Electron Elastic Collision Superconductivity Theory

Hongyuan Ye

[Abstract] The BCS theory hypothesis explains the superconducting properties of Class I conventional metal and alloy superconductors, but it violates Coulomb's law and Heisenberg's uncertainty principle, cannot interpret the superconducting phenomenon of Class II unconventional superconductors. Based on the elastic collision theory of Newtonian classical mechanics, this paper proposes Electron elastic collision superconductivity theory, which reveals that the microscopic mechanism of superconducting states is that the free electrons in a current-carrying wire only undergo complete elastic collisions with the atomic lattices, and there is no energy exchange between the free electrons and the atomic lattices. The current-carrying wire shows zero-resistance superconducting states. The Electron elastic collision superconductivity theory proposes the superconducting state free electron critical speed V_C, and theoretically derives the formula for calculating the critical temperature T_C: $2\ \Delta_E = 2.55\ k_B\ T_C$. The Elastic collision superconductivity theory interprets the microscopic mechanism of the superconducting state critical temperature T_C, the critical magnetic field H_C, the critical current density j_C, the superconducting state energy gap and the high-pressure superconductor. Unlike Class I conventional superconductors, Class II unconventional superconductors have anisotropic lattices. There are different critical speeds V_C, different critical temperatures T_C and different critical magnetic fields H_C in different directions. When the direction of lattices is the same as that of the current carrying wire, it is beneficial for the formation of superconducting current. Therefore, unconventional superconductors can achieve high-temperature superconductivity. Based on the Electron elastic collision superconductivity theory, it is feasible to achieve a zero-resistance superconducting state at normal temperature.

[keyword] BCS theory, Class I conventional superconductor, Class II unconventional superconductor, Coulomb's law, Electron elastic collision superconductivity theory, Free electron critical speed, Critical temperature, Critical magnetic field, Critical current density, Axial critical magnetic field, Radial critical magnetic field.

1. Introduction

In 1911, the Dutch physicist Onnes discovered that mercury suddenly enters a new state with zero-resistance when the temperature drops to around 4.2 K, which is called the superconducting state[1].

In 1933, the German physicist Meissner discovered that when a magnetic field is applied to a superconductor, the magnetic field cannot enter the superconductor at all. This completely diamagnetic phenomenon is known as the "Meissner effect"[2]. Zero-resistance and complete diamagnetism are two independent criteria for proving whether a substance is superconductive or not. The superconducting state has a series of critical parameters, such as the critical temperature T_C, the critical magnetic field H_C, the critical current density j_C, etc. Superconducting materials are widely found in metal/non-metal elemental substances, alloys, intermetallic compounds, transition metal oxides, sulfides, selenides, as well as some organic conductors, graphene, C60 structural materials, etc. At present, tens of thousands of superconducting materials have been discovered.

To explain the mechanism of superconductors, scientists have proposed a variety of theories, including: the London equation[3], which was proposed in 1935 to describe the relationship between superconducting currents and weak magnetic fields; Pippard theory[4], which was proposed in 1950~1953 to improve the London equation; GL theory[5], proposed in 1950 to describe the relationship between superconducting currents and strong magnetic fields; In 1957, the BCS theory[6], which is the most important theory, was proposed to interpret the microscopic mechanism of superconductors.

Based on the electron-phonon coupling interaction, the BCS theory suggests that two electrons with opposite spins in metals can pair up to form a Cooper electron pair, which can move losslessly within the lattices to form superconducting currents. As shown in Figure 1.1. The electrons moving within the atomic lattices attract positively charged atoms in adjacent lattices, resulting in local distortion of the lattice, forming a localized high positive charge region. This localized region of high positive charge attracts another electron with opposite spin, and pairs with the original electron with a certain binding energy.

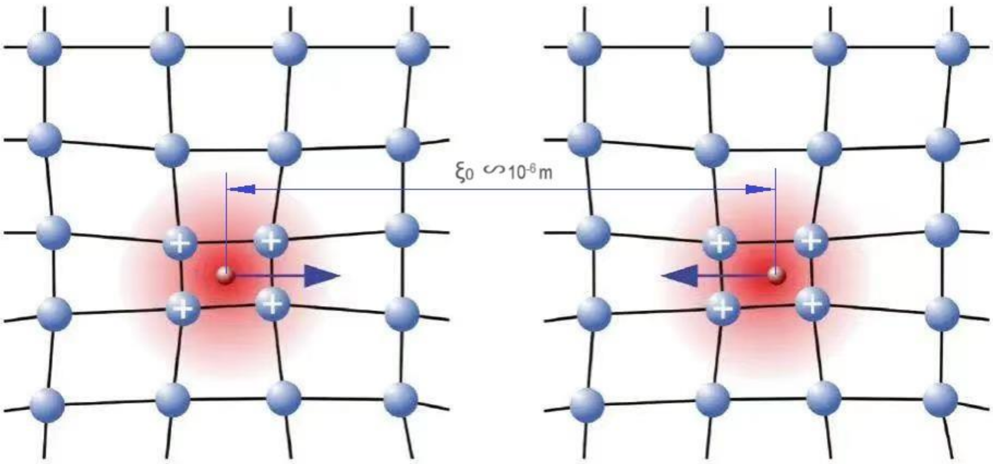

Figure1.1 Microscopic mechanism of BCS Theory

The BCS theory hypothesis violates Coulomb's law. Taking conventional metal superconductors as an example, as shown in Figure 1.1, the scale range of the atom is 10^{-10} m, and the scale range of the distance between atomic lattices and lattices, the scale range of the distance between atomic lattices and free electrons, and the scale range of the distance between electrons and electrons are all 10^{-10}m. According to Rutherford's famous alpha particle scattering experiment in 1911, Coulomb's law still holds strictly in the scale range of 3×10^{-14} m.

There is an attractive force between a negative charge free electron and a positive charge atomic lattice, since the mass of the atomic lattice is much larger than that of the free electron, it can only be the free electron attracted by the atomic lattice, rather than the atomic lattice distorted by the electron. If there is a paired electron nearby, according to Coulomb's law, there can only be a repulsive force between two electrons, and the paired electron will push the free electron closer to the atomic lattice faster. Two adjacent electrons cannot form a Cooper electron pair with a weak attractive force.

