HOCO}}\downarrow,0}^2(\Delta E_{\text{unit}}) \right\} \\
 &= B_{\text{induced},k_{\text{HOCO}}}(\Delta E_{\text{unit}}, 0) = -\Delta B_{\text{unit}}. \tag{75}
 \end{aligned}$$

The induced magnetic field $B_{\text{induced},k_{\text{HOCO}}}(\Delta E_{\text{unit}}, 0)$ expels the initially applied external magnetic field ΔB_{unit} from the normal metallic specimen (Fig. 7 (c)). Therefore, the induced magnetic field $B_{\text{induced},k_{\text{HOCO}}}(\Delta E_{\text{unit}}, 0)$ is the origin of the Faraday’s law in the normal metallic states and the Meissner effects in the superconducting states. It should be noted that the magnetic field $B_{\text{induced},k_{\text{HOCO}}}(\Delta E_{\text{unit}}, 0) (\neq 0)$ is induced but the spin magnetic moment of an electron with opened-shell electronic structure is not changed ($\sigma_{\text{spin}} = 0$).

This is very similar to the diamagnetic currents in the superconductivity in that the supercurrents are induced ($v_{\text{em}} \neq 0$) but the total canonical momentum is zero ($p_{\text{canonical}} = 0$). The magnetic field is induced not because of the change of each element of the spin magnetic moment σ_{spin} of an electron (similar to the $p_{\text{canonical}}$ in the superconducting states) but because of the change of the total magnetic momentum as a whole B_{induced} (similar to the v_{em} in the superconducting states).

On the other hand, such excited bosonic electronic state pairing of an electron with the induced magnetic fields $|k_{\text{HOCO}}(T)((\Delta B_{\text{unit}}, 0), (\Delta E_{\text{unit}}, 0), B_{\text{induced}}; 0)\rangle$ can be immediately destroyed because the induced electric field penetrates into the normal metallic specimen, and the electronic state becomes another bosonic excited supercurrent state for $j = 0$ ($|k_{\text{HOCO}}(T)((\Delta B_{\text{unit}}, 0), (\Delta E_{\text{unit}}, \Delta E_{\text{unit}}), B_{\text{induced}}; v_{\text{em}})\rangle$) (Fig. 7 (d)). In the $|k_{\text{HOCO}}(T)((\Delta B_{\text{unit}}, 0), (\Delta E_{\text{unit}}, \Delta E_{\text{unit}}), B_{\text{induced}}; v_{\text{em}})\rangle$ state, an electron receives the electromotive force ΔE_{unit} , and thus the superconducting current can be induced, and thus there is kinetic energy ($E_{\text{kinetic}}(\Delta E_{\text{unit}}, \Delta E_{\text{unit}})$) of the supercurrent. In such a case, the $B_{k_{\text{HOCO}}}(\Delta E_{\text{unit}}, \Delta E_{\text{unit}})$ and $I_{k_{\text{HOCO}}}(\Delta E_{\text{unit}}, \Delta E_{\text{unit}})$ values for the $|k_{\text{HOCO}}(T)((\Delta B_{\text{unit}}, 0), (\Delta E_{\text{unit}}, \Delta E_{\text{unit}}), B_{\text{induced}}; v_{\text{em}})\rangle$ state can be estimated as

$$\begin{aligned}
 B_{k_{\text{HOCO}}}(\Delta E_{\text{unit}}, \Delta E_{\text{unit}}) &= B_{k_{\text{HOCO}}}(\Delta E_{\text{unit}}, 0) \\
 &= \left\{ P_{\text{excited}}(T)c_{+k_{\text{HOCO}}\uparrow,0}^2(\Delta E_{\text{unit}}) \right. \\
 &\quad \left. + P_{\text{ground}}(T)c_{-k_{\text{HOCO}}\uparrow,0}^2(\Delta E_{\text{unit}}) \right\} \\
 &\quad - \left\{ P_{\text{excited}}(T)c_{-k_{\text{HOCO}}\downarrow,0}^2(\Delta E_{\text{unit}}) \right. \\
 &\quad \left. + P_{\text{ground}}(T)c_{+k_{\text{HOCO}}\downarrow,0}^2(\Delta E_{\text{unit}}) \right\} \\
 &= 2P_{\text{excited}}(T) \left\{ c_{+k_{\text{HOCO}}\uparrow,0}^2(\Delta E_{\text{unit}}) \right. \\
 &\quad \left. - c_{-k_{\text{HOCO}}\downarrow,0}^2(\Delta E_{\text{unit}}) \right\} \\
 &= B_{\text{induced},k_{\text{HOCO}}}(\Delta E_{\text{unit}}, 0) = -\Delta B_{\text{unit}}, \tag{76}
 \end{aligned}$$

$$\begin{aligned}
 I_{k_{\text{HOCO}}}(\Delta E_{\text{unit}}, \Delta E_{\text{unit}}) &= I_{k_{\text{HOCO}}}(\Delta B_{\text{unit}}, 0) \\
 &= \left\{ P_{\text{excited}}(T)c_{+k_{\text{HOCO}}\uparrow,0}^2(\Delta B_{\text{unit}}) \right. \\
 &\quad \left. + P_{\text{ground}}(T)c_{+k_{\text{HOCO}}\downarrow,0}^2(\Delta B_{\text{unit}}) \right\}
 \end{aligned}$$

$$\begin{aligned}
 & - \left\{ P_{\text{excited}}(T) c_{-k_{\text{HOCO} \downarrow, 0}}^2 (\Delta B_{\text{unit}}) \right. \\
 & \left. + P_{\text{ground}}(T) c_{-k_{\text{HOCO} \uparrow, 0}}^2 (\Delta B_{\text{unit}}) \right\} \\
 & = 2 P_{\text{excited}}(T) \left\{ c_{+k_{\text{HOCO} \uparrow, 0}}^2 (\Delta B_{\text{unit}}) \right. \\
 & \quad \left. - c_{-k_{\text{HOCO} \downarrow, 0}}^2 (\Delta B_{\text{unit}}) \right\} \\
 & = \nu_{\text{em}, k_{\text{HOCO}}} (\Delta E_{\text{unit}}, \Delta E_{\text{unit}}) = \Delta E_{\text{unit}}. \quad (77)
 \end{aligned}$$

That is, the energy of the electromotive force ΔE_{unit} for the $|k_{\text{HOCO}}(T)((\Delta B_{\text{unit}}, 0); (\Delta E_{\text{unit}}, 0); B_{\text{induced}}; 0)\rangle$ state is converted to the kinetic energy of the supercurrent for the $|k_{\text{HOCO}}(T)((\Delta B_{\text{unit}}, 0); (\Delta E_{\text{unit}}, \Delta E_{\text{unit}}); B_{\text{induced}}; \nu_{\text{em}})\rangle$ state. Both the supercurrent ($\nu_{\text{em}, k_{\text{HOCO}}} (\Delta E_{\text{unit}}, \Delta E_{\text{unit}})$) and the magnetic field ($B_{\text{induced}, k_{\text{HOCO}}} (\Delta E_{\text{unit}}, \Delta E_{\text{unit}})$) can be induced under the condition of the opened-shell electronic structure with zero spin magnetic momentum and canonical momentum ($\sigma_{\text{spin}} = 0; p_{\text{canonical}} = 0$).

On the other hand, such excited bosonic normal metallic states with supercurrents ($|k_{\text{HOCO}}(T)((\Delta B_{\text{unit}}, 0); (\Delta E_{\text{unit}}, \Delta E_{\text{unit}}); B_{\text{induced}}; \nu_{\text{em}})\rangle$) can be immediately destroyed because of the unstable opened-shell electronic states subject to the external applied magnetic field, and the electronic state becomes another excited fermionic normal metallic states for $j = 0$ ($|k_{\text{HOCO}}(T)((\Delta B_{\text{unit}}, 0); (\Delta E_{\text{unit}}, \Delta E_{\text{unit}}); \sigma_{\text{spin}}; p_{\text{canonical}})\rangle$) (Fig. 7 (e)). In such a case, the $B_{k_{\text{HOCO}}} (\Delta E_{\text{unit}}, \Delta E_{\text{unit}})$ and $I_{k_{\text{HOCO}}} (\Delta E_{\text{unit}}, \Delta E_{\text{unit}})$ values for the $|k_{\text{HOCO}}(T)((\Delta B_{\text{unit}}, 0); (\Delta E_{\text{unit}}, \Delta E_{\text{unit}}); \sigma_{\text{spin}}; p_{\text{canonical}})\rangle$ state can be estimated as

