© 2019 IJSRST | Volume 6 | Issue 3 | Print ISSN: 2395-6011 | Online ISSN: 2395-602X
Themed Section: Science and Technology
DOI : https://doi.org/10.32628/IJSRST

An Evaluation of Thermal Conductivity of High-Temperature Super Conductors

Dr. Lav Kumar
PGT Department of Physics, S.R.P.S Govt.+2 School Road No. 16,
Gardnibagh Patna, Bihar, India

ABSTRACT

The paper presents a method of evaluation of thermal conductivity of high T_c superconductivity as a function of temperatures. The high Tc superconductors are La_{2-x} Sr_xCuo_4 of difference volumes of x (as x=0.15, T_c=38k and x=0.20, T_c =30k) and $YBa_2Cu_3O_{7-s}$ (T_c =92k) we have compared our theoretical results with that of Graebner[20] and Morelli[21]. Our theoretically evaluated results are in good influent with these workers. Our theoretical results indicate that thermal conductivities of the above superconductors increases with temperature. As it was pointed out by Uher et al[22] that phonons contribute close to 90% of the thermal conductivity in $YBa_2Cu_5O_{7-8}$ at T_c. Given the relatively large magnitude of T_c for $YBa_2Cu_3O7_{-\delta}$ (Tc/θ debye[2]0.25). It is possible that the transition occurs in a region were the thermal conductivity's is limited mainly by phonon- phonon and carriers-phonon scattering. The enhancement of the thermal conductivity above the normal state conductivity for T<Tc in $YBa_2Cu_5O7_{-\delta}$ in consistent with this interpretation. It indicates that the phonons make a major contribution to the thermal conductivity and that carrier phonon scattering is important in limiting the phonon contribution to the thermal conductivity at T_c. On the other hand the data for $La_{2-x}Sr_nCuO_4$ are less conclusive. Although phonon makes major contribution to the thermal conductivity at T_c, no clear enhancement is observed as for $YBa_2Cu_3O7_{-\delta}$ only a slight change in shape is noticeable at T_c. An outstanding of the scattering mechanisms which lead to the low magnitude of the thermal conductivity for $LaCuO_4$ will be important for explains[24,25] the magnitude and temperature behaviour of the thermal conductivity of $La_{2-x}Sr_xCuO_4$.

Keywords :- Thermal conductivity, High T_c Superconductor, Scattering mechanism, Phonon-Phoron scattering, Phonon defect.

I. INTRODUCTION

The scattering mechanisms involved in heat transport may be investigated through thermal conductivity measurements. In particular, measurements on high temperature superconductor $YBa_2Cu_30_{7-5}$ and Laj 85Sr015Cu04 provide information on the scattering of photons by electrons for T ~ Tc. Low temperature measurements on single crystal $YBa_2Cu_30_{7-5}$ can give information on photon scattering by two level systems2 characteristic of amorphones solids. In order to interpret the thermal conductivity experiments on the high Tc superconductor it is useful to compare their behaviour with that of conventional superconductor (i.e. superconductor which are well discussed by the Bio-mechanism of photon-mediated hooper pois formation.

II. THERMAL CONDUCTIVITY OF HIGH TC SUPERCONDUCTOR NON-IDEAL SAMPLES

Thermal conductivity measurements on high Tc superconductor have been limited mainly to ceramic samples of $YBa_2Cu_30_{7-\delta}$ and $La_{2-x}Sr_x$ $Cu0_4$. Since the thermal conductivity is sensitive to the scattering mechanisms in a solid, the presence of pom and interval boundaries in ceramic materials makes the thermal conductivity data more difficult to interpret than for single crystal materials. Nonetheless, the qualitative form of the thermal conductivity as a function of temperature for the $La_{2-x}Sr_x$ $Cu0_4$and $YBa_2Cu_30_{7-\delta}$ ceramics can give us information of the scattering of phonons by electrons for T ~ Tc. Note that no matter what the mechanism for superconductivity is for the high Tc superconductor, electrons below Tc which have condensed with the good state cannot transport heat or scatter -phonons. Only-one group[9] has measured the thermal conductivity of one sample each of single crystal $YBa_2Cu_30_{7-\delta}$ and $HoBa_2Cu_507-\delta$ Then data provide evidence for the existence of two level symptons10'11 in $YBa_2Cu_30_{7-\delta}$