The BCS theory also violates Heisenberg's uncertainty principle. According to Heisenberg uncertainty principle, the distance ξ_0 between two electrons of a Cooper pair, which is the BCS coherence length, has the scale range of 10^{-6}m, which is equivalent to the distance of about 10,000 atomic lattices. If an atomic lattice corresponds to a free electron, then there are 10,000 free electrons between two Cooper electrons. At such a long distance, two electrons cannot form a Cooper pair with a weak attractive force.

The BCS theory hypothesis contradicts the experimental results. If the atomic lattices are distorted as stated in the BCS theory. On the one hand, atomic lattice distortion cannot logically infer the existence of the Cooper electron pairs. On the other hand, we know that when the ambient temperature decreases and the pressure increases, the activity of the atomic lattices decreases, that is, the distortion of the atomic lattices decreases. In other words, a decrease in ambient temperature and an increase in pressure are not beneficial for the formation of superconducting states, which is exactly opposite to the experimental results.

The BCS theory hypothesis is based on the dynamical theory of lattices and the experimental data of conventional superconductors. The BCS theory hypothesis explains the superconducting properties of Class I conventional metal and alloy superconductors, but it cannot interpret the superconducting phenomenon of Class II unconventional superconductors. According to the BCS theory, the critical temperature of superconductors cannot be higher than 40K, but the critical temperature of unconventional superconductors is much higher than 40K, such as copper oxide superconductors, whose critical temperature can be as high as more than 100K. With high-pressure, even for conventional superconductors, their critical temperature also can be higher than 40K. The microscopic mechanism of superconductivity still needs further research, which is one of the big challenges in physics today.

2. Preliminary knowledge

2.1 Elastic collisions, inelastic collisions, and completely inelastic collisions

According to Newtonian classical mechanics, the collisions of two elastic objects can be divided into elastic collisions (completely elastic collisions), inelastic collisions, and completely inelastic collisions. Without loss of generality, there are two elastic small balls on the ideal smooth plane XOY, with masses of m_1 and m_2 respectively. The mass m_1 is much smaller than m_2, and the elastic small ball m_2 is stationary. There are four springs inside the small balls of m_1 and m_2 to represent their elastic characteristics, as shown in Figures 2.1a, 2.1b, and 2.1c.

2.1.1 Elastic collisions

The elastic ball with mass m_1 collides with the stationary elastic ball with mass m_2 at a speed V_{11}, as shown in Figure 2.1a. During the collision, the springs of the two elastic balls are only elastically deformed, not plastically deformed. The kinetic energy of the ball m_1 is only converted to elastic potential energy. After the collision, the two elastic balls are separated, and the speed of ball m_1 is V_{12}， the ball m_2 remains stationary, and the springs inside the two elastic balls return to their original shape before the collision. According to the conservation of energy, the speed of the small ball m_1 before and after collision is equal, that is, $V_{11}=V_{12}$. When the elastic collision between two elastic small balls, the force of the ball m_1 in the y direction $F_{1y}=0$, the momentum in the y direction is conserved before and after the collision, so the incident angle θ_{11} and the reflection angle θ_{12} of the ball m_1 are equal, that is, $\theta_{11} = \theta_{12}$. The above collision of two small balls is called elastic collision, or completely elastic collisions. In the process of elastic collision, if the incident angle θ_{11} is zero, the ball m_1 and the ball m_2 collide concentrically at speed V_{11}, the deformation of the spring is also the largest.

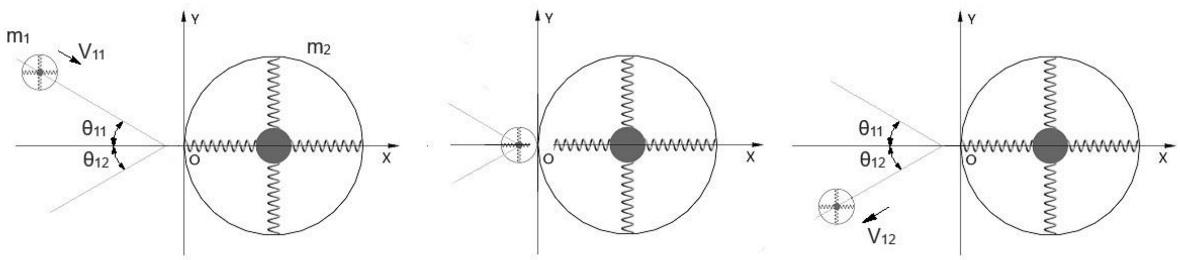

Figure 2.1a Elastic collisions

2.1.2 Inelastic collisions

Increase the speed of elastic ball m_1, and ball m_1 collides with the stationary ball m_2 at speed V_{21}, as shown in Figure 2.1b. During the collision, the springs of the two elastic balls are both elastically deformed and plastically deformed, and the kinetic energy of the balls m_1 is partly converted to the elastic potential energy of the springs, and partly to the plastic deformation of the springs. After the collision, the two elastic balls are separated, the speed of the ball m_1 is V_{22}, the plastic deformation of the spring cannot be recovered. According to the conservation of energy, the speed of the small ball m_1 after collision is smaller than the speed before collision, that is, $V_{22}<V_{21}$. The above collision of two small balls is called inelastic collision.

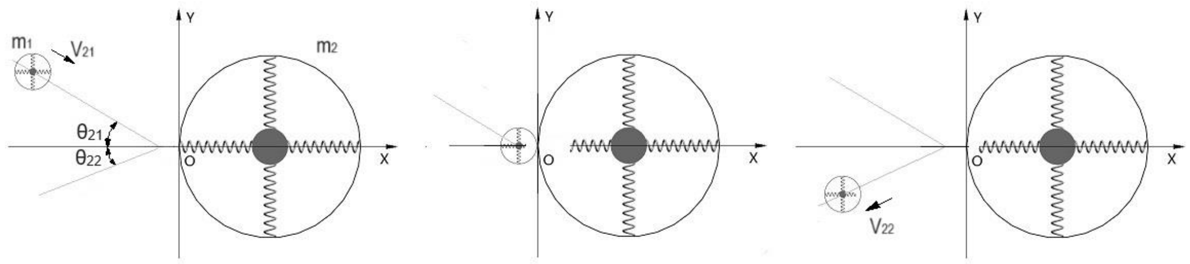

Figure 2.1b Inelastic collisions

2.1.3 Completely inelastic collisions

Continue to increase the speed of elastic ball m_1, and the ball collides with the stationary m_2 ball at speed V_{31}, as shown in Figure 2.1c. During the collision, the springs of the two elastic balls are both severely plastically deformed, and the kinetic energy of the balls m_1 is completely converted to the plastic deformation of the springs. After the collision, the speed of the ball m_1 is 0, that is, the ball m_1 and the ball m_2 stick together and remain stationary. Such a collision is called completely inelastic collision.

