Characteristics of the Origin of High T_c Copper Oxidized Cooper Pairs

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Received: March 30, 2014 / Accepted: April 22, 2014 / Published: April 25, 2014.

Abstract: The mechanism of the superconductivity of high T_c copper oxidized superconductors is a important and basic research subject. The characteristics of high T_c copper oxidized Cooper pairs was studied by the mechanism of high T_c superconductivity combined with the theory of quantum chemical bond and Sanderson's electronegativity principle. It was concluded that the high T_c copper oxidized Cooper pairs originated from the non-bonding electrons which undertook the elements of the superconductivity.

Key words: High T_c copper oxidized superconductors, characteristics of Cooper pairs, theory of quantum chemical bonds, Sanderson's electronegativity principle.

1. Introduction

In 1986, Bednorze and Muller discovered in La_2CuO_4 that La-Ba-Cu-O compound was of high superconducting transition temperature by doping [1]. In 1987, Gough et al. [2] found in their research that the superconductive carrier in high T_c copper oxides was based on Cooper pair (that is, the frequency of Shapiro's stage was $2eV/h$). But the forming mechanism of Cooper pair was still not clear [3]. The combination of the chemical bonds between the conventional superconductive elements of high T_c copper oxides was completely different from that between the elements of the conventional superconductors. Between the elements of the conventional superconductors was the combination of the metallic bonds and chemical bonds and metallic bonds were two completely different combination ways between two elements in essence [5]. According to the theory of quantum chemical bonds and the principle of Sanderson's electronegativity, the

mechanism of high T_c superconductivity studied the characteristics of Cooper pair in the high T_c copper oxidized superconductors. It was concluded that Cooper pair in high T_c copper oxidized superconductors originated from the non-bonding electrons that undertook the elements of superconductivity.

2. Methods

2.1 Theory of Quantum Chemical Bonds

Pauling gave the definition of the chemical bonds [6] that as far as two atoms or atomic groups were concerned, if the force that acted between them could lead to the formation of aggregation and the stability of the aggregation was big enough for chemists to treat it as an independent category of element, it was claimed that there were chemical bonds between these atoms or atom groups and in the chemical bonds there were ionic bonds and covalent bonds.

2.1.1 Ionic Bonds

Pauling maintained that [6] the ionicity of the bonds was caused by the difference in the abilities of attracting electrons of atoms in molecules. When the

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chemical compounds of AB type was formed and the abilities of attracting electrons of atom B was bigger than those of atom A and even big enough to make them form the type of A^+B^- , this bond was the ideal ionic bond. When the abilities of attracting electrons of atom B was not enough to form the type of A^+B^- but the electrons of the bond a little deviated to atom B, the ionic bonds were partially formed.

Because of the formation of the ionic bonds, there were great changes in the nature of the formed ionic bonds.

The changes of the formation of A^+ were listed as follows:

- (1) The number of the outermost electrons of atom A^+ was much more than that of atom A;
- (2) The structure of the outermost electrons of Atom A^+ was different from that of Atom A and the formed magnetism of atom A^+ was completely different from that of atom A;
- (3) The radius of atom A^+ was smaller than that of atom A;
- (4) The outermost electronic ionic potential of atom A^+ was far bigger than that of atom A;

The changes of the formation of B^- were listed as follows:

- (5) The number of the outermost bonded electrons of atom B^- was far less than that of atom B;
- (6) Because of the electronic structure formed by the bonded electrons, the outermost of atom B^- differed from that of Atom B;
- (7) The radius of Atom B^- was far bigger than that of atom B;
- (8) The ionic potential of the outermost bonded electrons of atom B^- was much less than that of atom B.

According to the relationship among $N(E_F)$, the number of the electrons and the radius of Fermi surface in Ref. [9] of the references, the relationship between V and ionic potential could be obtained as follows. In the ionic bonds, the bonded electrons could not form the effective Cooper pair to Atom A^+ , Atom B^- or atom $A^{+\delta q}$ or atom $B^{+\delta q}$, let alone produce high T_c .

Other magnetic variations and changes of radius could produce direct influence on the replacement of the doped crystal lattice and the magnetism and the lattice constant of the replaced chemical compound.

2.1.2 Covalent Bonds

The definition of covalent bond was [6] that because the shared electrons between the bonding atoms made the bonds combined together, such kind of bond was called bond of electron pair or covalent bond.

