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Research Article

THEORETICAL DETERMINATION OF ELECTRONIC TRANSITION TEMPERATURE OF HIGH-T_c CUPRATE SUPERCONDUCTORS BASED ON POLARONIC MECHANISM, INTERLAYER AND INTRALAYER INTERACTIONS

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ABSTRACT
Developing the microscopic theory for high-T_c superconductors is one of the most challenging problems in condensed matter Physics. High-temperature superconductors such as cuprates (HTSCs) have unique physical properties in both the normal state and superconducting state. To comprehend the Physics of these complex compounds is one of the main tasks of the theory of High-T_c superconductivity. The most important task is to understand and predict the pairing mechanism between the charge carriers ensuring HTSC. At present there exists no mechanism which would explain the totality of thermodynamic, magnetic and superconductive properties of HTSCs from a single point of view. To explain HTSC a lot of models and mechanisms of this unique phenomenon have been proposed. The key question is the nature of the mechanism of pairing of charge carriers. In order to comprehend the nature of the superconducting state, it is necessary to construct a consistent microscopic theory which should be able to describe Superconductive and normal properties of HTSCs. It is therefore proposed that the pairing mechanism in Cuprate Superconductors can be understood on the basis of the Polaronic model of charge carriers coupled with interlayer and intralayer interactions. The model Hamiltonian, H for the system is formulated for two-layer superconductor and diagonalized using Bogoliubov canonical transformations. The diagonalized Hamiltonian gives $H_{diagonal}$ whose Eigen value is represented by E_i, the quasi-particle energy of a state i. The value of E_i depends on t, U and W. For t=0.015eV, W=-1.117eV and U=0.048eV, E_i=0.0153eV. For t=0.025eV, W=-1.177eV and U=0.061eV, E_i=0.0147eV. These values of E_i were used to calculate the transition temperature of Yttrium Barium Copper Oxide (YBCO) which is considered in this study.

Keywords*: Transition temperature, entropy, canonical transformations, Polaronic mechanism, interlayer and intralayer interactions*

INTRODUCTION
Superconductivity is the vanishing of the electrical resistance occurring in certain materials below a characteristic temperature called critical (transition) temperature, T_c. It was discovered by H. Kamerlingh in 1911 at Leiden, Holland. He found that when the temperature of pure frozen mercury was reduced below 4.2K, its electrical resistance disappeared resulting in the flow of electrical current of the order 10^5 amperes. A number of pure metals, alloys and doped semiconductors were found to have this property. The superconductivity exhibited by metals, alloys and doped semiconductors is called conventional (low temperature) superconductivity. The electrical resistivity of a metallic conductor decreases gradually as the temperature is lowered. However, in ordinary conductors such as copper and silver, this decrease is limited by impurities and other defects. Even near absolute zero, a real sample of copper shows some resistance. The properties exhibited by conventional superconductors are well explained by the BCS theory (Bardeen *et al.,* 1957). The BCS theory envisages an attractive interaction between electrons mediated by phonons resulting in the formation of cooper pairs.

Research Article

High-temperature superconductors ($HTSC_s$ or High-T_c) are materials that have a superconducting transition (T_c) above 30K (-243.2 ^{0}C). In 1986 Bednorz and Muller discovered superconductivity in a lanthanum- based cuprate which had a transition temperature of 35K. (Bednorz,1986, & Muller, 1986.). It was later found by Chu and Wu that replacing the Lanthanum with yttrium making YBCO, raised the critical temperature to 92K which was important because liquid nitrogen could then be used as a refrigerant since its boiling point is 77K at atmospheric pressure. (Chu *et al.*, 1988). The discovery of possible high –T_c superconductivity in Lanthanum – Barium – Copper-Oxide (La- Ba –Cu-O, T_c =30K) system (Bednorz et al.,1986) was important and decisive breakthrough in the high- T_c superconductivity research. The great success with La-Ba-Cu-O and La-Sr-Cu-O compounds, led to the discovery of multilayered compounds whose transition temperatures were more than 90K. After the discovery of high-temperature superconductivity in cuprate perovskites (Bednorz *et al.*, 1986) the record T_c of 164 K was held by $HgBa_2Ca_{m-1}Cu_mO_{2m+2+\delta}$ with m = 3 and at high pressure (Gao *et al.*, 1994). In 2015 Eremets and his collaborators succeeded in observing superconductivity in sulfur hydride with a very high T_C of 203 K at an ultrahigh pressure of 150 GPa (Eremets, 2015) which has been confirmed experimentally by several groups (Einaga *et al.*, 2016, Goncharov, 2017) and it is the object of high theoretical interest (Gor'kov *et al.*, 2016, Gordon, 2016, Bianconi *et al.*, 2015). The cuprate superconductors are technologically important since the transition temperature is high.