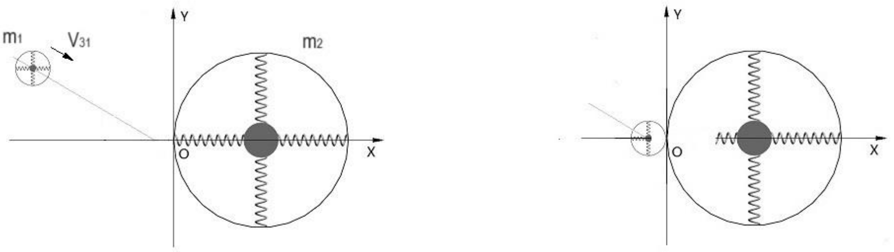

Figure 2.1c Completely inelastic collisions

During the above collisions of the small balls, when the speed of small ball m_1 is low, the kinetic energy of the ball m_1 can only cause elastic deformation of the two small balls. Before and after the collision, the kinetic energy of the small ball m_1 remains unchanged, and the temperature of the two elastic small balls remains unchanged. When the speed of ball m_1 increase, during the collision process, part of the kinetic energy of ball m_1 is converted into plastic deformation of the elastic balls, and the temperature of the two elastic balls increases. When the speed of ball m_1 increases to a certain speed, during the collision process, all the kinetic energy of ball m_1 is converted into plastic deformation of the two elastic balls. After the collision, the two elastic balls stick together, and the temperature of the two elastic balls increases the most.

In the process of above collisions, if the incident angle is zero, that is, the small ball m_1 and the small ball m_2 collide concentrically. Let the incident speed of small ball m_1 increase from low to high. When the speed of small ball m_1 is V_C, the plastic deformation of the small ball m_1 and small ball m_2 begins to occur during the collision process, that is, the elastic collision of the two small balls begins to transition to inelastic collision, the speed V_C is called the critical speed of small ball elastic collision.

2.2 The movement of free electrons within a current-carrying wire

In general, taking copper current-carrying wire as an example, the number of free electrons per unit in copper is n_e=8.5 x$10^{28}$$m^{-3}$, and the charge amount of an electron q_e=1.6x10^{-19}C. Let the cross-sectional area of the copper wire be S =1.0 mm^2 =1.0x10^{-6} m^2, the current passing through the copper wire is I=1.0A, and the directional speed of electrons in the wire is V_{eE} driven by the electric field. Then according to the definition, the current:

$$I = q_e\ n_e\ S\ V_{eE} \quad (2\text{-}1)$$

From the above formula, the current density passing through the copper wire:

$$j= q_e\ n_e\ V_{eE} \quad (2\text{-}2)$$

From formula (2-1), the directional speed of electrons:

$$V_{eE}= I / (q_e\ n_e\ S) \quad (2\text{-}3)$$

$$V_{eE} =1.0 / (1.6 \times 10^{-19} \times 8.5 \times 10^{28} \times 1.0 \times 10^{-6})$$

$$V_{eE}=7.4 \times 10^{-5}\ m/s$$

From the above formula, the directional speed of electrons V_{eE} is 7.4 x 10^{-5} m/s. However, according to the classical free electron theory of metals, the average speed of the random thermal motion of free electrons in a metal conductor is:

$$V_{eT} = ((8\ k_B\ T) / (\pi\ m_e))^{1/2} \quad (2\text{-}4)$$

Where k_B=1.38×10^{-23} J/K, which is the Boltzmann constant, m_e=0.91×10^{-30} Kg is the electron mass, T is the thermodynamic temperature. If t=27℃, then T=300K. Substituting these values into equation (2-4), then V^{eT}=1.08 × 10^5 m/s.

In summary, in a current-carrying wire at normal temperature, the speed of free electrons is a combination of massive random thermal motion with a very small directional movement. The ratio of the directional speed V_{eE} to the thermal speed V_{eT} is in the scale range of 10^{-10}. The random thermal speed of free electrons in the current-carrying wire is huge, and the thermal speed of the atomic lattices is also quite large.

3. Electron elastic collision superconductivity theory

From the above analysis, it can be concluded that in the normal temperature, without the electric field, the free electrons and the atomic lattices both take high-speed random thermal motion. However, the high-speed thermal motion is relative to its zero-point position, and the zero-point position is unchanged. The free electron at high-speed thermal motion is confined within a fixed atomic lattice, then the collision between the electron and the adjacent atomic lattice is mainly an elastic collision, which will not produce a lot of heat. Driven by the electric field, the free electrons move directionally. Although the directional movement speed is small, the free electrons pass through different atomic lattices. The collision between free electrons and atomic lattices is mainly an inelastic collision. An energy exchange occurs between free electrons and atomic lattices, which generates a huge amount of heat.

When the temperature drops to near absolute temperature, the random thermal motion of free electrons and atomic lattices is low, and the motion speed is close to zero. Driven by an electric field, the free electrons in the current-carrying wire move directionally, which is the main movement of free electrons, and the speed of free electrons is in the scale range of 10^{-5} m/s. That is, when the free electrons pass through different atomic lattices, the relative speed between free electrons and atomic lattices is in the scale range of 10^{-5} m/s. At such a low-speed, the collision can only be an elastic collision, and the speed of the free electrons remains unchanged before and after the collision. There is no energy exchange between free electrons and atomic lattices. The current-carrying wire shows a zero-resistance superconducting state. Based on the analysis above, we can draw the following conclusions:

Electron elastic collision superconductivity theory: The microscopic mechanism of superconducting states is that during the directional motion of the free electrons in the current-carrying wire, only complete elastic collisions occur between the free electrons and the atomic lattices, and there is no energy exchange between the free electrons and the atomic lattices. The current-carrying wire shows zero-resistance superconducting states.