In the bonding, the covalent bonds were of the characteristics of directivity and saturability.

The directivity of the covalent bonds was that the symmetry direction of the bonded electron pairs orbit to form the covalent bonds must be the same with that of the orbit which provided the electrons of valence bonds. The saturable characteristics of the covalent bonds was a stable orbit made use of by atoms to generate a bond of electron pair.

Because of the formation of the covalent bonds, big changes in essence would take place to the elements of forming the covalent bond.

Atom B in B-B bonds (B was the atoms of forming covalent bond) to atom B:

(1) Electrons of covalent bonds influenced by the strong acting force of Coulomb were fixed in the crystal lattice between B-B. Thus the substances formed by covalent bonds were insulators with little flexible electrons;

(2) There was no change of the number of electrons averaged to atom B in B-B bonds. Because of the formation of the covalent bonds, the orbit of the outermost electrons changed. In order to form the orbit of equivalent electronic covalent bonds, hybridization took place at the sub-electronic layer of the same electronic layer, even the electronic orbit of the neighboring empty electronic layer participated in hybridization, such as hybridizations of SP and of SPd. It was because of the formation of the B-B covalent bond, the bonded electrons were fixed. The formation of the hybridized orbit and the changes of the radius of the atom made the covalent bonds of electrons unable

form efficient Cooper pair, let alone produce the value of high T_c .

2.2 Sanderson's Electronegativity Equalization Principle

Sanderson pointed out [7] that in the process of formation of polyatom into the material of polyelectro, the differences of electronegativity of the elements in each part of the system made electrons transfer from the region of low electronegativity to the region of high electronegativity (that is, electrons transferred from the region of high chemical potential to the region of low chemical potential) to make the electronegativity of each element in the substances forming the system of polyelectron tend to become balanced.

That is:

$$x_a = x_b = \dots = x \quad (1)$$

x_a , x_b represent the electronegativity of different elements.

Besides, there are the constraint conditions of electric charge

$$\sum_a q_a = Q \quad (2)$$

X and Q are the electronegativity and the total charge of the system.

Among the superconductors formed by bonds between the elements, heterogeneity was formed because of the existence of the following conditions.

(1) The atomic natures of forming the superconductors and the distributions were different;

(2) The atoms of forming the superconductors were the same but the bonding ways were different and distributions were different, too;

(3) The atoms of forming the superconductors were the same and the ways of bonding were also same but the crystal forms were different.

According to the principle of the balance of electronegativity between different regions, to obtain:

$$x'_I = x'_II = \dots = x' \quad (3)$$

x'_I , x'_II were the regional electronegativity in different regions.

In the same region

$$x_a = x_b = \dots = x_I \quad (4)$$

$$x'_a = x'_b = \dots = x_{II} \quad (5)$$

$$x^n_a = x^n_b = \dots = x_n \quad (6)$$

$x_a, x'_a, \dots, x^n_a$, $x_b, x'_b, \dots, x^n_b$ were the electronegativity of the elements in different regions.

But there were not always equality between $x_a, x'_a, \dots, x^n_a$, $x_b, x'_b, \dots, x^n_b$.

In the structure of the high T_c copper oxidized superconductors, their crystals were divided into conducting layers and carrier bank layers according to the different electric properties. But the same crystals have: $x_{\text{conducting layer}} = x_{\text{carrier bank}}$ [8]

2.3 Mechanism of High T_c Superconductivity

Because of the characteristics of the high T_c copper oxidized materials, μ_B (μ_B is the Coulomb's constant interaction between the bonded electrons) which was associated with the bonded electrons could meet the stable conditions of crystal lattice $\mu_B > \lambda_B$ (λ_B is the relevant constant of the bonded electrons and the phonons of the crystal lattice) while λ_c (is the relevant constant of Cooper pair and the phonons of the crystal lattice) which was associated with the non-bonded electrons could meet the conditions of the generation of superconductivity $\lambda_c > \mu_c$ (μ_c is the Coulomb's constant interactions between the Cooper pairs). In the high T_c copper oxidized superconductive materials, chemical bonds were formed between the elements. $N(O)$ is a Blah state density of per unit energy distributed on Fermi surface and V ($V = \langle V_{KK'} \rangle$ average), $V_{KK'}$ could be replaced by an average constant matrix element V . Cooper pair jumped in the section of $-\hbar\omega < \varepsilon < \hbar\omega$ and its transition outside the section was zero. ω was the average frequency of phonons) was of special changes. The mechanism of electron phonons could produce high T_c superconductivity. On the basis of the characteristics of high T_c copper oxidized superconductivity and materials, it was concluded that high T_c copper oxidized superconductivity was produced from the

mechanism of electron phonons [9].