Superconductivity in cuprate superconductors seems to be controlled by the number of charge carriers (electrons and holes) in these layers through the oxidation states of the copper atoms (Dagotto, 1994). Moreover the transition temperature increases with the number of CuO_2 layers in a unit cell upto three layers. The transition temperature T_c does not increase if the number of layers is more than three, thereafter it saturates. Studies reveal that interlayer and intralayer interactions play an important role in the increase of the superconducting transition temperature, T_c and in stabilizing superconducting order with respect to fluctuations. (Khandka 2006; Singh, 2006). Hence the increase in T_c due to the increase in the number of layers in cuprates clearly emphasizes that layered structure of the cuprate compounds is crucial to high-T_c superconductors.

After two decades of enormous experimental and theoretical efforts, there is still little consensus on the pairing mechanism of high temperature superconductivity (HTSC or High-T_c) in cuprates. (Kruchinin *et al.*, 2011). High temperature superconductors have unique physical properties in both normal state and superconducting state. To comprehend the physics of these complex compounds is one of the main tasks of the theory of superconductivity, whose solution may allow one to explain the pairing mechanism ensuring HTSC. At present there exists no mechanism which would explain the totality of thermodynamical, magnetic and superconductive properties of HTSCs from a single point of view. (Askerzade *et al.*, 2012). The electron–phonon pairing mechanism (Bardeen *et al.*, 1957) being the principal one in low temperature superconductors, makes considerable contribution to the establishment of the superconducting state in HTCSs. But in order to obtain proper description, it is necessary to consider the other mechanism inherent in HTCSs (Plakida, 2010). Since Cuprate superconductors have layered structure, studies have revealed that the interlayer and intralayer interactions play a significant role in enhancing transition temperature in layered cuprates. The discovery of high-T_c cuprates superconductors and their properties which are quite different from the conventional BCS type superconductors has led to enormous theoretical research to look for the kind of electron pairing mechanisms that may exist in these superconductors. (Kakani , 2007; Anderson, 1997). In the recent past several electron pairing mechanisms have been proposed which are different from the type of electron pairing mechanism used in BCS theory.Some of the electron pairing mechanisms are known as resonance valence bond state, bipolarons, excitons, Plasmons, fermion-boson, charge transfer electron pairing mechanism and exotic pairing (pairing between electrons without the exchange of phonons (Khanna, 2008). Some recent theoretical models postulate the mechanism of antiferromagnetic spin fluctuations so that the electron scattering on them can be the reason for the pairing of electrons.