In the superconducting states, the free electrons moving at low speed can be regarded as an elastic microsphere with a negative charge e. Although the total charge of an atomic lattice carries a positive charge, protons with a positive charge are all concentrated in a narrow space located at the core center of the atomic lattice, and electrons with a negative charge are all located on the periphery of the atomic lattice. The core center of the atomic lattice shows positive charge electric field characteristics, and the periphery of the atomic lattice shows negative charge electric field characteristics. As shown in Figure 3.1, blue indicates a positive charge electric field, and red indicates a negative charge electric field. The free electron is a red elastic small ball, and its red color slowly fades from the inside to the outside, the depth of red color represents the strength of the negative electric field. The core center of the atomic lattice is a blue central circle, and the blue color slowly fades from the inside to the outside, the depth of blue color represents the strength of the positive electric field. The outer periphery of the blue central circle is a red ring, and the depth of red color represents the strength of the negative electric field. The width of the red outer ring is ΔD_C, and the radius of the blue central circle is R_C. The region of the atomic lattice within the radius R_C is the positive charge electric field, and the region outside the radius R_C is the positive charge electric field, and the region outside the radius R_C is the negative charge electric field.

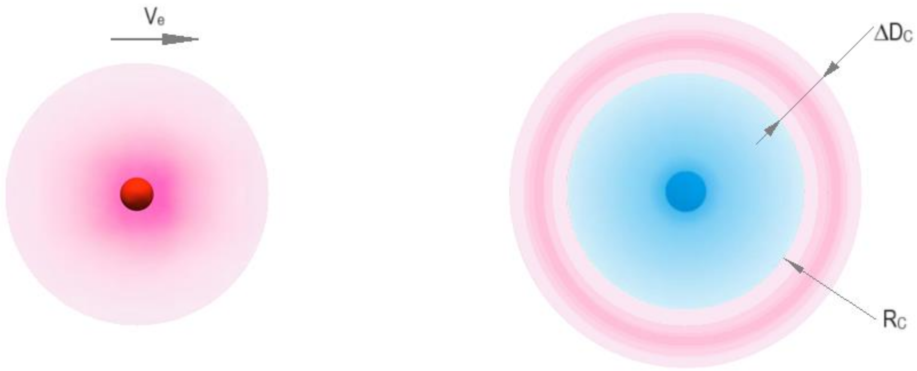

Figure 3.1 The electric field characteristics of electrons and atomic lattices

In the process of collision between free electrons and atomic lattices, if the collision only occurs in the red peripheral region of the lattices, it is an elastic collision, there is no energy exchange between the free electrons and the lattices, and the current-carrying wire shows zero-resistance superconducting states. If the free electrons break through the red peripheral region of the lattices ΔD_C and reach the blue region within R_C, the collision at this time is an inelastic collision, there is an energy exchange between the free electrons and the lattices, and the current-carrying wire shows normal resistance states. ΔD_C is called the lattice critical elastic width, and R_C is called the lattice critical elastic radius.

At normal temperature, the random thermal motion speed of the atomic lattices is huge. In the superconducting states, the random thermal motion speed of the lattices is very small. In order to simplify the influence of random thermal motion of lattices, the atomic lattices are considered as stationary, and the lattice critical elastic width ΔD_C and the lattice critical elastic radius R_C are adjusted according to the random thermal motion of lattices. When the ambient temperature increases, the random thermal motion speed of the lattices increases, the critical elastic width ΔD_C decreases and the critical elastic radius R_C increases. On the contrary, the random thermal motion speed of the lattices decreases, the critical elastic width ΔD_C increases and the critical elastic radius R_C decreases.

As shown in Figure 3.1, since the free electron is an elastic small ball with a negative electric field, and the periphery of the atomic lattice is also a weak negative electric field, there is a repulsive force between the free electron and the lattice. In the superconducting states, the free electron moves closer to the atomic lattice at a low speed V_e, and the free electron decelerates under the electric field repulsive force. The free electron and the lattice undergo elastic collision only within the red peripheral region of the lattice. After the collision, the free electron accelerates away from the lattice under the electric field repulsive force, and the free electron accelerates to the original speed V_e. Therefore, before and after the collision between the free electron and the lattice, the speed of the free electron remains the same, and there is no energy exchange between the free electron and the lattice.

When a free electron and an atomic lattice collide concentrically. Let the incident speed of the free electron increase to V_C, the free electron begins to break through the red peripheral region of the lattice and reaches the blue region within R_C, the speed V_C is called free electron critical speed. When the free electron enters the blue region within the R_C, there is an energy exchange between the free electron and the lattice, and the current-carrying wire enters a normal resistance state. The kinetic energy of the free electron corresponding to the critical speed V_C is Δ_E, which is called free electron critical kinetic energy. The corresponding atomic lattice elastic potential energy is called the atomic lattice critical elastic potential energy. The critical kinetic energy of the free electron is equal to the critical elastic potential energy of the atomic lattice.

The important reason for the widespread acceptance of BCS theory is the famous formula for calculating the critical temperature T_C [6].

$$2\Delta = 3.53\, k_B T_C \qquad (3\text{-}1)$$

Where $k_B=1.38\times10^{-23}$J/K, which is the Boltzmann constant; The energy gap Δ and critical temperature T_C are both experimental measurement values. The energy gap Δ can be measured through experiments such as far-infrared absorption, electron tunnel experiment, and critical field experiment.

Table 3.1 shows the experimental measurement values of $2\Delta/k_BT_C$[7][8]. From Table 3.1, it can be concluded: With different experimental methods, there is a significant difference between the theoretical values of coefficient 3.53 and experimental values. Even with the same experimental method but different experimental groups, the experimental coefficients are still significant different.

Table 3.1 Experimental measurement values of $2\Delta/k_BT_C$.