$$\begin{aligned}
 B_{k_{\text{HOCO}}} (\Delta E_{\text{unit}}, \Delta E_{\text{unit}}) & = B_{k_{\text{HOCO}}} (\Delta E_{\text{unit}}, 0) \\
 & = \left\{ P_{\text{excited}}(T) c_{+k_{\text{HOCO} \uparrow, 0}}^2 (\Delta E_{\text{unit}}) \right. \\
 & \quad \left. + P_{\text{ground}}(T) c_{-k_{\text{HOCO} \uparrow, 0}}^2 (\Delta E_{\text{unit}}) \right\} \\
 & \quad - \left\{ P_{\text{excited}}(T) c_{-k_{\text{HOCO} \downarrow, 0}}^2 (\Delta E_{\text{unit}}) \right. \\
 & \quad \left. + P_{\text{ground}}(T) c_{+k_{\text{HOCO} \downarrow, 0}}^2 (\Delta E_{\text{unit}}) \right\} \\
 & = 2 P_{\text{excited}}(T) \left\{ c_{+k_{\text{HOCO} \uparrow, 0}}^2 (\Delta E_{\text{unit}}) \right. \\
 & \quad \left. - c_{-k_{\text{HOCO} \downarrow, 0}}^2 (\Delta E_{\text{unit}}) \right\} \\
 & = \sigma_{\text{spin}, k_{\text{HOCO}}} (\Delta E_{\text{unit}}, \Delta E_{\text{unit}}) = -\Delta B_{\text{unit}}, \quad (78)
 \end{aligned}$$

$$\begin{aligned}
 I_{k_{\text{HOCO}}} (\Delta E_{\text{unit}}, \Delta E_{\text{unit}}) & = I_{k_{\text{HOCO}}} (\Delta B_{\text{unit}}, 0) \\
 & = \left\{ P_{\text{excited}}(T) c_{+k_{\text{HOCO} \uparrow, 0}}^2 (\Delta B_{\text{unit}}) \right. \\
 & \quad \left. + P_{\text{ground}}(T) c_{+k_{\text{HOCO} \downarrow, 0}}^2 (\Delta B_{\text{unit}}) \right\} \\
 & \quad - \left\{ P_{\text{excited}}(T) c_{-k_{\text{HOCO} \downarrow, 0}}^2 (\Delta B_{\text{unit}}) \right. \\
 & \quad \left. + P_{\text{ground}}(T) c_{-k_{\text{HOCO} \uparrow, 0}}^2 (\Delta B_{\text{unit}}) \right\} \\
 & = 2 P_{\text{excited}}(T) \left\{ c_{+k_{\text{HOCO} \uparrow, 0}}^2 (\Delta B_{\text{unit}}) \right. \\
 & \quad \left. - c_{-k_{\text{HOCO} \downarrow, 0}}^2 (\Delta B_{\text{unit}}) \right\} \\
 & = p_{\text{canonical}, k_{\text{HOCO}}} (\Delta E_{\text{unit}}, \Delta E_{\text{unit}}) = \Delta E_{\text{unit}}. \quad (79)
 \end{aligned}$$

It should be noted that the electronic $|k_{\text{HOCO}}(T)((\Delta B_{\text{unit}}, 0); (\Delta E_{\text{unit}}, \Delta E_{\text{unit}}); \sigma_{\text{spin}}; p_{\text{canonical}})\rangle$ state is now somewhat fermionic because the $p_{\text{canonical}}$ value is not 0. In other words, the $|k_{\text{HOCO}}(T)((\Delta B_{\text{unit}}, 0); (\Delta E_{\text{unit}}, \Delta E_{\text{unit}}); \sigma_{\text{spin}}; p_{\text{canonical}})\rangle$ state is closely related to the normal conducting states in that the normal metallic current with $p_{\text{canonical}} \neq 0$ and $\nu_{\text{em}} = 0$ is induced by the induced electromotive forces.

Such excited fermionic normal metallic states with currents and the induced magnetic field ($|k_{\text{HOCO}}(T)((\Delta B_{\text{unit}}, 0); (\Delta E_{\text{unit}}, \Delta E_{\text{unit}}); \sigma_{\text{spin}}; p_{\text{canonical}})\rangle$) can be immediately destroyed because of the unstable opened-shell electronic states subject to the external applied magnetic field, and the induced current and the magnetic field can be immediately destroyed, and thus the initially external applied magnetic field can start to penetrate into the normal metallic specimen. Therefore, the electronic state tries to become another ground bosonic metallic state for $j = 1$ ($|k_{\text{HOCO}}(T)((\Delta B_{\text{unit}}, \Delta B_{\text{unit}}); (0, 0); 0; 0)\rangle$) (Fig. 7 (f)). In such a case, the $B_{k_{\text{HOCO}}} (\Delta B_{\text{unit}}, \Delta B_{\text{unit}})$ and $I_{k_{\text{HOCO}}} (\Delta B_{\text{unit}}, \Delta B_{\text{unit}})$ values for the $|k_{\text{HOCO}}(T)((\Delta B_{\text{unit}}, \Delta B_{\text{unit}}); (0, 0); 0; 0)\rangle$ state can be estimated as

$$\begin{aligned}
 I_{k_{\text{HOCO}}} (\Delta B_{\text{unit}}, \Delta B_{\text{unit}}) & = \left\{ P_{\text{excited}}(T) c_{+k_{\text{HOCO} \uparrow, \Delta B_{\text{unit}}}}^2 (0) \right. \\
 & \quad \left. + P_{\text{ground}}(T) c_{+k_{\text{HOCO} \downarrow, \Delta B_{\text{unit}}}}^2 (0) \right\} \\
 & \quad - \left\{ P_{\text{excited}}(T) c_{-k_{\text{HOCO} \downarrow, \Delta B_{\text{unit}}}}^2 (0) \right.
 \end{aligned}$$

$$+ P_{\text{ground}}(T) c_{-k_{\text{HOCO}} \uparrow, \Delta B_{\text{unit}}}^2(0) \Big\} = 0, \tag{80}$$

and thus

$$B_{k_{\text{HOCO}}}(\Delta B_{\text{unit}}, \Delta B_{\text{unit}}) = \left\{ P_{\text{excited}}(T) c_{+k_{\text{HOCO}} \uparrow, \Delta B_{\text{unit}}}^2(0) + P_{\text{ground}}(T) c_{-k_{\text{HOCO}} \uparrow, \Delta B_{\text{unit}}}^2(0) - \left\{ P_{\text{excited}}(T) c_{-k_{\text{HOCO}} \downarrow, \Delta B_{\text{unit}}}^2(0) + P_{\text{ground}}(T) c_{+k_{\text{HOCO}} \downarrow, \Delta B_{\text{unit}}}^2(0) \right\} \right. \\ \left. = 2 P_{\text{excited}}(T) \left\{ c_{+k_{\text{HOCO}} \uparrow, \Delta E_{\text{unit}}}^2(0) - c_{-k_{\text{HOCO}} \downarrow, \Delta E_{\text{unit}}}^2(0) \right\} \right. \\ \left. = \sigma_{\text{spin}, k_{\text{HOCO}}}(\Delta B_{\text{unit}}, \Delta B_{\text{unit}}) = \Delta B_{\text{unit}}. \tag{81}$$

It should be noted that the ground bosonic $|k_{\text{HOCO}}(T)((\Delta B_{\text{unit}}, \Delta B_{\text{unit}}); (0, 0); 0; 0)\rangle$ state is unstable with respect to the ground bosonic state for zero magnetic field $|k_{\text{HOCO}}(T)((0, 0); (0, 0); 0; 0)\rangle$.

The $f_{\text{Bose}, \Delta B_{\text{unit}}}(0)$ value is smaller than the $f_{\text{Bose}, 0}(0)$ value. It should be noted that the $f_{\text{Bose}, B_{\text{in}}}(0)$ value decreases with an increase in the $|B_{\text{in}}|$ value. That is, the bosonic and fermionic properties decrease and increase with an increase in the $|B_{\text{in}}|$ value, respectively. The London penetrating length $\lambda_L(\Delta B_{\text{unit}}, \Delta B_{\text{unit}})$ value and the mass of a photon $m_{\text{photon}}(\Delta B_{\text{unit}}, \Delta B_{\text{unit}})$ for the ground bosonic normal metallic $|k_{\text{HOCO}}(T)((\Delta B_{\text{unit}}, \Delta B_{\text{unit}}); (0, 0); 0; 0)\rangle$ state can be estimated to be $+\infty$ and 0, respectively. That is, a photon becomes massless at the ground bosonic electronic states $(|k_{\text{HOCO}}(T)((B_{\text{in}}, B_{\text{in}}); (0, 0); 0; 0)\rangle)$ under the magnetic field of $B_{k_{\text{HOCO}}}(B_{\text{in}}, B_{\text{in}})$, and thus the external applied magnetic field can penetrate into the normal metallic medium.