The presence of square planer Cu-O layer in the high-T_c cuprates clearly establishes the importance of interlayer interaction of charge carriers. In a bilayer or multilayer cuprates the separation between adjacent CuO_2 planes within the unit cell is smaller than the adjacent layers in a single layer system; therefore, it is natural to include interlayer interactions in multilayer cuprates. The Coulomb interaction between a conduction electron and the lattice ions results in a strong electron-phonon coupling. Even with no real phonons present, the electron is always surrounded by a cloud of virtual phonons. The cloud of virtual phonons corresponds physically to the electron pulling nearby positive ions towards it and pushing nearby ions away. The electron and its virtual phonon taken together can be treated as a new composite particle called polaron. The idea of polaron is based on the assumption about the auto-localization of an electron in the ion crystal due to its interaction with the longitudinal optical vibrations under the local polarization which is caused by the electron itself. The electron is confined to the local-polarization induced potential well and conserves it by its own field. Therefore, while considering the polaronic mechanism in high-T_c cuprates, the interlayer and intralayer interactions is indispensable. The theory of polaronic mechanism, interlayer and intralayer interactions of high-T_c cuprate superconductors developed in this study was used to study the thermodynamic properties such as transition temperature of a two-layer high-T_c cuprate. The model Hamiltonian for such a system has been written, and then diagonalized using Bogoliubov transformation to obtain the equation for the transition temperature of these multilayer high-T_c cuprates. The values obtained and the nature of graphs drawn is used for comparison with the experimental results available to determine the validity of this theory.

Theoretical formulation

To explain high-temperature superconductivity a large number of different theories have been proposed from time to time to explain the properties of different types of superconductors, especially the high-T_c superconductors. It turns out that each superconductor has its own characteristics manifested via its superconducting order parameters. What is common among all superconductors is the stream of electron pairs carrying superconducting current. What is not known exactly are the types of electron-electron interactions in a superconductor. In this study a multilayer superconductor is considered assuming the existence of some physically acceptable interactions. To formulate a theory for the high-T_c superconductors, the principle of the existence of strong correlations between the electrons that contribute to the superconducting current has been used. Thus the model Hamiltonian H for a multilayer system of cuprates is written as,

$$H = H_e + H_{ph} + H_{e-ph} + H_{ee} + H_{intra} + H_{inter} \quad (1)$$

Where H_e the kinetic energy of the electrons, H_{ph} is the energy of phonons, H_{e-ph} is the electron-phonon interaction (electron-phonon Hamiltonian), H_{ee} is the Coulomb interaction. H_{intra} is the intralayer electron pairing part of the Hamiltonian and H_{inter} is the interlayer electron pairing part of the Hamiltonian.

In one band approximation H_e has the form

$$H_e = \sum_{k\sigma} E_k a^+_{k\sigma} a_{k\sigma} \quad (2)$$

where k and σ denote the wave vector and spin, respectively. E_k is the bare band energy, $a^+_{k\sigma}$ is the creation operator, it creates an electron with momentum k and spin σ and $a_{k\sigma}$ is the destruction operator.

H_{ph} can be expressed in terms of phonon operators $d(q): q = (q, v)$ where v is the type of vibrational mode and q is the wave vector

$$H_{ph} = \sum_{q} \omega(q) d_q^{+} d_q \tag{3}$$

The electron-phonon interaction is described by the Froehlich Hamiltonian as

$$H_{e-ph} = \sum_{k,q,\sigma} \left\{ \omega(q)\gamma(q) \frac{1}{\sqrt{2N}} a_{k+q,\sigma}^{+} a_k d_q + H.C \right\} \tag{4}$$

where $\omega(q)$ and $\gamma(q)$ are the phonon frequency and interaction matrix element in a parent crystal without charge carriers respectively, N is the number of unit cells per volume is and $H.C$ is the Hermitian conjugate

H_{ee} is the electron-electron Hamiltonian (Coulomb electron-electron correlations) denoted by U.

H_{intra} can be written as

$$H_{intra} = \sum_{r,k,\sigma} \varepsilon_k a_{r,k,\sigma}^{+} a_{r,k,\sigma} + U \sum_{r,k,k'\sigma} a_{r,k+q\uparrow}^{+} a_{r,k'-q\downarrow}^{+} a_{r,k'\downarrow} a_{r,k\uparrow} \tag{5}$$

The first term in equation 5 is the kinetic energy of the electrons. The second term describes the destruction of a cooper (two electrons with opposite momentum and spin) and the subsequent creation of another cooper pair.