Superconducting material	Experimental group	Far-infrared absorption	Electron tunnel	Critical field
Al	I		4.2±0.6	3.53
	II		2.5±0.3	
	III		3.37±0.1	
Sn	I	3.6	3.46±0.1	3.61
	II		3.10±0.05	3.57
	III		2.8–4.06	
In	I	4.1	3.63±0.1	3.65
	II		3.45±0.07	
Pb	I	4.14	4.29±0.04	3.95
	II		4.38±0.01	
Hg	I	4.6	4.6±0.05	3.95
Nb	I	2.8	3.84±0.06	3.65
	II		3.6	

Equation (3-1) is an approximate calculation formula for conventional superconductors, which is derived based on quantum free electron theory and solid band theory, solid-state physics. The theoretical derivation process does not require the introduction of the Cooper electron pairs, there is no relationship between Cooper electron pairs and equation (3-1). The introduction of Cooper electron pairs is only to explain that the free electrons can move losslessly within the lattices to form superconducting currents.

Based on Electron elastic collision superconductivity theory and classical Free electron theory of metals, we also can derive the formula for calculating the critical temperature T_C. Set the critical speed is V_C, and its corresponding critical temperature is T_C. The relationship between V_C and T_C is obtained from formula (2-4):

$$V_C = ((8\ k_B\ T_C) / (\pi\ m_e))^{1/2} \quad (3\text{-}2)$$

Where m_e=0.91 × 10^{-30} Kg, which is the electron mass. The critical kinetic energy of the free electron at the critical speed V_C is:

$$\Delta_E = m_e\ V_C^2 / 2 \quad (3\text{-}3)$$

From equations (3-2) and (3-3), it can be concluded that:

$$2\Delta_E = 2.55\ k_B\ T_C \quad (3\text{-}4)$$

Equations (3-4) and (3-1) have similar expressions, but their proportion coefficients are different. For equation (3-1) itself, the experimental coefficients are significant different if the experimental methods are different. Therefore, it's acceptable that the proportion coefficients is different between equations (3-4) and (3-1). The critical kinetic energy Δ_E of the electron in equation (3-4) is equal to the critical elastic potential energy of the atomic lattices. In equation (3-4), the physical concept of Δ_E is clearer and it's also easier to experimentally measure.

Below is an experimental measurement method for the critical kinetic energy Δ_E of electrons. As shown in Figure 3.2, the experiment uses a superconducting thin film with a thickness in the nanometer scale, which is placed in a vacuum insulation box. On the left side of the vacuum insulation box, there is an electron emission gun, and on the left and right sides of the vacuum insulation box, there are electron speed measurement sensors. The vacuum insulation box is also equipped with a temperature sensor for measuring the temperature of superconducting thin film.

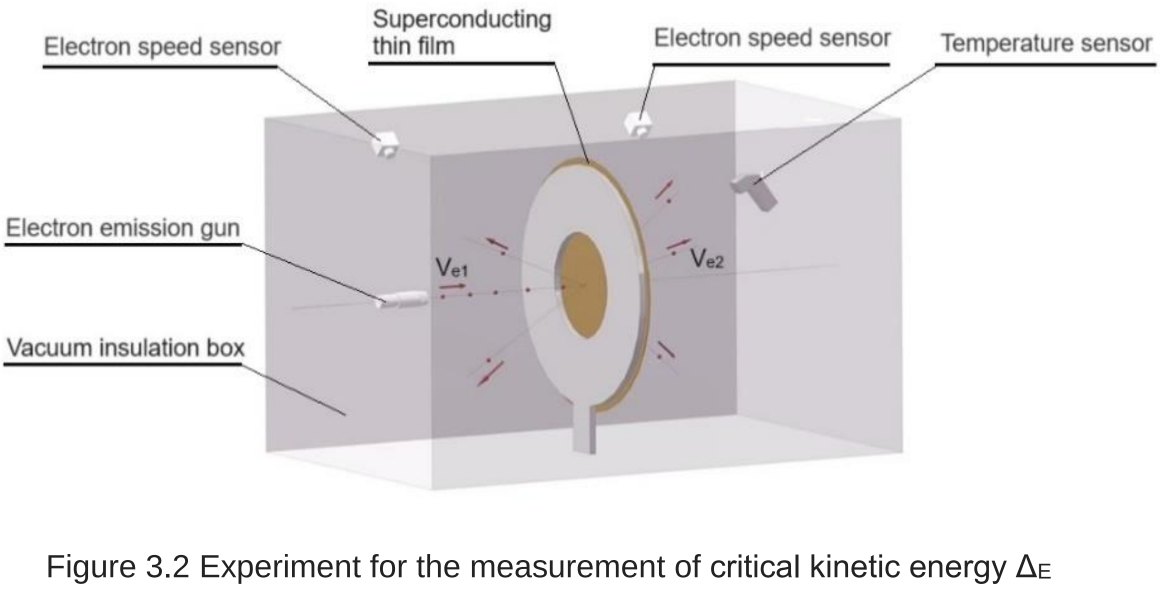

Figure 3.2 Experiment for the measurement of critical kinetic energy Δ_E

In the experiment, firstly, cool the superconducting thin film to T_{C1}, which is below the critical temperature T_C. The electrons emitted by the electron gun move towards the superconducting thin film at a speed V_{e1}. After the collision between the electrons and the superconducting thin film, the speed of the electrons is V_{e2}. Some electrons reflect back to the left side of the vacuum box, while others pass through the superconducting thin film and enter the right side of the vacuum box. When the electrons move at a low speed V_{e1}, the collisions between the electrons and the superconducting thin film are elastic collisions, and the speed of electrons remains unchanged after the collisions, that is, $V_{e1}=V_{e2}$. At the same time, the temperature of the superconducting thin film measured by the temperature sensor remains unchanged. Increase the speed of electrons to V_{C1}, and after the collisions between electrons and superconducting thin film, the speed of some electrons decreases. That means the collisions between electrons and superconducting thin film are inelastic collisions. At the same time, the temperature of the superconducting thin film measured by the temperature sensor has increased. Substitute T_{C1} and V_{C1} into equations (3-3) and (3-4) to verify these two equations. Using different T_{C2} and T_{C3}, and obtaining the corresponding V_{C2} and V_{C3} by experiments, further verifying whether the Boltzmann constant k_B maintains unchanged near absolute zero.