The copper and oxygen on the CuO_2 plane of high T_c copper oxide had obvious isotope effect and was closely correlated with α_{Cu} and α_O , from which it was learnt that the phonons of the copper and oxygen on the CuO_2 plane of high T_c copper oxide participated in the relevance of electron phonons [10].

The copper and oxygen on the CuO_2 plane of high T_c copper oxide formed chemical bonds and the acting force of copper on the bonded electrons was equal to that of the acting force of oxygen. Thus, the bonded electrons could form Cooper pair and the electrons formed by the copper and oxygen on the plate of copper and oxygen correlated with phonons to form Cooper pair were the non-bonded electrons in the respective localization of copper and oxygen and the non-bonded electrons of the localization of the copper and oxygen on the plate of copper and oxygen could obtain the result $\nu_{Cu} \approx \nu_O$, which was beneficial to superconductivity [11].

3. Symmetry of the Superconductive Electron Pair of High T_c Copper Oxide

The symmetry of superconductive electrons was decided by the symmetry of spin wave functions and space wave functions. If spin wave functions were symmetrical (spin triplet state), the space wave functions of Pauli exclusion principle must be antisymmetrical. In the contrary, if the spin wave functions were antisymmetrical (spin singlet), the space wave functions must be symmetrical. The symmetrical features of superconductive electron pair originated from the features of the electron orbit of atoms. Conversely, the features of originated electron orbit of the formed electron pair could be learnt through the symmetry of the superconductive electrons. In Table 1, the power exponent functions of the physical quantity in the state of low temperature (or low energy) of d wave superconductor were presented, which were different from those of S wave superconductors of BCS. In 1993, Hardy et al were the

first to observe the identical λ linear behavior by means of magnetic penetration depth in the twin crystal YBCO of high quality [12]. The conclusions drawn from the study of light conducted by Raman, $\text{YBa}_2\text{Cu}_3\text{O}_{7-\delta}$ [12], $\text{Bi}_2\text{Sr}_2\text{CaCu}_3\text{O}_{8+\delta}$ [12], $\text{La}_{2-x}\text{Sr}_x\text{CuO}_4$ [12], $\text{Tl}_2\text{Ba}_2\text{CuO}_6$ [12], $\text{Tl}_2\text{Ba}_2\text{Ca}_2\text{Cu}_2\text{O}_{10}$ [12] etc. conformed to d wave superconductors. In Fig. 1, it was the results of the experiment on the differentiation of photoelectron emission spectroscopy at an angle of $\text{Bi}_2\text{212}$ basically supported the high T_c superconductive d wave pairing theory [13].

Table 1 Some functional relations varying with temperature and energy of the leading items of important physical quantities of intrinsic d wave superconductors under the conditions of the low temperature ($T \ll \Delta_0$) or low energy ($\omega \ll \Delta_0$) (coefficients omitted).

Physical quantity	D wave superconductor
$2\Delta_0/T_c$	4.28
Energy gap $1 - \Delta(T)/\Delta_0$	T^3
State density $\rho(\omega)$	ω
Specific heat $C(T)$	T^2
penetration depth $\lambda(T)/\lambda(0) - 1$	T
spinning-crystal lattice relaxation rate T^{-1}	T^3
knight shift K	T
Raman scattering section	$\omega(A_{1g} \text{ or } B_2 \text{ model})$ $\omega^3(B_{1g} \text{ model})$

Fig. 1 The changing curves and full lines of were the theoretical results of the variations with the changes of frequency of $\text{Bi}_2\text{Sr}_2\text{CaCu}_3\text{O}_{8+\delta}$ superconductors' Raman scattering cross section d wave superconductors after putting Coulomb screening into consideration.

4. Conclusions

The characteristics of high T_c copper oxides Cooper pair by the theory of quantum chemical bonds, Sanderson's the principle of the balance of electronegativity and the mechanism of high T_c superconductivity and it was concluded that the electrons of the high T_c copper oxidized superconductor's Cooper pair originated from the non-bonded electrons which carried the elements of superconductivity.

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