H_{inter} Can written as

$$H_{inter} = (-t) \sum_{r,s,k,\sigma} a_{r,k,\sigma}^{+} a_{s,k,\sigma} + W \sum_{r,s,k,k',\sigma,\sigma' q} a_{r,k+q,\sigma}^{+} a_{s,k'-q,\sigma}^{+} a_{s,k',\sigma'} a_{r,k,\sigma} \tag{6}$$

Here r = 1 (2) and s = 2 (1) are the layer indices for a two-layer system such that when the layer r is denoted by 1, the layer s is denoted by 2 and vice versa. $a_{k\sigma}^{+}$ is the creation operator, and $a_{k\sigma}$ is the annihilation operator of charge carriers in CuO_2 plane with the wave vector 'k' and spin 'σ′. U is a measure of such interactions (on-site repulsion), t is the interlayer hopping and the second term represents attractive interlayer interaction 'W' and it contains the contributions from exciton or Plasmon mediated interaction and direct Coulomb interaction between charge carriers of different layers. Here W is negative (attractive nature) and for the repulsive case U > 0, the hopping integral t is taken to be positive (Zhang W. et. al 1992)

The Hamiltonian in equation 1 can now be written as

$$\begin{aligned} H = & \sum_{k\sigma} E_k a_{k\sigma}^{+} a_{k\sigma} + \sum_{q} \omega(q) d_q^{+} d_q + \sum_{k,q,\sigma} \left\{ \omega(q)\gamma(q) \frac{1}{\sqrt{2N}} a_{k+q,\sigma}^{+} a_k d_q + H.C \right\} + U \\ & + \sum_{r,k,\sigma} \varepsilon_k a_{r,k,\sigma}^{+} a_{r,k,\sigma} + U \sum_{r,k,k'\sigma} a_{r,k+q\uparrow}^{+} a_{r,k'-q\downarrow}^{+} a_{r,k'\downarrow} a_{r,k\uparrow} \\ & + (-t) \sum_{r,s,k,\sigma} a_{r,k,\sigma}^{+} a_{s,k,\sigma} + W \sum_{r,s,k,k',\sigma,\sigma' q} a_{r,k+q,\sigma}^{+} a_{s,k'-q,\sigma'}^{+} a_{s,k',\sigma'} a_{r,k,\sigma} \end{aligned} \tag{7}$$

The model Hamiltonian H for a multilayer system of cuprate superconductors in equation 7 is diagonalized using Bogoliubov canonical transformations (Bogoliubov, 1958 & Valatin, 1958) so as to study the specific heat, such a multilayer cuprate.

For fermions the new operators $\gamma_k^{'s}$ can be expressed in terms of the old operators $a_k^{'s}$ as

$$\left.\begin{aligned}\gamma_{\mathrm{k}} &= u_k a_k - v_k a_{-k}^{+} \\ \gamma_{-k} &= u_k a_{-k} + v_k a_k^{+}\end{aligned}\right\} \tag{8}$$

u_k and v_k are the Bogoliubov coherence factors where $u_k^2 = \frac{1}{2}\left(1+\frac{\varepsilon_k}{E_k}\right)$ and $v_k^2 = \frac{1}{2}\left(1-\frac{\varepsilon_k}{E_k}\right)$ such that $u_k^2 + v_k^2 = 1$ for Fermions (electrons) For Bosons (phonons) the new operators $c_q{}^{,s}$ can be expressed in terms of the old operators $d_q{}^{,s}$ as

$$\left.\begin{aligned}\mathrm{c_q} &= u_q d_q - v_q d_{-q}^{+} \\ c_{-q} &= u_q d_{-q} - v_q d_q^{+}\end{aligned}\right\} \tag{9}$$

such that $u_q^2 - v_q^2 = 1$ for bosons (phonons)

The diagonalized form of the Hamiltonian in equation 7 is given by

$$\begin{aligned}&\sum_q \omega(q) v_q^2 = \sum_k \varepsilon_k v_k^2 + \sum_{k,q,\sigma} \omega(q)\gamma(q) \frac{1}{\sqrt{2N}} \left(\frac{m\omega}{2\eta}\right)^{\frac{1}{2}} \frac{\pi}{a}\left[v_k^2 u_q + v_k^2 v_q\right] \\ &+ U + \sum_k \varepsilon_k v_k^2 + U\sum_k u_k^2 v_k^2 - t\sum_k v_k^2 + W\sum_k u_k^2 v_k^2 \\ &= H_{diagonal} = E_i\end{aligned} \tag{10}$$