Before and after a collision of the free electron and lattice, the momentum of the free electron changes. However, the collisions between the free electron and lattices occur randomly, the number of collisions is large, and the number of free electrons in the current-carrying wire is also very large. Based on the macroscopic statistics of random collisions, the momentum of the free electrons is conserved, that is, the direction of the movement of the free electrons remains unchanged.

4. The Interpretation of Superconducting States by Electron Elastic Collision Superconductivity Theory

The microscopic mechanism of the superconducting states is that only elastic collisions occur between free electrons and atomic lattices, and no energy exchange occurs between free electrons and lattices. The current-carrying wire shows zero-resistance superconducting states.

4.1 The superconducting state free electron critical speed V_C

Within a current-carrying wire, the free electron speed V_e is the essence of the superconducting states. With no external magnetic fields and at normal environmental pressure, when the temperature decreases to the critical temperature T_C, the current-carrying wire enters the zero-resistance superconducting states, the corresponding speed of the free electrons at that time is called the superconducting state critical speed V_C. The critical speed Vc is a combination of the free electron directional speed V_{eE} and the random thermal speed V_{eT}, that is:

$$V_C= V_{eE} + V_{eT} \qquad (4\text{-}1)$$

For a free electron at critical speed V_C, its corresponding critical kinetic energy:

$$\Delta_E=m_e V_C^2/2$$

The critical kinetic energy Δ_E is equal to the critical elastic potential energy of the atomic lattice.

4.2 The critical temperature T_C, the critical magnetic field H_C, and the critical current density j_C

The critical temperature T_C, the critical magnetic field H_C and the critical current density j_C are the three important critical parameters of the superconducting states.

The current carrying wire enters a zero-resistance superconducting state when the temperature drops to the critical temperature T_C. With temperature decreasing, the random thermal motion speed of free electrons and atomic lattices decreases. The critical temperature T_C corresponds to the free electron critical speed V_C. The critical temperature T_C is the macroscopic statistical representation of the superconducting states, and the critical speed V_C is the microscopic mechanism of the superconducting states.

A magnetic field is applied axially along the superconducting current-carrying wire, which will excite and generate vortex currents radially to counteract the external magnetic field, so as to maintain the zero magnetic induction intensity within the superconductor. In the process of applied magnetic field, the magnetic field will produce a Lorentz magnetic field force on the free electrons in the current-carrying wire, and the free electrons will superimpose a vortex current speed V_{eB} on the original speed, which is proportional to the applied magnetic field.

When the applied magnetic field reaches the critical magnetic field H_C, the superimposed vortex current speed V_{eB} makes the speed of the free electrons reach the critical speed V_C, and the current-carrying wire enters the normal resistance states from the zero-resistance superconducting state. The microscopic mechanism of the critical magnetic field H_C is that the speed of the free electrons is superimposed on the speed of the vortex current V_{eB}.

Experiments also show that the superconducting state of a current-carrying wire is limited by the current density. When the current density reaches a certain critical current density j_C, the current-carrying wire recovers from the zero-resistance superconducting state to the normal resistance state. According to formula (2-2), the directional motion speed V_{eE} of free electrons is directly proportional to the current density. When the current density reaches the critical current density j_C, the corresponding free electron speed also reaches the critical speed V_C. The current-carrying wire enters the normal resistance state from the zero-resistance superconducting state. The microscopic mechanism of the critical current density j_C is the increasing of the directional motion speed of free electrons.

In summary, the microscopic mechanism of the critical temperature T_C, the critical magnetic field H_C and the critical current density j_C of the superconducting state is the change of the critical speed V_C of the free electrons.

4.3 Gap Energy

Far-infrared absorption is a method of experimentally measuring the energy gap Δ. The cavity is made of superconducting materials, and the far-infrared radiation is introduced into the cavity through a light pipe, and a far-infrared radiation detection element is placed in the cavity. Far-infrared photons can be detected by the detection element after multiple reflections in the cavity. When the frequency of far-infrared light $\gamma < \gamma_g$, the energy of far-infrared photons is too small, the collision between far-infrared photons and superconducting wall lattices of the cavity is a completely elastic collision, there is no energy exchange between far-infrared photons and superconducting wall lattices. The superconducting wall does not absorb any far-infrared photon, all far-infrared photons are retained in the cavity, and a large radiation signal can be detected by the detection element. When the radiation frequency is $\gamma >= \gamma_g$, the energy of far-infrared photons is large enough, the collision between far-infrared photons and superconducting wall lattices is an inelastic collision, there is energy exchange between far-infrared photons and superconducting wall lattices. The superconducting wall absorbs a large number of far-infrared photons, only part of the far-infrared photons is retained in the cavity, the signal received on the detection element decreases rapidly. The frequency γ_g is called the critical frequency, and the critical photon energy with the frequency γ_g is called the energy gap of the superconductor:

$$\Delta = h\ \gamma_g$$

Where $h = 6.626 \times 10^{-34}$ J·s, which is Planck's constant.

4.4 Class I conventional superconductor and class II unconventional superconductor

Metal, alloy and compound superconductors are usually referred to as class I conventional superconductors, and high-temperature superconductors such as copper oxide superconductors, iron-based superconductors, organic superconductors, and two-dimensional superconductors are called class II unconventional superconductors. The lattice structure of conventional superconductors is relatively simple, and it is generally face-centered, body-centered, hexagonal dense pile, quadrangular crystal system, rhomboidal crystal system, etc., they all have isotropic, zero resistance and completely diamagnetic superconducting properties. Based on the dynamical theory of lattices and the experimental data of conventional superconductors, in 1957, Bardeen, Cooper and Schrieffer put forward the famous BCS theoretical hypothesis. According to the BCS theory, the superconducting critical temperature cannot be higher than 40 K at normal atmospheric pressure.

In 1986, Swiss scientists Bernorz and Miller discovered a barium-lanthanum-copper oxide superconductor, which superconducting critical temperature may be higher than 35 K. Later, through the efforts of scientists from many countries, the superconducting critical temperature was soon increased to 90K. The high-temperature unconventional superconductor is a huge challenge to the BCS theory. Class II unconventional superconductors have complex lattice structures and generally have anisotropic superconducting properties. Fig. 4.1a shows the lattice structure of $YBa_2Cu_3O_7$ with a critical temperature T_C at 90K; Fig. 4.1b shows the lattice structure of $Bi_2Sr_2Ca_2Cu_3O_{10+y}$ with a critical temperature T_C up to 110K.

