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RELATIVE STUDY BETWEEN SUPERCONDUCTING PARAMETERS AND NORMAL STATE RESISTIVITY OF ELECTRON DOPED AND HOLE DOPED CUPRATE SUPERCONDUCTOR

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ABSTRACT

In present paper author is trying to provide the relative analysis of hole doped and electron doped cuprate super conductor. The approach developed is then tested to estimate the physical properties. Using the proposed formulation derived on the basis of free electrons in the conducting layer with various interactions, the normal state and superconducting parameters will be estimated. Nevertheless, these parameters will be of immense use to look for the physical properties of electron doped superconductors. The developed approach will used to estimate the normal state transport properties as resistivity, specific heat and superconducting state properties as critical transition temperature, oxygen isotope effect, energy gap parameter and other associated parameters of the electron doped superconductors for the maximum doping concentration. Furthermore, we will try to explain the full composition range for the physical properties.

Key Words : *Electron Doped Cuparate, Superconductors, Resistivity*.

I. INTRODUCTION

The normal as well as superconducting properties of high $T_c$cuprates with various stacked-layer sequence offer a great challenge for theoretical explanation. The occurrence of superconductivity in the $Ln_{2-x}Ce_xCuO_{4-y}$ (Ln = Nd, Pr and Sm) family gives a new prospect for understanding the attractive force as the valence of the Ce dopant suggest the superconducting carriers electron rather than holes[Tokura et al 89 &Hidika& Suzuki 89]. Further interest arises from the fact that $Ln_{2-x}Ce_xCuO_4$ systems have a different crystallographic structure, the so- called T' phase and is characterized by the absence of apical oxygen between the adjacent CuO_2 layers, thus, co-ordination of Cu atoms in layers is four instead of five, as in $Nd_{2-x}Ce_xSr_2CuO_4$ (T' phase), or six, as in $La_{2-x}Sr_xCuO_4$ (T' phase).

The fundamental structural unit is CuO_2 layers, in which charge carriers are responsible for superconductivity are localized, and are identical in all cases. Nd-Ce-CuO has the tetragonal Nd_2CuO_4 structure in which lines of oxygen atoms along the c- axis perpendicular to the CuO_2 planes are formed. Parent Nd_2CuO_4 compounds have the space group I4/mmm with lattice parameters a≈ 3.94 Å and c ≈ 12.16 Å [Muller-Buschbaum&Wollschlager 75]. The parent compound $Nd_2CuO_{4-\delta}$ produces an orthorhombic distorted structure. Chemical substitution of tetravalent Ce in the trivalent Nd lattice introduces the mobile electrons and the T' phase that is $Nd_{2-x}Ce_xCuO_4$posses lattice parameters a≈ 3.96 Å and c ≈ 12.1 Å.

Bulk superconductivity in $Nd_{2-x}Ce_xCuO_{4-\delta}$occurs around x= 0.15 (in the range $0.14 \leq x \geq 0.18$) and small changes in oxygen stoichiometry ($\delta \approx 0.02$) have a dramatic effect on electrical transport properties for example, $Nd_{1.85}Ce_{0.15}CuO_{4-\delta}$, δ = 0.02 is a superconductor with $T_c \approx 25$ K and $Nd_{1.85}Ce_{0.15}CuO_{4-\delta}$, δ = 0.0 shows semiconductor characteristics [Tokura et al 89, Hidika& Suzuki 89, Strobel et al 90].

II. NORMAL STATE RESISTIVITY OF ELECTRON DOPED CUPRATES

The normal as well as superconducting state properties of high $T_c$cuprates with various stacked-layer sequences offer a great challenge for theoretical explanation. As many of normal state transport properties of layered high $T_c$cuprates (electrical resistivity, thermal conductivity, optical conductivity etc.) are differed with those observed in typical metals. i.e. are unusual for a Fermi liquid. In most of the high $T_c$cuprates, the in-plane resistivity, $\rho_{ab,}$ decreases

linearly with decreasing temperature over a wide temperature range, while the out of plane resistivity, ρ_c , increases rapidly at low temperatures indicating the semiconducting nature[Iye 91].