E_i is the quasi-particle energy of state i after diagonalization. The temperature dependence of the energy E_i will be introduced through the thermal activation factor $e^{-E_i/k_B T}$. The system energy E_i will be multiplied by $e^{-E_i/k_B T}$ such that the temperature dependent energy of the system becomes

$$E = E_i e^{-E_i/k_B T} \tag{11}$$

RESULTS AND DISCUSSION

From Bogoliubov coherence factors where $u_k^2 = \frac{1}{2}\left(1+\frac{\varepsilon_k}{E_k}\right)$ and $v_k^2 = \frac{1}{2}\left(1-\frac{\varepsilon_k}{E_k}\right)$ such that $u_k^2 + v_k^2 = 1$ for Fermions (electrons), when $\varepsilon_k = E_k$, then $u_k^2 = \frac{1}{2}$ and $v_k^2 = \frac{1}{2}$, hence $u_k = v_k = \frac{1}{\sqrt{2}}$. For phonons $\left|u_q^2 - v_q^2\right| = 1$, then it implies that when $u_q = 0$ then $v_q = 1$, and when $v_q = 0$, $u_q = 1$. For high-T_c cuprates, experimental data suggests that the Fermi energy, ε_f ranges between $\varepsilon_f = 0.1eV - 0.3eV$. For YBCO, $\varepsilon_f = 0.23eV$ (Kakani *et al.*, 2013). The choice of YBCO is due to the excellent experimental heat capacity data being available. The results obtained will then be generalized to other cuprates with the same properties as YBCO. These data will give a good comparison with the results of this study. Taking the numerical values of the constants as;

$$\varepsilon_f = \varepsilon_k = 0.23eV, v_k = \frac{1}{\sqrt{2}}, u_k = \frac{1}{\sqrt{2}}, a = 3.8228\times10^{-10}\,m, N = 1, \omega = 5\times10^{-7}\,eV,$$

$$W -1.117eV, -1.177eV, t = 0.015eV, 0.025eV, u_q = v_q = 0 or 1$$

$$\eta = 6.58\times10^{-16}\,eV.s, \gamma(q) = 4, m = 9.1\times10^{-31}\,kg,$$

Then the value of E_i from equation 11 can be written as

$$E_i = \varepsilon_k v_k^2 + \omega(q)v_q^2 + \omega(q)\gamma(q)\frac{1}{\sqrt{2N}}\left(\frac{m\omega}{2\eta}\right)^{\frac{1}{2}}\frac{\pi}{a}\left[v_k^2 u_q + v_k^2 v_q\right] + U\left(u_k^2 v_k^2\right) + \varepsilon_k v_k^2 +$$

$$U + U\left(u_k^2 v_k^2\right) - t v_k^2 + W\left(u_k^2 v_k^2\right)$$

$$E_i = 0.115 + 5\times10^{-7} + 2.162\times10^{-7}\left(v_k^2 u_q + v_k^2 v_q\right) + 0.25U + 0.115 + U + 0.25U - 0.5t + 0.25W$$

$$E_i = 0.230000716 + 1.5U - 0.5t + 0.25W \tag{12}$$

The total energy of the system becomes

$$E = E_i e^{-E_i/k_B T} \tag{13}$$

The transition temperature T_c of the system is obtained from the condition that

$$\left(\frac{\partial C_s}{\partial T}\right)_{T=T_c} = 0$$

The energy expression in equation 13 will be used to calculate the specific heat and transition temperature T_c of the high-T_c cuprates.