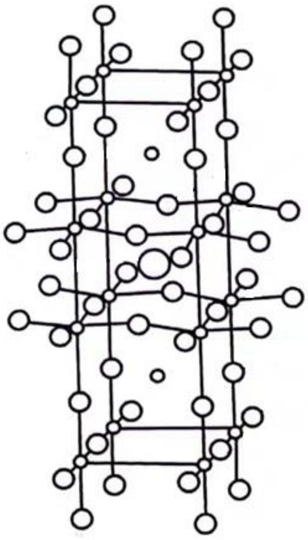

Figure 4.1a $YBa_2Cu_3O_7$

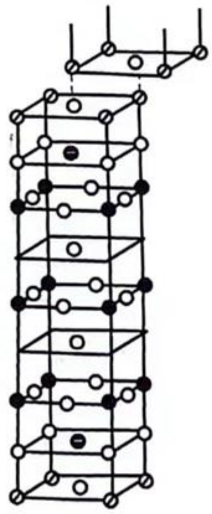

Figure 4.1b $Bi_2Sr_2Ca_2Cu_3O_{10+y}$

Class II unconventional superconductor generally includes different atomic lattices, and the atomic lattices are distributed in different direction. Class II unconventional superconductor can be simplified as long cylindrical lattice. If the direction of the long cylindrical lattice is the same as that of the current-carrying wire, on the one hand, the long cylindrical lattice provides a smooth channel for the flow of free electrons, and on the other hand, unconventional superconductor lattice has a low random thermal motion even at higher relative temperatures. For these two reasons, class II unconventional superconductors have a high free electron critical speed V_C, and their corresponding critical temperature T_C is also higher.

For Class I conventional superconductors, when an external magnetic field $H_a < H_C$ is applied, the superconductor shows complete diamagnetism, and when $H_a = H_C$, the superconductor returns to a normal resistance state. Class II unconventional superconductors have a lower critical magnetic field H_{C1} and an upper critical magnetic field H_{C2}, and $H_{C1} < H_{C2}$. When the applied external magnetic field $H_a < H_{C1}$, the superconductor shows a complete diamagnetic phenomenon. When the applied magnetic field $H_a = H_{C1}$, the magnetic field begins to enter the superconductor, but the superconductor maintains zero-resistance state. When the applied magnetic field $H_a > H_{C1}$, the magnetic field enters the superconductor more and more, but the superconductor still maintains zero-resistance state. When the applied magnetic field $H_a = H_{C2}$, the superconductor returns to the normal resistance state, and the magnetic field completely enters the conductor.

Below is an in-depth analysis of the reasons why the critical magnetic field of Class II superconductors is significantly different from that of Class I superconductors

Class II unconventional superconductors have complex lattice structures and have anisotropic superconducting properties. As shown in Figure 4.2, the direction of the long cylindrical lattice is the same as that of the current-carrying wire, which provides a smooth channel for the axial flow of free electrons, Therefore, class II superconductors have a higher free electron critical speed in the axial direction, which is the axial critical speed V_{C2}. Corresponding to the axial critical speed V_{C2} is the axial critical magnetic field H_{C2}, which is the upper critical magnetic field.

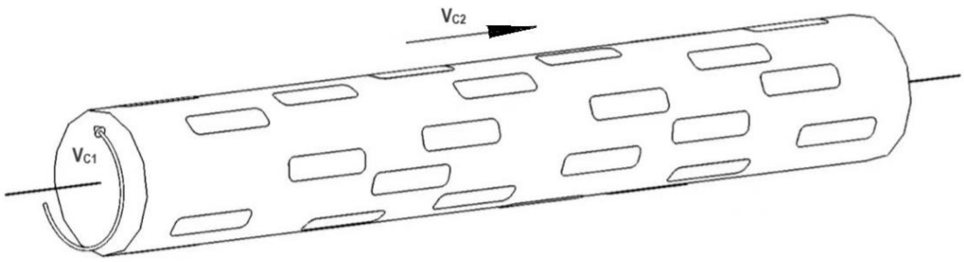

Figure 4.2

The applied external magnetic field Ha generates vortex currents in the radial direction of the current carrying wire, and the radial flow of free electrons is not as smooth as the axial flow. Class II superconductors have a lower free electron critical speed in the radial direction, which is the radial critical speed V_{C1}. Corresponding to the radial critical velocity V_{C1} is the radial critical magnetic field H_{C1}, which is the lower critical magnetic field. The axial critical speed is greater than the radial critical speed, that is, $V_{C2} > V_{C1}$. The axial critical magnetic field is greater than the radial critical magnetic field, that is, $H_{C2} > H_{C1}$.

When the applied external magnetic field $H_a < H_{C1}$, the radial speed of the free electrons $V_a < V_{C1}$. The axial and radial flow of the free electrons both remain zero-resistance states, and the superconductor shows a complete diamagnetism. When the applied magnetic field $H_a = H_{C1}$, and the radial speed of the free electrons $V_a = V_{C1}$. The radial flow of the free electrons begins to enter a normal resistance state, the vortex current cannot completely offset the applied magnetic field H_{C1}, then the magnetic field begins to enter the superconductor, but the axial flow of free electrons remains in a zero-resistance state.

When the applied magnetic field $H_a > H_{C1}$, the radial speed of the free electrons $V_a > V_{C1}$. The magnetic field entering the superconductor increases with the increasing of the applied magnetic field Ha, but the axial flow of the free electrons still remains in a zero-resistance state. When the applied magnetic field $H_a = H_{C2}$, the axial speed of the free electrons also reaches the critical speed V_{C2}, the axial flow and radial flow of the free electrons both enter the normal resistance states, the superconductor returns to the normal resistance states, and the magnetic field completely enters the conductor.

To sum up, zero-resistance state and complete diamagnetism are not two independent criteria for superconducting states. The essence of superconducting state is zero resistance. The diamagnetism is due to the fact that the magnetic field generated by vortex current can offset the external applied magnetic field, so that the superconductor shows a complete diamagnetic phenomenon. For class II unconventional superconductors, when $H_{C1} < H_a < H_{C2}$, the superconductor is still in a state of zero resistance, but the magnetic field generated by vortex current cannot completely offset the external applied magnetic field, so the external magnetic field enters the superconductor.