In summary, because of the very large stabilization energy ($V_{\text{kin}, \text{Fermi}, k_{\text{HOCO}}} \sigma(0) \approx 35 \text{ eV}$) for the Bose-Einstein condensation ($p_{\text{canonical}} = 0$; $V_{\text{kin}, \text{Bose}, k_{\text{HOCO}}} \sigma(0) = 0 \text{ eV}$), the magnetic momentum of an electron cannot be changed but electromotive force (ΔE_{unit}) can be induced soon after the external magnetic field is applied. This is the excited bosonic normal metallic state for $j = 0$

$(|k_{\text{HOCO}}(T)((\Delta B_{\text{unit}}, 0); (\Delta E_{\text{unit}}, 0); 0; 0)\rangle)$. In such a case, the induced electric field as well as the applied external magnetic field is expelled from the normal metallic specimen. It should be noted that the electronic $|k_{\text{HOCO}}(T)((\Delta B_{\text{unit}}, 0); (\Delta E_{\text{unit}}, 0); 0; 0)\rangle$ state is still bosonic since the $p_{\text{canonical}}$ value is 0. The electric and magnetic momentum of a bosonic electronic state pairing of an electron cannot be changed but the magnetic field can be induced soon after the electromotive force is induced. Therefore, the electronic state becomes $|k_{\text{HOCO}}(T)((\Delta B_{\text{unit}}, 0); (\Delta E_{\text{unit}}, 0); B_{\text{induced}}; 0)\rangle$. This is the origin of the Ampère's law. This induced magnetic field B_{induced} can expel the initially external applied magnetic field $B_{\text{out}} (= \Delta B_{\text{unit}})$ from the normal metallic specimen. That is, the B_{induced} and $B_{\text{out}} (= \Delta B_{\text{unit}})$ values are completely compensated by each other. This is the origin of the Lenz's law. On the other hand, such excited bosonic supercurrent states with the induced magnetic fields $|k_{\text{HOCO}}(T)((\Delta B_{\text{unit}}, 0); (\Delta E_{\text{unit}}, 0); B_{\text{induced}}; 0)\rangle$ can be immediately destroyed because the electromotive force penetrates into the normal metallic specimen, and the electronic state becomes another bosonic excited supercurrent state for $j = 0$ ($|k_{\text{HOCO}}(T)((\Delta B_{\text{unit}}, 0); (\Delta E_{\text{unit}}, \Delta E_{\text{unit}}); B_{\text{induced}}; v_{\text{em}})\rangle$). In the state $|k_{\text{HOCO}}(T)((\Delta B_{\text{unit}}, 0); (\Delta E_{\text{unit}}, \Delta E_{\text{unit}}); B_{\text{induced}}; v_{\text{em}})\rangle$ state, the supercurrent can be induced, and thus there is kinetic energy ($E_{\text{kinetic}}(\Delta E_{\text{unit}}, \Delta E_{\text{unit}})$). This is the origin of the Faraday's law. That is, the energy of the electromotive force ΔE_{unit} for the $|k_{\text{HOCO}}(T)((\Delta B_{\text{unit}}, 0); (\Delta E_{\text{unit}}, 0); B_{\text{induced}}; 0)\rangle$ state is converted to the kinetic energy of the supercurrent for the $|k_{\text{HOCO}}(T)((\Delta B_{\text{unit}}, 0); (\Delta E_{\text{unit}}, \Delta E_{\text{unit}}); B_{\text{induced}}; v_{\text{em}})\rangle$ state. Both the supercurrent ($v_{\text{em}, k_{\text{HOCO}}}(\Delta E_{\text{unit}}, \Delta E_{\text{unit}})$) and the magnetic field ($B_{\text{induced}, k_{\text{HOCO}}}(\Delta E_{\text{unit}}, \Delta E_{\text{unit}})$) can be induced under the condition of the opened-shell electronic structure with zero spin magnetic momentum and canonical momentum ($\sigma_{\text{spin}} = 0$; $p_{\text{canonical}} = 0$). This is the origin of the Faraday's and Ampère's law. Such excited bosonic states with supercurrents $|k_{\text{HOCO}}(T)((\Delta B_{\text{unit}}, 0); (\Delta E_{\text{unit}}, \Delta E_{\text{unit}}); B_{\text{induced}}; v_{\text{em}})\rangle$ can be immediately destroyed because of the unstable opened-shell electronic states, and the induced supercurrent can be immediately destroyed, and the electronic state becomes another excited fermionic normal

metallic state for $j = 0$ ($|k_{\text{HOCO}}(T)((\Delta B_{\text{unit}}, 0); (\Delta E_{\text{unit}}, \Delta E_{\text{unit}}); \sigma_{\text{spin}}; p_{\text{canonical}})\rangle$). The excited fermionic normal metallic ($|k_{\text{HOCO}}(T)((\Delta B_{\text{unit}}, 0); (\Delta E_{\text{unit}}, \Delta E_{\text{unit}}); \sigma_{\text{spin}}; p_{\text{canonical}})\rangle$) state is very unstable and try to become another ground bosonic metallic state for $j = 1$, and the induced electrical current and the induced magnetic field can be immediately dissipated, and thus the initially applied external magnetic field can penetrate into the ground bosonic normal metallic state ($|k_{\text{HOCO}}(T)((\Delta B_{\text{unit}}, \Delta B_{\text{unit}}); (0, 0); 0; 0)\rangle$) medium.

4.3 Energy Levels for Various Electronic States

Let us look into the energy levels for various electronic states when the applied magnetic field (B_{out}) increases from 0 to ΔB_{unit} at 0 K in superconductor, in which the HOCO is partially occupied by an electron. The total energy $E_{\text{total}}(x_{\text{out}}, x_{\text{in}})$ for various electronic states with respect to the Fermi level before electron-phonon interactions at 0 K and $x_{\text{out}} = x_{\text{in}} = 0$ (Fig. 4) can be expressed as

$$E_{\text{total}}(x_{\text{out}}, x_{\text{in}}) = E_{\text{SC}}(x_{\text{out}}, x_{\text{in}}) - E_{\text{NM}}(0, 0) = E_{\text{electronic}}(x_{\text{out}}, x_{\text{in}}) + E_{\text{magnetic}}(x_{\text{out}}, x_{\text{in}}). \quad (82)$$

At $B_{\text{out}} = B_{\text{in}} = 0$, the electronic state is in the ground normal metallic ($|k_{\text{HOCO}}(T)((0, 0); (0, 0); 0; 0)\rangle$) state for $j = 0$. The electronic and magnetic energies for the ($|k_{\text{HOCO}}(T)((0, 0); (0, 0); 0; 0)\rangle$) state can be expressed as

$$E_{\text{electronic}}(0, 0) = -2V_{\text{one}} f_{\text{Bose}, 0}(0) = -2V_{\text{one}}. \quad (83)$$

$$E_{\text{magnetic}}(0, 0) = 0. \quad (84)$$

The $E_{\text{electronic}}(\Delta B_{\text{unit}}, 0)$ value for the ($|k_{\text{HOCO}}(T)((\Delta B_{\text{unit}}, 0); (\Delta E_{\text{unit}}, 0); 0; 0)\rangle$) state can be estimated as

$$E_{\text{electronic}}(\Delta B_{\text{unit}}, 0) = -2V_{\text{one}} f_{\text{Bose}, 0}(0) + E_{I_{k_{\text{HOCO}}}}(\Delta B_{\text{unit}}, 0) = -2V_{\text{one}} f_{\text{Bose}, 0}(\Delta B_{\text{unit}}), \quad (85)$$

where the $E_{I_{k_{\text{HOCO}}}}(\Delta B_{\text{unit}}, 0)$ value denotes the energy of the electromotive force, and is estimated as

$$E_{I_{k_{\text{HOCO}}}}(\Delta B_{\text{unit}}, 0) = 2V_{\text{one}} (f_{\text{Bose}, 0}(0) - f_{\text{Bose}, 0}(\Delta B_{\text{unit}})) = 2V_{\text{one}} (1 - f_{\text{Bose}, 0}(\Delta B_{\text{unit}})) \quad (86)$$

Furthermore, we must consider the magnetic energy ($E_{\text{magnetic}}(\Delta B_{\text{unit}}, 0)$) as a consequence of the expelling of the external initially applied magnetic field ΔB_{unit} ,

$$E_{\text{magnetic}}(\Delta B_{\text{unit}}, 0) = E_{\text{expeI}}(\Delta B_{\text{unit}}, 0) = \frac{1}{2} \mu_0 \Delta B_{\text{unit}}^2 v_{\text{SC}}, \quad (87)$$

where the μ_0 denotes the magnetic permeability in vacuum, and the v_{SC} denotes the volume of the specimen. The total energy level for the ($|k_{\text{HOCO}}(T)((\Delta B_{\text{unit}}, 0); (\Delta E_{\text{unit}}, 0); 0; 0)\rangle$) state can be estimated as

$$E_{\text{total}}(\Delta B_{\text{unit}}, 0) = E_{\text{electronic}}(\Delta B_{\text{unit}}, 0) + E_{\text{magnetic}}(\Delta B_{\text{unit}}, 0) = -2V_{\text{one}} f_{\text{Bose}, 0}(\Delta B_{\text{unit}}) + \frac{1}{2} \mu_0 \Delta B_{\text{unit}}^2 v_{\text{SC}}. \quad (88)$$