The specific heat C_v is given by:

$$C_v = \left(\frac{\partial E}{\partial T}\right)$$

and hence the electronic specific heat capacity in the superconducting state is given by,

$$C_{eS} = \frac{E_i^{\,2}}{k_B T^2} e^{-E_i/k_B T} \tag{14}$$

The transition temperature T_c of the system is obtained from the condition that

$$\left(\frac{\partial C_{eS}}{\partial T}\right)_{T=T_c} = 0$$

$$\frac{\partial}{\partial T}\left(\frac{E_i^{\,2}}{k_B T^2} e^{-E_i/k_B T}\right) = 0$$

$$\frac{E_i^{\,3}}{k_B{}^2 T_c^{\,4}} e^{-E_i/k_B T} - \frac{2E_i^{\,2}}{k_B T_c^{\,3}} e^{-E_i/k_B T} = 0$$

$$\left(\frac{E_i^{\,3}}{k_B{}^2 T_c^{\,4}}\right) e^{-E_i/k_B T} = \left(\frac{2E_i^{\,2}}{k_B T_c^{\,3}}\right) e^{-E_i/k_B T}$$

$$\frac{E_i}{k_B T_c} = 2$$

Or

$$T_c = \frac{E_i}{2k_B} \quad (15)$$

Equation 15 shows that T_c depends on the value of the quasi-particle energy E_i that depends on the values of the different parameters of the proposed interactions between the electrons that are responsible for the superconducting current. By varying the values of the parameters U, t and W we get different values of T_c. Such variations will indicate how to increase the value of T_c. The values of critical temperature T_c corresponding to the values of E_i are calculated from equation 15. When t=0.015 eV, W=-1.117 eV the values of E_i and T_c are calculated for the values of U in the range $0.041eV \leq U \leq 0.050eV$ shown in table 1. The choice of the values of U is such that $E_i > 0$. This will give physically acceptable values. In this case for Ei > 0, then U > 0.038eV.

Table 1: Transition temperature, Energy of state and Coulomb repulsion for t=0.015eV and W=-1.117eV

U(eV)	0.041	0.042	0.043	0.044	0.045	0.046	0.047	0.048	0.049	0.050
E_i(eV)	0.0048	0.0063	0.0078	0.0093	0.0108	0.0123	0.0138	0.0153	0.0168	0.0183
T_c(K)	27.39	36.03	44.67	53.31	61.95	70.59	79.23	87.87	96.51	105.16

From table 1, the variation of transition temperature T_c with U for t=0.015eV, W=-1.117eV is shown figure 1 below

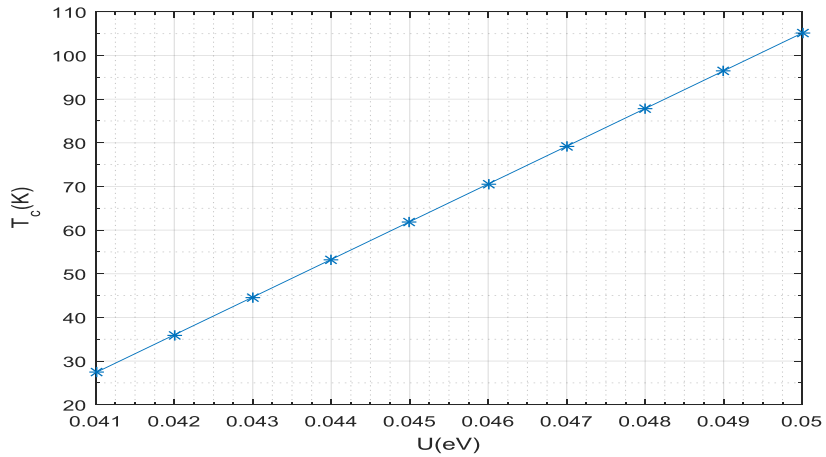

Figure 1: Variation of transition temperature T_c with U for t=0.015eV, W=- 1.117eV

Figure 5.1 shows a linear dependence of transition temperature on U. For T_c =90K, the transition temperature of YBCO, the cuprate considered in this study, U=0.04825eV. The variation of transition temperature T_c with E_i for t= 0.015eV, W= -1.117eV is shown figure 2