Our aim to study the in-plane resistivity behavior of hole doped cuparate superconductors due to two fold reasons: A tremendous amount of work has been carried out in under doped and over doped single crystals. It is apparent from these studies that in $La_{1.85}Sr_{0.15}CuO_4$ superconductor, ρ_{ab} is proportional to temperature for (x≈ 0.15), where asρ_c is non-metallic in over- and under-doped materials [Ito et al 91]. A crossover [Nakamura & Uchida 93] from 2-D transport to anisotropic 3-D transport occurs at compositions (over-doped) near the disappearance of bulk superconductivity.

Secondly, the La- based cupratespossess a relatively simple electronic structure with single conducting CuO_2 layer well separated from LaO reservoirs in comparison to that in Y-Ba-CuO systems, the presence of one dimensional CuO chain makes the structure little complicated. The behavior of in-plane resistivity in over and under- doped systems is also a significant problem which we do not discuss in this work.

III. RESULT AND DISCUSSION

The realistic values of some physical parameters based on experimental data are used to compute the superconducting transition temperature of $Nd_{1.85}Ce_{0.15}CuO_4$ superconductors. For a layered stacking sequence well separated by an average spacing (d=c/2), the effective mass of the electron along the CuO_2 plane is obtained from the electronic specific heat coefficient γ, using the relation m*= $\frac{3\hbar^2\gamma d}{\pi K_B^2}$. Takinginterplanar separation d=6A^o and γ=53 mJmol^{-1} K^{-2} from the specific heat measurement [Marcenat et al 93], m*≅ 41m$_e$ is obtained. The mass of a unit cell (M) for one CuO_2 layer is 12.77 amu. The background dielectric constant $\epsilon_\infty$is taken as 3.5. We have obtained the 2D charge carrier density n$_c$≅ 2.8 ×10^{14} cm^{-2} and ionic density as n$_i$≅ 6.2 ×10^{14} cm^{-2} from the lattice parameters. With the above values of input parameters, the upper and lower mode frequencies $\hbar\Omega_+$and$\hbar\Omega_-$ are deduced as 0.73 eV and 11.34 meV respectively which is consistent with the optical reflectance spectroscopy [Zhang et al 91]. The other parameters of the electrons are the Fermi velocity V$_F$≅1.4 ×10^7 cms^{-1} and the Fermi energy E$_F$≅0.21 eV.

In the present work, we have emphasized on the screened phonon contribution for the description of normal state in-plane resistivity of optimized doped La-Sr-CuO superconductors. For this purpose, realistic values of some physical parameters are derived from experimental data as follows. For a layered stacking sequence well separated by an average spacing, d(=c/2), the effective mass of the carriers along the conducting CuO_2 plane is obtained from the electronic specific heat coefficient γ , using the relation m*= $\frac{3\hbar\gamma d}{\pi K_B^2}$. Takinginterplanar separation d=6.6A^o and γ=6.6 mJmol^{-1} K^{-2} from the specific heat measurement, m*≅4m$_e$ is obtained.

IV. CONCLUSION

The behavior of the multi-layer systems critically depends only on the planar electron density and the spacings between the layers, and not on the form of single particle distribution function, the layer thickness or the number of layers.For a stack of 2D conducting planes well separated by an average spacing d, the condition for optimized pairing [Varshney et al 2000] infers the 2D electronic charge carrier density and follows $n_c d^2 = 1$ to obtain n$_c$≅ 2.3 ×10^{14} cm^{-2} . The other parameters of the electrons are the Fermi velocity V$_F$≅1.1 ×10^7 cms^{-1} and the screened plasma frequency is about 0.81 eV.

In conclusion, the large magnitude of resistivity at room temperature as well as the temperature dependence of optimized La- based cuprates is well understood with low frequency screened phonon mechanism as arises from inter-layer interactions in the frame work of Fermi liquid description. The present model can easily be extended to the other members of the family of cuprates superconductors having a large number of CuO_2 layers. Multiple layers can be incorporated in the effective interaction potential and one may expect additional excitation branches

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