We can consider from Eqs. (85)–(88) that the energy for the excited normal metallic ($|k_{\text{HOCO}}(T)((\Delta B_{\text{unit}}, 0); (\Delta E_{\text{unit}}, 0); 0; 0)\rangle$) state is $-2V_{\text{one}}$ with the energy of the electromotive force $2V_{\text{one}} (f_{\text{Bose}, 0}(0) - f_{\text{Bose}, 0}(\Delta E_{\text{unit}}))$ and the energy of the expelling of the external initially applied magnetic field $E_{\text{magnetic}}(\Delta E_{\text{unit}}, 0)$, and thus the total energy for the bosonic excited normal metallic ($|k_{\text{HOCO}}(T)((\Delta B_{\text{unit}}, 0); (\Delta E_{\text{unit}}, 0); 0; 0)\rangle$) state is $-2V_{\text{one}} f_{\text{Bose}, 0}(\Delta E_{\text{unit}}) + E_{\text{expeI}}(\Delta B_{\text{unit}}, 0)$. In other words, the energy for the applied magnetic field ΔB_{unit} is converted to the energy of the electromotive force $2V_{\text{one}} (f_{\text{Bose}, 0}(0) - f_{\text{Bose}, 0}(\Delta E_{\text{unit}}))$ and the energy of the expelling of the external initially applied magnetic field $E_{\text{expeI}}(\Delta B_{\text{unit}}, 0)$.

The $E_{\text{electronic}}(\Delta E_{\text{unit}}, 0)$ value for the ($|k_{\text{HOCO}}(T)((\Delta B_{\text{unit}}, 0); (\Delta E_{\text{unit}}, 0); B_{\text{induced}}; 0)\rangle$) state can be estimated as

$$E_{\text{electronic}}(\Delta E_{\text{unit}}, 0) = -2V_{\text{one}} f_{\text{Bose}, 0}(0) + E_{I_{k_{\text{HOCO}}}}(\Delta E_{\text{unit}}, 0)$$

$$= -2V_{\text{one}} f_{\text{Bose},0}(\Delta E_{\text{unit}}) \quad (89)$$

Furthermore, we must consider the magnetic energy ($E_{\text{magnetic}}(\Delta E_{\text{unit}}, 0)$) as a consequence of the induced magnetic field $E_{B_{k_{\text{HOCO}}}}(\Delta E_{\text{unit}}, 0)$,

$$\begin{aligned} E_{\text{magnetic}}(\Delta E_{\text{unit}}, 0) &= E_{B_{k_{\text{HOCO}}}}(\Delta E_{\text{unit}}, 0) \\ &= \frac{1}{2} \mu_0 \Delta B_{\text{unit}}^2 v_{\text{SC}}. \end{aligned} \quad (90)$$

The total energy level for the $|k_{\text{HOCO}}(T)((\Delta B_{\text{unit}}, 0), (\Delta E_{\text{unit}}, 0), B_{\text{induced}}; 0)\rangle$ state can be estimated as

$$\begin{aligned} E_{\text{total}}(\Delta E_{\text{unit}}, 0) &= E_{\text{electronic}}(\Delta E_{\text{unit}}, 0) + E_{\text{magnetic}}(\Delta E_{\text{unit}}, 0) \\ &= -2V_{\text{one}} f_{\text{Bose},0}(\Delta B_{\text{unit}}) + \frac{1}{2} \mu_0 \Delta B_{\text{unit}}^2 v_{\text{SC}}. \end{aligned} \quad (91)$$

We can consider from Eqs. (89)–(91) that the energy for the normal metallic $|k_{\text{HOCO}}(T)((\Delta B_{\text{unit}}, 0), (\Delta E_{\text{unit}}, 0), B_{\text{induced}}; 0)\rangle$ state is $-2V_{\text{one}}$ with the expelling energy of the electromotive force $2V_{\text{one}}(f_{\text{Bose},0}(0) - f_{\text{Bose},0}(\Delta E_{\text{unit}}))$ and the energy of the induced magnetic field $E_{B_{k_{\text{HOCO}}}}(\Delta E_{\text{unit}}, 0)$, and thus the total energy for the bosonic excited normal metallic $|k_{\text{HOCO}}(T)((\Delta B_{\text{unit}}, 0), (\Delta E_{\text{unit}}, 0), B_{\text{induced}}; 0)\rangle$ state is $-2V_{\text{one}} f_{\text{Bose},0}(\Delta E_{\text{unit}}) + E_{B_{k_{\text{HOCO}}}}(\Delta E_{\text{unit}}, 0)$. In other words, the energy for the applied magnetic field ΔB_{unit} is converted to the expelling energy of the electromotive force $2V_{\text{one}}(f_{\text{Bose},0}(0) - f_{\text{Bose},0}(\Delta E_{\text{unit}}))$ and the induced magnetic field $E_{B_{k_{\text{HOCO}}}}(\Delta E_{\text{unit}}, 0)$.

The $E_{\text{electronic}}(\Delta E_{\text{unit}}, \Delta E_{\text{unit}})$ value for the $|k_{\text{HOCO}}(T)((\Delta B_{\text{unit}}, 0), (\Delta E_{\text{unit}}, \Delta E_{\text{unit}}), B_{\text{induced}}; v_{\text{em}})\rangle$ state can be estimated as

$$\begin{aligned} E_{\text{electronic}}(\Delta E_{\text{unit}}, \Delta E_{\text{unit}}) &= -2V_{\text{one}} f_{\text{Bose},0}(0) + E_{v_{\text{em}}}(\Delta E_{\text{unit}}, \Delta E_{\text{unit}}) \\ &= -2V_{\text{one}} f_{\text{Bose},0}(\Delta E_{\text{unit}}) \end{aligned} \quad (92)$$

where the $E_{v_{\text{em}}}(\Delta E_{\text{unit}}, \Delta E_{\text{unit}})$ value denotes the kinetic energy of the supercurrent, and is estimated as

$$\begin{aligned} E_{v_{\text{em}}}(\Delta E_{\text{unit}}, \Delta E_{\text{unit}}) &= 2V_{\text{one}}(f_{\text{Bose},0}(0) - f_{\text{Bose},0}(\Delta E_{\text{unit}})) \end{aligned}$$

$$= 2V_{\text{one}}(1 - f_{\text{Bose},0}(\Delta E_{\text{unit}})) \quad (93)$$

Furthermore, we must consider the magnetic energy ($E_{\text{magnetic}}(\Delta E_{\text{unit}}, \Delta E_{\text{unit}})$) as a consequence of the induced magnetic field $E_{B_{k_{\text{HOCO}}}}(\Delta E_{\text{unit}}, \Delta E_{\text{unit}})$,

$$\begin{aligned} E_{\text{magnetic}}(\Delta E_{\text{unit}}, \Delta E_{\text{unit}}) &= E_{B_{k_{\text{HOCO}}}}(\Delta E_{\text{unit}}, \Delta E_{\text{unit}}) \\ &= \frac{1}{2} \mu_0 \Delta B_{\text{unit}}^2 v_{\text{SC}}. \end{aligned} \quad (94)$$

The total energy level for the $|k_{\text{HOCO}}(T)((\Delta B_{\text{unit}}, 0), (\Delta E_{\text{unit}}, \Delta E_{\text{unit}}), B_{\text{induced}}; v_{\text{em}})\rangle$ state can be estimated as

$$\begin{aligned} E_{\text{total}}(\Delta E_{\text{unit}}, \Delta E_{\text{unit}}) &= E_{\text{electronic}}(\Delta E_{\text{unit}}, \Delta E_{\text{unit}}) + E_{\text{magnetic}}(\Delta E_{\text{unit}}, \Delta E_{\text{unit}}) \\ &= -2V_{\text{one}} f_{\text{Bose},0}(\Delta E_{\text{unit}}) + \frac{1}{2} \mu_0 \Delta B_{\text{unit}}^2 v_{\text{SC}}. \end{aligned} \quad (95)$$

We can consider from Eqs. (92)–(95) that the energy level for the excited normal metallic $|k_{\text{HOCO}}(T)((\Delta B_{\text{unit}}, 0), (\Delta E_{\text{unit}}, \Delta E_{\text{unit}}), B_{\text{induced}}; v_{\text{em}})\rangle$ state is $-2V_{\text{one}}$ with the kinetic energy of the supercurrent $2V_{\text{one}}(f_{\text{Bose},0}(0) - f_{\text{Bose},0}(\Delta E_{\text{unit}}))$ and the energy of the induced magnetic field $E_{B_{k_{\text{HOCO}}}}(\Delta E_{\text{unit}}, \Delta E_{\text{unit}})$, and thus the total energy for the bosonic excited normal metallic $|k_{\text{HOCO}}(T)((\Delta B_{\text{unit}}, 0), (\Delta E_{\text{unit}}, \Delta E_{\text{unit}}), B_{\text{induced}}; v_{\text{em}})\rangle$ state is $-2V_{\text{one}} f_{\text{Bose},0}(\Delta E_{\text{unit}}) + E_{B_{k_{\text{HOCO}}}}(\Delta E_{\text{unit}}, \Delta E_{\text{unit}})$. In other words, the energy for the initially applied magnetic field ΔB_{unit} is converted to the kinetic energy of the supercurrent $2V_{\text{one}}(f_{\text{Bose},0}(0) - f_{\text{Bose},0}(\Delta E_{\text{unit}}))$ and the energy of the induced magnetic field $E_{B_{k_{\text{HOCO}}}}(\Delta E_{\text{unit}}, \Delta E_{\text{unit}})$.