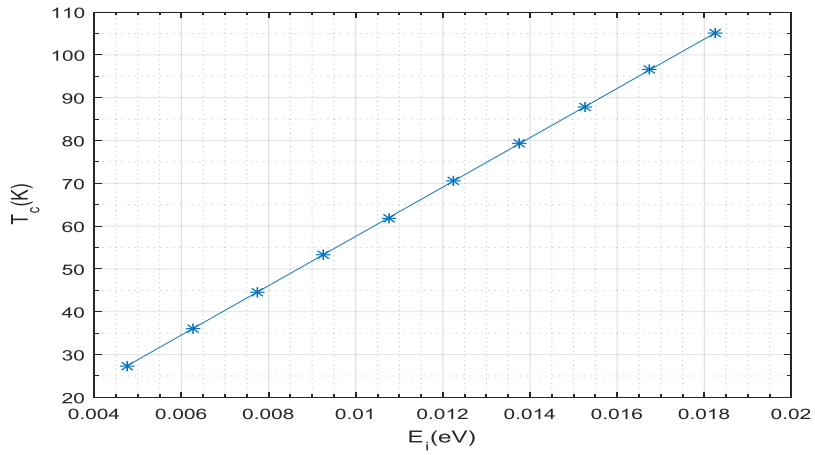

Figure 2: Variation of transition temperature T_c with E_i for t=0.015eV, W= -1.117eV

From figure 1 and 2 respectively, the value of U ≈ 0.04825eV and E_i ≈ 0.01525eV gives the value of transition temperature as 90K.

When t=0.025 eV, W= -1.177 eV the values of E_i and T_c are calculated for the values of U shown in table 2. In this case for $E_i > 0$, then U > 0.051eV.

Table 2: Transition temperature, Energy of state and Coulomb repulsion for t=0.025eV and W= -1.177eV

U(eV)	0.054	0.055	0.056	0.057	0.058	0.059	0.060	0.061	0.062	0.063
E_i(eV)	0.0043	0.0058	0.0073	0.0088	0.0102	0.0117	0.0132	0.0147	0.0163	0.0178
T_c(K)	24.48	33.12	41.76	50.40	59.04	67.68	76.32	84.96	93.61	102.24

The variation of T_c with E_i for t=0.025eV and W= -1.177eV is shown in figure 3

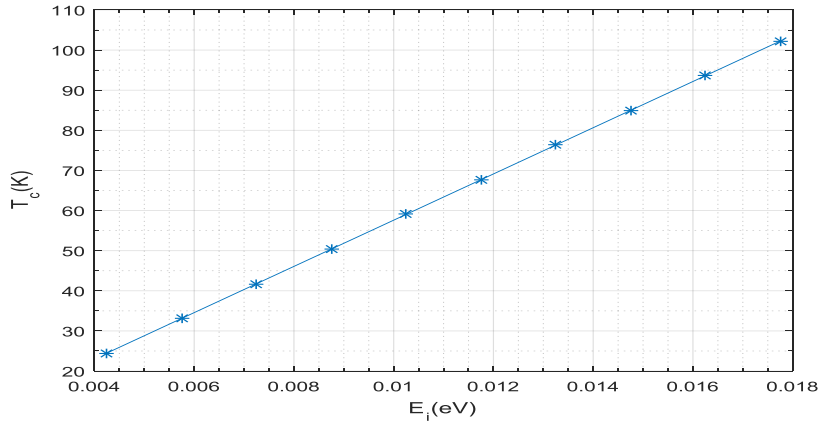

Figure 3: Variation of transition temperature T_c with E_i for t=0.025eV, W= -1.177eV

Figure 3 also shows a linear dependence of transition temperature with the Coulomb on-site repulsion U for t=0.025eV and W= -1.177eV.