Below is a proposed verification experiment on the diamagnetism of superconducting states. As shown in Figure 4.3, coating a superconducting thin film on a silicon cylindrical substrate. The superconducting thin film material can be either Class I conventional superconductor or Class II unconventional superconductor. The thickness of the superconducting thin films ranges from 0.1nm to 1.0 nm, then the thin films themselves cannot form vortex currents. Along the axis of the silicon cylinder, a longitudinal groove is opened on the superconducting thin films, so that the superconducting thin films coated on the silicon cylinder substrate cannot form vortex currents. The magnetic fields can enter the superconducting thin film of this structure even for Class I conventional superconductors.

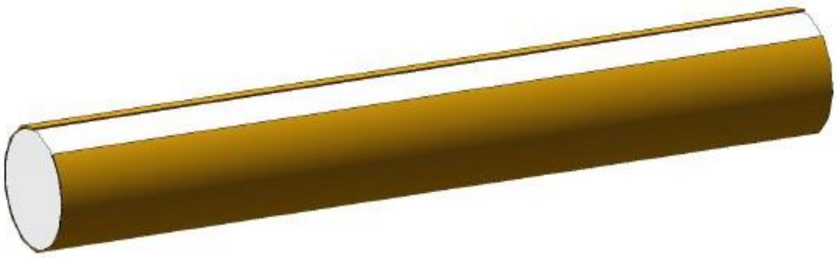

Figure 4.3 Experiment of ferromagnetism in superconducting thin film

4.5 High pressure superconductor

Temperature and pressure are the two most important environmental parameters. Similar to the decreasing in temperature, the increasing of ambient pressure also will reduce the random thermal movement speed of free electrons and lattices, thus, in higher temperature environments, the movement speed of free electrons remains below the critical speed V_C. A high-pressure environment is beneficial for the formation of superconducting states.

5. Summary and discussion

The BCS theory hypothesis explains the superconducting properties of Class I conventional metal and alloy superconductors, but it violates Coulomb's law and

Heisenberg's uncertainty principle, cannot interpret the superconducting phenomenon of Class II unconventional superconductors.

Based on the elastic collision theory of Newtonian classical mechanics, this paper proposes Electron elastic collision superconductivity theory, which reveals that the microscopic mechanism of superconducting states is that the free electrons in a current-carrying wire only undergo complete elastic collisions with the atomic lattices, and there is no energy exchange between the free electrons and the atomic lattices. The current-carrying wire shows zero resistance superconducting states. The electron elastic collision superconductivity theory proposes the superconducting state free electron critical speed V_C, and theoretically derives the calculation formula for the critical temperature T_C: $2\ \Delta_E = 2.55\ k_B\ T_C$. The elastic collision superconductivity theory interprets the microscopic mechanism of the superconducting state critical temperature T_C, the critical magnetic field H_C, the critical current density j_C, the superconducting state energy gap and the high-pressure superconductor. Unlike Class I conventional superconductors, Class II unconventional superconductors have anisotropic lattices. There are different critical speeds V_C, different critical temperatures T_C and different critical magnetic fields H_C in different directions. When the direction of lattices is the same as that of the current carrying wire, it is beneficial for the formation of superconducting current. Therefore, unconventional superconductors can achieve high-temperature superconductivity.

Based on the Electron elastic collision superconductivity theory, it is theoretically feasible to achieve a zero-resistance superconducting state at normal temperature. The lattices of ceramic materials have very small random thermal motion at normal temperature, by infiltrating metal nano atoms, they are a promising normal temperature superconducting material. Another feasible superconducting material is carbon, which is easy to form different atomic lattices, two-dimensional carbon film and one-dimensional carbon fiber are the development direction of normal temperature superconductors.

The electron elastic collision superconductivity theory will provide new insights into solid-state physics and quantum optics.

Classical free electron theory, quantum free electron theory, and band theory are important contents of solid-state physics. Classical free electron theory regards free electrons as molecules in an ideal gas. Based on the thermal random motion of free electrons and atomic lattices, formula (2-4), which explains the relationship between free electron speed and absolute temperature, is derived. The classical free electron theory explains Ohm's law from a microscopic perspective. However, quantum free electron theory holds that classical free electron theory cannot explain the relationship between free electrons and the heat capacity and magnetization of metal materials. At normal temperature, although the thermal random motion speed of electrons is high, the mass of electrons is very small, and the kinetic energy of electrons is relatively small compared to the kinetic energy of atomic lattices. The heat capacity mainly comes from the kinetic energy of atomic lattice thermal motion, and heat capacity comes from free electrons is very small. In addition, without the effect of an external electric field, the motion of free electrons is a thermal random motion. Free electrons not only have no promoting effect on the magnetization of metal materials, but on the contrary, the high-speed thermal random motion of free electrons hinders the formation of molecular currents that magnetize metal materials. Therefore, metal materials with excellent conductivity, such as copper, silver, aluminum, etc., are often not magnetic materials.

According to the principle of blackbody radiation, any object, which absolute temperature is above zero, will emit light quanta, and the wavelength of light quanta is related to temperature. The higher the temperature of an object, the higher the frequency and the shorter the wavelength of the light quanta. For example, when metal copper is heated to 1000K, it appears red. The reason is that the electrons of copper atoms undergo energy level transitions under high-temperature excitation. The electron transition is from high energy levels to low energy levels, it releases light quantum with a wavelength of about 600nm. At normal temperature, electrons within copper atoms cannot achieve energy level transitions, but free electrons undergo high-speed thermal random vibrations, and their kinetic energy constantly changes within a small certain range, releasing low-frequency, low-energy light quanta. When the absolute temperature approaches zero, the thermal random motion speed of free electrons approaches zero from equations (3-4).

The electron elastic collision superconductivity theory reveals that free electrons and atomic lattices only undergo complete elastic collisions in superconductors. Can this theory be extended to the propagation of light quanta in glass media? Light quantum propagates in a glass medium, and it only undergoes a complete elastic collision with the glass medium. Light quantum can propagate without loss in the glass medium.

Author: Hongyuan Ye

yehongabc@buaa.edu.cn

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