The $E_{\text{electronic}}(\Delta E_{\text{unit}}, \Delta E_{\text{unit}})$ value for the $|k_{\text{HOCO}}(T)((\Delta B_{\text{unit}}, 0), (\Delta E_{\text{unit}}, \Delta E_{\text{unit}}), \sigma_{\text{spin}}; p_{\text{canonical}})\rangle$ state can be estimated as

$$\begin{aligned} E_{\text{electronic}}(\Delta E_{\text{unit}}, \Delta E_{\text{unit}}) &= -2V_{\text{one}} f_{\text{Bose},0}(0) + E_{p_{\text{canonical}}}(\Delta E_{\text{unit}}, \Delta E_{\text{unit}}) \\ &= -2V_{\text{one}} f_{\text{Bose},0}(\Delta E_{\text{unit}}) \end{aligned} \quad (96)$$

where the $E_{p_{\text{canonical}}}(\Delta E_{\text{unit}}, \Delta E_{\text{unit}})$ value denotes the kinetic energy of the normal current, and is estimated as

$$\begin{aligned} E_{p_{\text{canonical}}}(\Delta E_{\text{unit}}, \Delta E_{\text{unit}}) &= 2V_{\text{one}}(f_{\text{Bose},0}(0) - f_{\text{Bose},0}(\Delta E_{\text{unit}})) \\ &= 2V_{\text{one}}(1 - f_{\text{Bose},0}(\Delta E_{\text{unit}})) \end{aligned} \quad (97)$$

Furthermore, we must consider the magnetic energy ($E_{\text{magnetic}}(\Delta E_{\text{unit}}, \Delta E_{\text{unit}})$) as a consequence of the induced spin magnetic moment

$$\begin{aligned} E_{\sigma_{\text{spin,HOMO}}}(\Delta E_{\text{unit}}, \Delta E_{\text{unit}}) \\ E_{\text{magnetic}}(\Delta E_{\text{unit}}, \Delta E_{\text{unit}}) &= E_{\sigma_{\text{spin,HOMO}}}(\Delta E_{\text{unit}}, \Delta E_{\text{unit}}) = \frac{1}{2} \mu_0 \Delta B_{\text{unit}}^2 \nu_{\text{SC}}. \end{aligned} \quad (98)$$

The total energy level for the $|k_{\text{HOCO}}(T)((\Delta B_{\text{unit}}, 0); (\Delta E_{\text{unit}}, \Delta E_{\text{unit}}); \sigma_{\text{spin}}; p_{\text{canonical}})\rangle$ state can be estimated as

$$\begin{aligned} E_{\text{total}}(\Delta E_{\text{unit}}, \Delta E_{\text{unit}}) &= E_{\text{electronic}}(\Delta E_{\text{unit}}, \Delta E_{\text{unit}}) + E_{\text{magnetic}}(\Delta E_{\text{unit}}, \Delta E_{\text{unit}}) \\ &= -2V_{\text{one}} f_{\text{Bose},0}(\Delta E_{\text{unit}}) + \frac{1}{2} \mu_0 \Delta B_{\text{unit}}^2 \nu_{\text{SC}}. \end{aligned} \quad (99)$$

The $E_{\text{electronic}}(\Delta B_{\text{unit}}, \Delta B_{\text{unit}})$ and $E_{\text{magnetic}}(\Delta B_{\text{unit}}, \Delta B_{\text{unit}})$ values for the $|k_{\text{HOCO}}(T)((\Delta B_{\text{unit}}, \Delta B_{\text{unit}}); (0, 0); 0; 0)\rangle$ state can be estimated as

$$E_{\text{electronic}}(\Delta E_{\text{unit}}, \Delta E_{\text{unit}}) = -2V_{\text{one}} f_{\text{Bose}, \Delta B_{\text{unit}}}(0), \quad (100)$$

$$E_{\text{magnetic}}(\Delta B_{\text{unit}}, \Delta B_{\text{unit}}) = 0. \quad (101)$$

The total energy level for the $|k_{\text{HOCO}}(T)((\Delta B_{\text{unit}}, \Delta B_{\text{unit}}); (0, 0); 0; 0)\rangle$ state can be estimated as

$$\begin{aligned} E_{\text{total}}(\Delta E_{\text{unit}}, \Delta E_{\text{unit}}) &= E_{\text{electronic}}(\Delta E_{\text{unit}}, \Delta E_{\text{unit}}) + E_{\text{magnetic}}(\Delta E_{\text{unit}}, \Delta E_{\text{unit}}) \\ &= -2V_{\text{one}} f_{\text{Bose}, \Delta B_{\text{unit}}}(0). \end{aligned} \quad (102)$$

The energy for the excited normal metallic $|k_{\text{HOCO}}(T)((\Delta B_{\text{unit}}, 0); (\Delta E_{\text{unit}}, \Delta E_{\text{unit}}); B_{\text{induced}}; \nu_{\text{em}})\rangle$ state is $-2V_{\text{one}}$ with kinetic energy of supercurrent

$2V_{\text{one}}(1 - f_{\text{Bose},0}(\Delta B_{\text{unit}}))$, and thus the total electronic energy for the bosonic excited normal metallic $|k_{\text{HOCO}}(T)((\Delta B_{\text{unit}}, 0); (\Delta E_{\text{unit}}, \Delta E_{\text{unit}}); B_{\text{induced}}; \nu_{\text{em}})\rangle$ state is $-2V_{\text{one}} f_{\text{Bose},0}(\Delta B_{\text{unit}})$. The electronic energy level for the bosonic ground normal metallic $|k_{\text{HOCO}}(T)((\Delta B_{\text{unit}}, \Delta B_{\text{unit}}); (0, 0); 0; 0)\rangle$ state is the same with those for the bosonic and fermionic excited normal metallic $|k_{\text{HOCO}}(T)((\Delta B_{\text{unit}}, 0); (\Delta E_{\text{unit}}, \Delta E_{\text{unit}}); B_{\text{induced}}; \nu_{\text{em}})\rangle$ and $|k_{\text{HOCO}}(T)((\Delta B_{\text{unit}}, 0); (\Delta E_{\text{unit}}, \Delta E_{\text{unit}}); \sigma_{\text{spin}}; p_{\text{canonical}})\rangle$ states, respectively. On the other hand, it should be noted that even though the electronic energies are conserved between them, the kinds of energies are different. The electronic energy level itself for the $|k_{\text{HOCO}}(T)((\Delta B_{\text{unit}}, \Delta B_{\text{unit}}); (0, 0); 0; 0)\rangle$ is $-2V_{\text{one}} f_{\text{Bose},0}(\Delta B_{\text{unit}})$ with zero kinetic energy for the supercurrent, while those for the $|k_{\text{HOCO}}(T)((\Delta B_{\text{unit}}, 0); (\Delta E_{\text{unit}}, \Delta E_{\text{unit}}); B_{\text{induced}}; \nu_{\text{em}})\rangle$ and $|k_{\text{HOCO}}(T)((\Delta B_{\text{unit}}, 0); (\Delta E_{\text{unit}}, \Delta E_{\text{unit}}); \sigma_{\text{spin}}; p_{\text{canonical}})\rangle$ states are $-2V_{\text{one}}$ with the kinetic energy of supercurrent $2V_{\text{one}}(1 - f_{\text{Bose},0}(\Delta B_{\text{unit}}))$. That is, the bosonic $|k_{\text{HOCO}}(T)((\Delta B_{\text{unit}}, 0); (\Delta E_{\text{unit}}, \Delta E_{\text{unit}}); B_{\text{induced}}; \nu_{\text{em}})\rangle$ and fermionic $|k_{\text{HOCO}}(T)((\Delta B_{\text{unit}}, 0); (\Delta E_{\text{unit}}, \Delta E_{\text{unit}}); \sigma_{\text{spin}}; p_{\text{canonical}})\rangle$ excited normal metallic states are unstable with respect to the ground bosonic state for zero magnetic field, in the space of the ground bosonic state for zero magnetic field $|k_{\text{HOCO}}(T)((0, 0); (0, 0); 0; 0)\rangle$. This is because the kinetic energy of currents ($2V_{\text{one}}(1 - f_{\text{Bose},0}(\Delta B_{\text{unit}}))$) for the $|k_{\text{HOCO}}(T)((\Delta B_{\text{unit}}, 0); (\Delta E_{\text{unit}}, \Delta E_{\text{unit}}); B_{\text{induced}}; \nu_{\text{em}})\rangle$ and $|k_{\text{HOCO}}(T)((\Delta B_{\text{unit}}, 0); (\Delta E_{\text{unit}}, \Delta E_{\text{unit}}); \sigma_{\text{spin}}; p_{\text{canonical}})\rangle$ states are larger than that (0) for the $|k_{\text{HOCO}}(T)((0, 0); (0, 0); 0; 0)\rangle$ state, while the electronic energy level for the $|k_{\text{HOCO}}(T)((\Delta B_{\text{unit}}, 0); (\Delta E_{\text{unit}}, \Delta E_{\text{unit}}); B_{\text{induced}}; \nu_{\text{em}})\rangle$ and $|k_{\text{HOCO}}(T)((\Delta B_{\text{unit}}, 0); (\Delta E_{\text{unit}}, \Delta E_{\text{unit}}); \sigma_{\text{spin}}; p_{\text{canonical}})\rangle$ states are the same ($-2V_{\text{one}}$) with that for