The electronic specific heat capacity in the superconducting state, C_{eS} is calculated from equation 15 in the temperature domain 10K ≤ T ≤ 300K for the values of E_i = 0.0063eV, 0.0108eV, 0.0153eV and

0.0183eV from table 1. Using these values of E_i in equation 14, the electronic specific heat capacity, C_{eS} of YBCO is calculated for the temperature range $10K \leq T \leq 300K$.
The variation of electronic specific heat capacity, C_{eS} with temperature is shown in figure 4

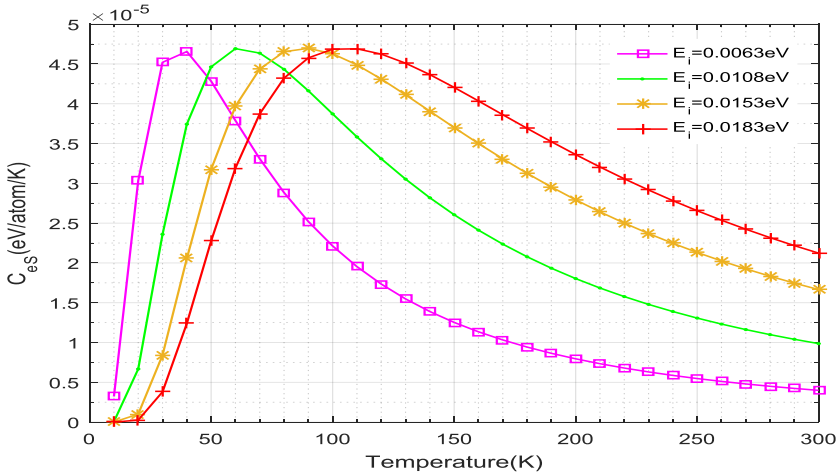

Figure 4: Variation of electronic specific heat capacity, C_{eS} with temperature for t=0.015eV, W=-1.117eV

From figure 4, for $T < T_c$, the graph increases exponentially with temperature. The shape of heat capacity graph for superconducting phase C_{eS} indicate specific heat jump at $T=T_c$ typical of superconducting state. From figure 4, the transition temperatures for E_i = 0.0063eV, 0.0108eV, 0.0153eV and 0.0183eV are 40K, 60K, 90K and 100K respectively. The calculated values of transition temperatures from equation 15 for these values of E_i are 36.3K, 62.2K, 88K and 105K respectively. These compares well with the values estimated from the graph in figure 4. Hence be seen transition temperature increases as the value of quasi particle energy E_i increases. For YBCO cuprate considered in this study, T_c = 90K when E_i = 0.0153eV. This value of E_i is obtained from equation 1 when t=0.015eV, U= 0.048eV and W= -1.177eV.

CONCLUSION

The idea of polaron is based on the assumption about the auto-localization of an electron in the ion crystal due to its interaction with the longitudinal optical vibrations under the local polarization which is caused by the electron itself. The electron is confined to the local-polarization induced potential well and conserves it by its own field. Therefore, while considering the polaronic mechanism in high-T_c cuprates, the interlayer and intralayer interactions is indispensable. The theory of polaronic mechanism, interlayer and intralayer interactions of high-T_c cuprate superconductors developed in this study was used to study the variation of transition temperature with parameters U, t and W. The variation is depicted in figures 5.4 and 5.5 for t=0.015eV, W= -1.117eV and t=0.025eV, W= -1.177eV respectively. This is in agreement with the experimental value. It also indicates interlayer and intralayer interactions play a crucial in stabilizing superconducting transition temperature. It has been brought out in this study that the strong electron correlations between the electrons in the intralayer and interlayer can lead to the microscopic theory of superconductivity pairing. The value of E_i=0.0153eV used for YBCO gave results which compare well with experimental results. The results obtained in this study can be applied to other multilayer cuprates with the same properties as YBCO. A superconductor may be synthesized with different values of U, t and W. These values may be varied so as to get E_i which gives, $T_c \approx 300K$, hence a room temperature superconductor will be obtained. The current theoretical and experimental research is

focused in obtaining a superconductor which is can work at room temperature. (Eremets, 2015; Einaga, 2016 & Goncharov, 2017).

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