The Origination of the Cooper Pair Electrons with Doping in High $T_c$ Copper Oxides

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Abstract: The origin of Cooper Pair electrons in copper oxide superconductors is the key to establish the superconductivity mechanism, which is also reasonable to explain the complication properties of normal states and superconductivity. The doping characteristics on copper oxide superconductors are used to analyse the origin of high copper oxides, the conclusion is that Cooper pair electrons of high $T_c$ copper oxides originate from the non-bonded electrons of bearing superconductivity elements.

Key words: High $T_c$, copper oxides; Cooper Pair electron origin; doping properties.

1. Introduction

In 1986, Bednorz and Müller discovered that La-Ba-Cu-O chemical compounds have high superconducting transition temperature, which originates from the insulator through chemical doping [1].

In 1987, Gough, C. E. et al. [2] conducted the study and concluded that the carriers in high $T_c$ copper oxide are combined in pairs to form the Cooper pairs. Two electrons in the carrier pairs still make self-spinning in the opposing direction, their respective momentum are equal in force, but in opposite direction (i.e., the frequency of Shapiro steps are 2 eV/h). Soon followed by so-called 123 oxides of the general formula LnBa2Cu3O7 (Ln = Y, Nd, Sm, Eu, Gd, Dy, Ho, Er, Tm, La, or Yb) with $T_c$ values in the 90 K region [3]. Subsequently, a series of copper oxide superconductors were discovered, which are Bi series, Sr series, Nd series, Tl series, Hg series. The highest $T_c$ values are 134 K, 164 K at high pressures [3]. These oxides had attracted attention because of the possibility of a wide range of applications and because the science is fascinating [4, 5]. A material that possess an electrical current with virtually no loss is more remarkable when this occurs at liquid-nitrogen temperature instead of liquid helium temperature, what is the origin of high $T_c$ superconducting Cooper electric pairs? We obtain the conclusion is that the Cooper Pair electrons originate from the non-bonded electrons of bearing superconductivity.

2. Method

In light of the characteristics of the high $T_c$ copper oxide superconductors’ superconductivity and properties of superconductors, the $\mu_B$ ($\mu_B$ is Coulomb’s interaction between the bonded electrons) of the crystal lattice stability is correlated with the bonded electrons to satisfy the condition of $\mu_B > \lambda_B$ ($\lambda_B$ is the coupling constant of the bonded electrons and phonons), while $\lambda_C$ ($\lambda_C$ is the coupling constant of formation Cooper pairs electrons and phonons) is correlated with non-bonded electrons to satisfy the condition of $\lambda_C > \mu_C$ ($\mu_C$ is Coulomb’s interaction between the Cooper pairs electrons) [6]. Due to the chemical bond formation of the elements in the high $T_c$ copper oxide superconductors, the N(O) (N(O) is a kind of the density of the Bloch of one spin per unity energy at the
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Fermi surface) and $V = V_{K_1}^{\text{ave}}$, the matrix element and $V_{KK'}$ can be replaced by a constant average matrix element, for pairs making transition in the region $-\hbar\omega < \varepsilon < \hbar\omega$ and by zero outside this region, where $\omega$ is the average phonon frequency) will have special change, and the electron media phonon can generate high $T_c$ superconductivity [6].

Since the Cu and O on the CuO$_2$ plane of the high $T_c$ copper oxide superconductors have obvious isotope effects and they are inter-correlated, the phonons of Cu and O on CuO$_2$ plane participate in the electrons phonons coupling [7].

Because of chemical bond formation of Cu and O on CuO$_2$ plane, the $f_{Cu} = f_{O}$ ($f_{Cu}$ is the force of the bonded electrons exerted with Cu element, while $f_{O}$ is the force of the bonded electrons exerted with O element) is obtained. The bonded electrons are not beneficial to the superconductivity. The coupling electrons of Cu and O on CuO$_2$ plane are the locality of non-bonded electrons [7].

3. Discussion

With the increase of the doping in high $T_c$ copper oxidant CuO$_2$ plane, the insulation-metal phase transition will occur and the in gap state generates simultaneously with the state density rising with the increasing $x$. This result is confirmed [8]. The in gap state differs from Fermi energy in energy band which moves with $x$, and in this an added density state occur with $x$ in gap areas of the insulation materials. Fermi energy happens to be in the middle of the density area and basically does not change position with $x$. From Fig. 1, we can see that $\zeta$ increases with $x$. $x$ is the source of the hole carriers, or the electrons removed and that the increase of $\zeta$ has no relation to bonded electrons. Within the $3.8/\sqrt{x}$ range, the doped cavity controls $\zeta$. If $x$ rises, the $\zeta$ length is controlled by nonbonded electrons.

After carefully measuring the width of neutron scattering spectra, we come up with the change of correlation length $\zeta$ with $x$. Fig. 1 sketches the dependency of the correlation length $\zeta$ on $x$. In insulation-metal transition area, the value is not quite far away from $3.8/(\sqrt{x})^{1/2}$, which indicates that the average distance of the holes doped in CuO$_2$ plane, which is the distance of doped element of Sr or Ba. When it is far away from the density and near to the metal or superconductor area, correlation length is greater than the above mentioned average distance as is shown by the dotted line in Fig. 1. The distance between solid line and dotted line widens with the increase of $x$. From Fig. 1, we can see that $\zeta$ increases with $x$. $x$ is the source of the hole carriers, or the electrons removed and that the increase of $\zeta$ has no relation to bonded electrons. Within the $3.8/\sqrt{x}$ range, the doped cavity controls $\zeta$. If $x$ rises, the $\zeta$ length is controlled by nonbonded electrons.

Fig. 1  Change of $La_{2-x}(Sr,Ba)_x CuO_4$ spin correlation length with $x$. Hollow part indicating the ideal computing value of $\zeta$ at semi-peak value within the widest range by corresponding magnetic rate, and the value of $\hbar \omega (1 \text{ meV})$ and $T \geq T_c$ are taken under the minimum energy. The solid line showing the average distance between Ba or Sr impurities.
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4. Conclusions

To solve the anomalies of coupling constant $A_{iso}$ in hyperfine structure [9], Mila and Rice proposed to build a mixed orbit across two adjacent Cu atom, that is $\text{Cu}d_{\sigma} \rightarrow \text{O}p_{\sigma} \rightarrow \text{Cu}S$, and in magnetic resonance experiments, the spin knight shift with temperature changes of Cu and O follows the pattern as is shown in Fig. 2. And it serves as a strong evidence of the Model [9].

In short, from the features of high $T_c$ Copper oxidant superconductor resulted from doping, we conclude that the non-bonded electrons of Cu and O elements on CuO$_2$ plane are crucial to superconductivity.

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