$|k_{\text{HOCO}}(T)((0, 0); (0, 0); 0; 0)\rangle$. The bosonic $|k_{\text{HOCO}}(T)((\Delta B_{\text{unit}}, \Delta B_{\text{unit}}); (0, 0); 0; 0)\rangle$ ground state is unstable with respect to the ground bosonic state for zero magnetic field, in the space of the ground bosonic state for zero magnetic field $|k_{\text{HOCO}}(T)((0, 0); (0, 0); 0; 0)\rangle$. This is because the electronic energy level $(-2V_{\text{one}} f_{\text{Bose}, 0}(\Delta B_{\text{unit}}))$ for the $|k_{\text{HOCO}}(T)((\Delta B_{\text{unit}}, \Delta B_{\text{unit}}); (0, 0); 0; 0)\rangle$ is higher than that $-2V_{\text{one}}$ for the $|k_{\text{HOCO}}(T)((0, 0); (0, 0); 0; 0)\rangle$ state, while the kinetic energies for both the $|k_{\text{HOCO}}(T)((\Delta B_{\text{unit}}, \Delta B_{\text{unit}}); (0, 0); 0; 0)\rangle$ and $|k_{\text{HOCO}}(T)((0, 0); (0, 0); 0; 0)\rangle$ states are zero. That is, the total electronic energy is conserved when the $|k_{\text{HOCO}}(T)((\Delta B_{\text{unit}}, 0); (\Delta E_{\text{unit}}, \Delta E_{\text{unit}}); B_{\text{induced}}; \nu_{\text{em}})\rangle$ state is converted to the $|k_{\text{HOCO}}(T)((\Delta B_{\text{unit}}, \Delta B_{\text{unit}}); (0, 0); 0; 0)\rangle$ state via the $|k_{\text{HOCO}}(T)((\Delta B_{\text{unit}}, 0); (\Delta E_{\text{unit}}, \Delta E_{\text{unit}}); \sigma_{\text{spin}}; p_{\text{canonical}})\rangle$ state. During this conversion, the kinetic energy for the $|k_{\text{HOCO}}(T)((\Delta B_{\text{unit}}, 0); (\Delta E_{\text{unit}}, \Delta E_{\text{unit}}); B_{\text{induced}}; \nu_{\text{em}})\rangle$ and $|k_{\text{HOCO}}(T)((\Delta B_{\text{unit}}, 0); (\Delta E_{\text{unit}}, \Delta E_{\text{unit}}); \sigma_{\text{spin}}; p_{\text{canonical}})\rangle$ states can be changed to the higher electronic state energy for the $|k_{\text{HOCO}}(T)((\Delta B_{\text{unit}}, \Delta B_{\text{unit}}); (0, 0); 0; 0)\rangle$ state by the penetration of the magnetic field (ΔB_{unit}) .

On the other hand, the magnetic energy for the $|k_{\text{HOCO}}(T)((\Delta B_{\text{unit}}, 0); (\Delta E_{\text{unit}}, \Delta E_{\text{unit}}); B_{\text{induced}}; \nu_{\text{em}})\rangle$ state $(E_{\text{magnetic}}(\Delta B_{\text{unit}}, 0))$ with respect to the next ground normal metallic ground $|k_{\text{HOCO}}(T)((\Delta B_{\text{unit}}, \Delta B_{\text{unit}}); (0, 0); 0; 0)\rangle$ state $(E_{\text{magnetic}}(\Delta B_{\text{unit}}, \Delta B_{\text{unit}}))$ can be expressed as $\mu_0 \Delta B_{\text{unit}}^2 \nu_{\text{SC}} / 2$. Therefore, because of the magnetic energy $E_{\text{magnetic}}(\Delta B_{\text{unit}}, 0) > E_{\text{magnetic}}(\Delta B_{\text{unit}}, \Delta B_{\text{unit}})$, such excited normal metallic $|k_{\text{HOCO}}(T)((\Delta B_{\text{unit}}, 0); (\Delta E_{\text{unit}}, \Delta E_{\text{unit}}); B_{\text{induced}}; \nu_{\text{em}})\rangle$ state is not stable, and thus the bosonic excited normal metallic $|k_{\text{HOCO}}(T)((\Delta B_{\text{unit}}, 0); (\Delta E_{\text{unit}}, \Delta E_{\text{unit}}); B_{\text{induced}}; \nu_{\text{em}})\rangle$ electronic state is converted to the next bosonic ground normal metallic ground $|k_{\text{HOCO}}(T)((\Delta B_{\text{unit}}, \Delta B_{\text{unit}}); (0, 0); 0; 0)\rangle$ state via the another fermionic excited normal metallic

$|k_{\text{HOCO}}(T)((\Delta B_{\text{unit}}, 0); (\Delta E_{\text{unit}}, \Delta E_{\text{unit}}); \sigma_{\text{spin}}; p_{\text{canonical}})\rangle$ state.

The total energy level $(E_{\text{total}}(B_{\text{out}}, B_{\text{in}}))$ for the fermionic excited normal metallic $|k_{\text{HOCO}}(T)((\Delta B_{\text{unit}}, 0); (\Delta E_{\text{unit}}, \Delta E_{\text{unit}}); \sigma_{\text{spin}}; p_{\text{canonical}})\rangle$ state can be estimated to be the same with that for the bosonic excited normal metallic $|k_{\text{HOCO}}(T)((\Delta B_{\text{unit}}, 0); (\Delta E_{\text{unit}}, \Delta E_{\text{unit}}); B_{\text{induced}}; \nu_{\text{em}})\rangle$ state even though the potential energy $V_{\text{potential}}$ for the bosonic state is converted to the kinetic energy $V_{\text{kin, Fermi}, k_{\text{LUCCO}} \sigma(0)}$ for the fermionic state.

We can consider that the $E_{\text{total}}(\Delta B_{\text{unit}}, 0)$ values for the

$|k_{\text{HOCO}}(T)((\Delta B_{\text{unit}}, 0); (\Delta E_{\text{unit}}, \Delta E_{\text{unit}}); B_{\text{induced}}; \nu_{\text{em}})\rangle$ and

$|k_{\text{HOCO}}(T)((\Delta B_{\text{unit}}, 0); (\Delta E_{\text{unit}}, \Delta E_{\text{unit}}); \sigma_{\text{spin}}; p_{\text{canonical}})\rangle$ states are larger than that for the

$|k_{\text{HOCO}}(T)((\Delta B_{\text{unit}}, \Delta B_{\text{unit}}); (0, 0); 0; 0)\rangle$ state by the

$E_{\text{magnetic}}(\Delta B_{\text{unit}}, 0) - E_{\text{magnetic}}(\Delta B_{\text{unit}}, \Delta B_{\text{unit}})$

$(= \mu_0 \Delta B_{\text{unit}}^2 \nu_{\text{SC}} / 2)$ value. Therefore, the conversion

from the unstable

$|k_{\text{HOCO}}(T)((\Delta B_{\text{unit}}, 0); (\Delta E_{\text{unit}}, \Delta E_{\text{unit}}); \sigma_{\text{spin}}; p_{\text{canonical}})\rangle$

state to the stable

$|k_{\text{HOCO}}(T)((\Delta B_{\text{unit}}, \Delta B_{\text{unit}}); (0, 0); 0; 0)\rangle$ state occurs by

the first-order process of the electron-phonon interactions. In other words, the unstable

$|k_{\text{HOCO}}(T)((\Delta B_{\text{unit}}, 0); (\Delta E_{\text{unit}}, \Delta E_{\text{unit}}); \sigma_{\text{spin}}; p_{\text{canonical}})\rangle$

state is converted to the stable

$|k_{\text{HOCO}}(T)((\Delta B_{\text{unit}}, \Delta B_{\text{unit}}); (0, 0); 0; 0)\rangle$ state as a

consequence of the energy conversion from the magnetic energy

$(E_{\text{magnetic}}(\Delta B_{\text{unit}}, 0) - E_{\text{magnetic}}(\Delta B_{\text{unit}}, \Delta B_{\text{unit}}))$

$(= \mu_0 \Delta B_{\text{unit}}^2 \nu_{\text{SC}} / 2)$ to the photon emission V_{photon}

(electrical resistivity (Joule's heats)) energy. The magnetic

expelling energy

$(E_{\text{magnetic}}(\Delta B_{\text{unit}}, 0) - E_{\text{magnetic}}(\Delta B_{\text{unit}}, \Delta B_{\text{unit}}))$

$(= \mu_0 \Delta B_{\text{unit}}^2 \nu_{\text{SC}} / 2)$ has been basically created from the

energy originating from the dynamic change of the magnetic field (generation of electricity). Therefore, we

can conclude that initially dynamically created energy

originating from the dynamic change of the magnetic field (generation of electricity) is the origin of the Joule's heats

finally observed.

The energy for the magnetic field strength itself, which has not been considered to be origin of the electromotive forces, is closely related to the electromotive forces, the electrical current, and the resistivity. On the other hand, the dynamically created energy originating from the dynamic change of the magnetic field (generation of electricity), which has been considered to originate from the electromotive forces, is closely related to the Joule's heats, but not directly related to the electromotive forces.

As discussed in the previous studies [1-7], the Stern–Gerlach effect is the main reason why the even one electron can be in the bosonic state at usual low temperatures. And the very large stabilization energy ($V_{\text{kin, Fermi}, k_{\text{HOCO}} \sigma}(0) \approx 35 \text{ eV}$) for the Bose–Einstein condensation ($p_{\text{canonical}} = 0$; $V_{\text{kin, Bose}, k_{\text{HOCO}} \sigma}(0) = 0 \text{ eV}$) originating from the disappearance of the kinetic energy of an electron ($p_{\text{canonical}} = 0$; $V_{\text{kin, Bose}, k_{\text{HOCO}} \sigma}(0) = 0 \text{ eV}$) is the main reason why the magnetic momentum of an electron cannot be changed but electrical currents can be induced soon after the external magnetic field is applied. If an electron were not in the bosonic state, the applied magnetic field would immediately penetrate into the specimen as soon as the magnetic field is applied, and we would not observe any electrical current even in the normal metals. This bosonic electron is closely related to the concepts of the Higgs boson.

The electronic energy is conserved and thus the change of the electronic states is not directly related to the Joule's heats. Therefore, applied energy for the electromotive forces as a consequence of the change of the magnetic field strength itself are not dissipated. In other words, electrical resistivity can be observed because of the electronic properties (the disappearance of total momentum $p_{\text{canonical}} = 0$ and $v_{\text{em}} = 0$ under the statistic magnetic field), on the other hand, the Joule's heats can be observed not because of the electronic properties but because of the magnetic properties (the disappearance of the expelling energy of the magnetic fields originating from the energy for the change of the magnetic field at the beginning, created dynamically (generation of electricity)). We dynamically create the energy for the dynamic change of the magnetic field (generation of electricity) at the beginning, related to the Joule's heats, in addition to the energy for the magnetic field strength itself, related to the electromotive force, kinetic energy of an electron, and electrical resistivity.

4.4 Meissner Effects in the Two-Electrons Systems in Superconductivity

Because of the very large stabilization energy ($2V_{\text{kin, Fermi}, k_{\text{HOCO}} \sigma}(0) \approx 70 \text{ eV}$) for the Bose–Einstein

condensation ($p_{\text{canonical}} = 0$; $V_{\text{kin, Bose}, k_{\text{HOCO}} \sigma}(0) = 0 \text{ eV}$), the magnetic momentum of a bosonic Cooper pair cannot be changed but electromotive force (ΔE_{unit}) can be induced soon after the external magnetic field is applied. This is the excited bosonic superconducting state for $j = 0$ ($|k_{\text{HOCO}}(T)((\Delta B_{\text{unit}}, 0), (\Delta E_{\text{unit}}, 0); 0; 0)\rangle$) (Fig. 8 (b)).

In such a case, the electromotive force as well as the applied external magnetic field is expelled from the superconducting specimen. It should be noted that the electronic $|k_{\text{HOCO}}(T)((\Delta B_{\text{unit}}, 0), (\Delta E_{\text{unit}}, 0); 0; 0)\rangle$ state is still bosonic since the $p_{\text{canonical}}$ value is 0. The electric and magnetic momentum of a bosonic Cooper pair cannot be changed but the magnetic field can be induced soon after the electromotive force is induced (Fig. 8 (c)). Therefore, the electronic state becomes $|k_{\text{HOCO}}(T)((\Delta B_{\text{unit}}, 0), (\Delta E_{\text{unit}}, 0), B_{\text{induced}}; 0)\rangle$. This induced magnetic field B_{induced} can expel the initially external applied magnetic field $B_{\text{out}} (= \Delta B_{\text{unit}})$ from the superconducting specimen. That is, the B_{induced} and $B_{\text{out}} (= \Delta B_{\text{unit}})$ values are completely compensated by each other. This is the origin of the Meissner effect in superconductivity. On the other hand, such excited bosonic supercurrent states with the induced magnetic fields $|k_{\text{HOCO}}(T)((\Delta B_{\text{unit}}, 0), (\Delta E_{\text{unit}}, 0), B_{\text{induced}}; 0)\rangle$ can be immediately destroyed because the electromotive force penetrates into the superconducting specimen, and the electronic state becomes another bosonic excited supercurrent state for $j = 0$ ($|k_{\text{HOCO}}(T)((\Delta B_{\text{unit}}, 0), (\Delta E_{\text{unit}}, \Delta E_{\text{unit}}), B_{\text{induced}}; v_{\text{em}})\rangle$) (Fig. 8 (d)).


In the $|k_{\text{HOCO}}(T)((\Delta B_{\text{unit}}, 0), (\Delta E_{\text{unit}}, \Delta E_{\text{unit}}), B_{\text{induced}}; v_{\text{em}})\rangle$ state, the supercurrent can be induced, and thus there is kinetic energy ($E_{\text{kinetic}}(\Delta E_{\text{unit}}, \Delta E_{\text{unit}})$). That is, the energy of the electromotive force ΔE_{unit} for the $|k_{\text{HOCO}}(T)((\Delta B_{\text{unit}}, 0), (\Delta E_{\text{unit}}, 0), B_{\text{induced}}; 0)\rangle$ state is converted to the kinetic energy of the supercurrent for the $|k_{\text{HOCO}}(T)((\Delta B_{\text{unit}}, 0), (\Delta E_{\text{unit}}, \Delta E_{\text{unit}}), B_{\text{induced}}; v_{\text{em}})\rangle$ state. Both the supercurrent ($v_{\text{em}, k_{\text{HOCO}}}(\Delta E_{\text{unit}}, \Delta E_{\text{unit}})$) and the magnetic field ($B_{\text{induced}, k_{\text{HOCO}}}(\Delta E_{\text{unit}}, 0)$) can be induced under the condition of the closed-shell electronic structure with zero spin magnetic field and canonical momentum ($\sigma_{\text{spin}} = 0$; $p_{\text{canonical}} = 0$). This is the origin of the Ampère's law and the Meissner effect in superconductivity. Such excited bosonic states with

supercurrents

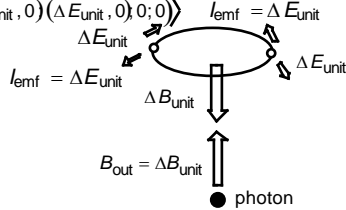
$|k_{\text{HOCO}}(T)((\Delta B_{\text{unit}}, 0), (\Delta E_{\text{unit}}, \Delta E_{\text{unit}}); B_{\text{induced}}; v_{\text{em}})\rangle$ cannot be destroyed because of the stable closed-shell electronic states, and the induced supercurrent cannot be destroyed. This is the reason why we can observe nondissipative currents in superconductivity during applying the magnetic field.

(a) ground bosonic normal metallic state for $j = 0$

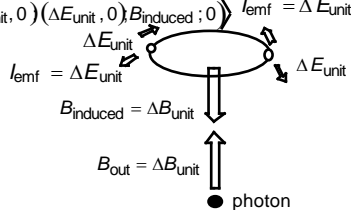
$$|k_{\text{HOCO}}(T)((0, 0)(0, 0); 0, 0)\rangle$$

$$B_{k_{\text{HOCO}}}(0, 0) = 0$$


(b) excited bosonic normal metallic state for $j = 0$

$$|k_{\text{HOCO}}(T)((\Delta B_{\text{unit}}, 0)(\Delta E_{\text{unit}}, 0); 0, 0)\rangle$$


(c) excited bosonic normal metallic state for $j = 0$

$$|k_{\text{HOCO}}(T)((\Delta B_{\text{unit}}, 0)(\Delta E_{\text{unit}}, 0); B_{\text{induced}}; 0)\rangle$$


(d) excited bosonic normal metallic state for $j = 0$

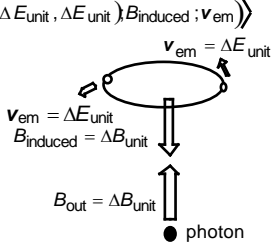
$$|k_{\text{HOCO}}(T)((\Delta B_{\text{unit}}, 0)(\Delta E_{\text{unit}}, \Delta E_{\text{unit}}); B_{\text{induced}}; v_{\text{em}})\rangle$$


Fig. 8 The electronic states between $j = 0$ and $j = 1$ in superconductivity.

4.5 Reconsideration of the Lenz's Law

According to the Lenz's law, it has been considered that the electrical current can be induced when the magnetic field is changed. On the other hand, according to our theory, the electrical current can be induced in order that the photon becomes massive (that is, the magnetic field is expelled from the specimen) by absorbing Nambu–Goldstone boson formed by the fluctuation of the electronic state pairing of an electron, because of the very large stabilization energy ($V_{\text{kin, Fermi}, k_{\text{LUCCO}} \sigma(0)} \approx 35 \text{ eV}$) for the Bose–Einstein condensation ($p_{\text{canonical}} = 0$);

$V_{\text{kin, Bose}, k_{\text{LUCCO}} \sigma(0)} = 0 \text{ eV}$), and the Stern–Gerlach effect. The initial electronic state tries not to change the electronic structure ($p_{\text{canonical}} = 0$) by induction of the electrical current and magnetic field. After that, the photon becomes massless (magnetic field can penetrate into the specimen), and thus the electrical current can be dissipated. And at the same time, photon is emitted from an electron and this is the origin of the Joule's heats.

The energy for the magnetic field strength itself, which has not been considered to be origin of the electromotive forces, is closely related to the electromotive force, the electrical current, and the resistivity. On the other hand, the dynamically created energy originating from the dynamic change of the magnetic field (generation of electricity), which has been considered to be origin of the electromotive forces, is closely related to the Joule's heats, but not directly related to the electromotive forces.

As discussed in the previous studies [1–7], the Stern–Gerlach effect is the main reason why the even one electron can be in the bosonic state at usual low temperatures. And the very large stabilization energy ($V_{\text{kin, Fermi}, k_{\text{LUCCO}} \sigma(0)} \approx 35 \text{ eV}$) for the Bose–Einstein condensation ($p_{\text{canonical}} = 0$; $V_{\text{kin, Bose}, k_{\text{LUCCO}} \sigma(0)} = 0 \text{ eV}$) originating from the disappearance of the kinetic energy of an electron ($p_{\text{canonical}} = 0$; $V_{\text{kin, Bose}, k_{\text{LUCCO}} \sigma(0)} = 0 \text{ eV}$) is the main reason why the magnetic momentum of an electron cannot be changed but electrical currents can be induced soon after the external magnetic field is applied. If an electron were not in the bosonic state, the applied magnetic field would immediately penetrate into the specimen as soon as the magnetic field is applied, and we would not observe any electrical current even in the normal metals. This bosonic electron is closely related to the concepts of the Higgs boson.

5. Concluding Remarks

We definitely discussed how the independent one electron is stabilized in energy in view of the second-order processes in vibronic and electron–phonon interactions in quantum field theory. In particular, by comparison with the conventional BCS theory, we suggested new interpretation of the role of electron–phonon interactions in electron pairing in superconductivity. According to our calculated results, two electronic states originating from independent one electron become stabilized because phonon is exchanged between these two electronic states of independent one electron. That is, phonon emitted by an electron is received by the same electron, and as a consequence of this phonon exchange between two electronic states with

opposite momentum and spins, this independent one electron becomes stabilized in energy.

Related to seeking for the room-temperature superconductivity, in this article, we compare the normal metallic states with the superconducting states. Furthermore, in this article, we elucidate the mechanism of the Faraday's law in normal metallic states and the Meissner effects in superconductivity, on the basis of the theory suggested in our previous researches.

In superconductivity, two electrons behave only as a Bose particle. On the other hand, in the normal metallic states, an electron behaves as bosonic as well as fermionic under the applied external magnetic or electric field. An electron in the bosonic state with zero kinetic energy ($p_{\text{canonical}} = 0$; $V_{\text{kin, Bose, } k_{\text{HOCO}}} \sigma(0) = 0 \text{ eV}$) is much more stable than an electron in the fermionic state with large kinetic energy of about 35 eV ($p_{\text{canonical}} \neq 0$; $V_{\text{kin, Fermi, } k_{\text{HOCO}}} \sigma(0) \approx 35 \text{ eV}$) by about 35 eV, in the normal metallic state. Two electrons in the bosonic state with zero kinetic energy ($p_{\text{canonical}} = 0$; $2V_{\text{kin, Bose, } k_{\text{HOCO}}} \sigma(0) = 0 \text{ eV}$) is much more stable than two electrons in the fermionic state with large kinetic energy of about 70 eV ($p_{\text{canonical}} \neq 0$; $2V_{\text{kin, Fermi, } k_{\text{HOCO}}} \sigma(0) \approx 70 \text{ eV}$) by about 70 eV, in the superconducting state [1–7]. Because of the very large stabilization energy ($V_{\text{kin, Fermi, } k_{\text{HOCO}}} \sigma(0) \approx 35 \text{ eV}$) for the Bose–Einstein condensation ($p_{\text{canonical}} = 0$; $V_{\text{kin, Bose, } k_{\text{HOCO}}} \sigma(0) = 0 \text{ eV}$), the magnetic momentum of an electron cannot be changed but electromotive force (ΔE_{unit}) can be induced soon after the external magnetic field is applied. Furthermore, the electric and magnetic momentum of a bosonic electronic state pairing of an electron cannot be changed but the magnetic field can be induced soon after the electromotive force is induced. Both the supercurrent ($v_{\text{em, } k_{\text{HOCO}}}(\Delta E_{\text{unit}}, \Delta E_{\text{unit}})$) and the magnetic field ($B_{\text{induced, } k_{\text{HOCO}}}(\Delta E_{\text{unit}}, \Delta E_{\text{unit}})$) can be induced under the condition of the opened-shell electronic structure with zero spin magnetic momentum and canonical momentum ($\sigma_{\text{spin}} = 0$; $p_{\text{canonical}} = 0$). This is the origin of the Faraday's and Ampère's law in the normal metallic state. Furthermore, this is the origin of the Meissner effect and Ampère's law in superconductivity. If an electron were not in the bosonic state, the applied magnetic field would immediately penetrate into the specimen as soon as the magnetic field is applied, and we would not observe any electrical current even in the normal metals.

The induced magnetic field $B_{\text{induced, } k_{\text{HOCO}}}(\Delta E_{\text{unit}}, 0)$ expels the initially applied external magnetic field ΔB_{unit} from the normal metallic specimen. Therefore, the

induced magnetic field $B_{\text{induced, } k_{\text{HOCO}}}(\Delta E_{\text{unit}}, 0)$ is the origin of the Faraday's law in the normal metallic states and the Meissner effects in the superconducting states. It should be noted that the magnetic field $B_{\text{induced, } k_{\text{HOCO}}}(\Delta E_{\text{unit}}, 0) (\neq 0)$ is induced but the spin magnetic moment of an electron with opened-shell electronic structure is not changed ($\sigma_{\text{spin}} = 0$). This is very similar to the diamagnetic currents in the superconductivity in that the supercurrents are induced ($v_{\text{em}} \neq 0$) but the total canonical momentum is zero ($p_{\text{canonical}} = 0$). The magnetic field is induced not because of the change of each element of the spin magnetic moment σ_{spin} of an electron (similar to the $p_{\text{canonical}}$ in the superconducting states) but because of the change of the total magnetic momentum as a whole B_{induced} (similar to the v_{em} in the superconducting states).

The electronic energy is conserved and thus the change of the electronic states is not directly related to the Joule's heats. Therefore, applied energy for the electromotive forces as a consequence of the change of the magnetic field strength itself are not dissipated. In other words, electrical resistivity can be observed because of the electronic properties (the disappearance of total momentum $p_{\text{canonical}} = 0$ and $v_{\text{em}} = 0$ under the statistic magnetic field), on the other hand, the Joule's heats can be observed not because of the electronic properties but because of the magnetic properties (the disappearance of the expelling energy of the magnetic fields originating from the energy for the change of the magnetic field at the beginning, created dynamically (generation of electricity)). We dynamically create the energy for the dynamic change of the magnetic field (generation of electricity) at the beginning, related to the Joule's heats, in addition to the energy for the magnetic field strength itself, related to the electromotive force, kinetic energy of an electron, and electrical resistivity.

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Author Profile

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