In this paper, we have evaluated the thermal conductivities of two high temperature superconductor $YBa_2Cu_30_7$-δ (Tc = 92K) and La2-xSrx Cu04for the values of x = 0.15 Tc = 38K and x = 7.209 and Tc = 30K as a function of temperature T. One theoretical results indicate that the thermal conductivity K increases with temperature. Here we have mention the given results in table T_1 & T_2,

III. MATHEMATICAL FORMATION USED IN THE EVALUATION

One knows that the heat currents carried by conduction electron are closely related to electrical currents. An additional complication in the heat transport case is that the carriers of heat can be either charge carriers like electrons or electrically neutral phonons, whereas electrical current arises only from charge carrier transport. The transformation to the superconducting state canges the nature of the carriers of the electric current. So it is to be expected that the transport of heat will be strongly affected.[12-16] The thermal current density J in the thermal energy per unit time crossing a unit area adjusted perpendicular to the direction of heat flow. It is a vector representing the transport of entropy during Sap at the velocity J.

$$V= TS\emptyset v. \quad (1)$$

From the hotter to the coolker region of the material. It is proportional to the gradient of the temperature VT through Founal's law

$$V= -K\nabla T \quad (2)$$

Where K is the coefficient of thermal conductivity.

In the normal state, electrical conductor are good conductor of heat in accordance with the law of wiedermann and Franz.

$$(K/\sigma) = \frac{3}{2}(K\beta / e)^2T \quad (3)$$

σ is the electrical conductivity. In the superconducting state, in contrast the heat conductivity can be much lower because cooper paris carry no entropy and do not scatter phonon. The principal carries of thermal energy through metals in the normal state are conduction electron and phonons. Heat conduction via each of these two channels acts independently, so that the two channels constitute parallel paths for the passage of heat. A simple model for the conduction of heat between two points A and B in the sample is to represent the two channels by parallel resition with conductivities Ke and Kph for the electronic and phonons paths. The conductivities add directly as the electrical analogue of parallel resistors to give the total thermal conductivities K.

$$K = Ke + Kph \quad (4)$$

The electronic path has an electron lattice contribution $K_{1\text{-}l}$ which is always present and an impurity term $K_{1\text{-}l}$ which becomes dominant at high defut concentrations. In like manner, the phonon path has a phonon- electron constitution $K_{ph\text{-}1}$, plus an additional contribution Kph-l from impurities. The result is

$$1/K_1 = 1/K_1\text{-}L + 1/K_1\text{-}L \quad (5)$$

$$1/K_{ph} = 1/K_{ph\text{-}L} + 1/K_{ph\text{-}L} \quad (6)$$

Applying the law of Widemann and Franz gives us

$$K1\text{-} L = \{Constant/T^2 \ \ T<< \theta_D\ ,\ Constant\ T>> \theta_D\} \quad (7)$$

For temperatures that are low and high respectively relative in the degree temperature θ_D We know that at the lowest temperatures the electrical conductivity $\sigma(T)$ approaches a limiting value, $\sigma(T) \longrightarrow \sigma(0)$ arising from the impurity contribution.

The temperatures dependence of Cph is more complicated than that predicted by the specific heat term, since Cph increases with T whereas the phonon mean free path 1ph decreases with increasing temperature which not only compensates for Cph but also tends to cause Kpl-l to drop. In two metals the electronic contribution to the thermal conductivity tends to dominate at all temperatures. When money defuts are present, as in deorganised alloys, they affect Kph more than Ke and the phonon contribution can approved or exceed that of the conduction items.

IV. DISCUSSION OF RESULTS

In this paper, we have presented a method of evaluation of thermal conductivity of high Tc superconductor as a function of temperatures. The high Tc superconductor are $La_{2\text{-}x}Sr_xCu0_4$ of difference volumes of x (as x = 0.15, Tc=38K and x = 0.20, Tc = 30K) and $YBa_2Cu_30_{7\text{-}\delta}$ (Tc = 92K). We have compared our theoretical results with that of Graebner20 and Morelli21. Our theoretically evaluated results are in good affunent with these workers. Our theoretical results indicate that thermal conductivities of the above superconductors increases with temperature. As it was pointed out by Uher et al[22] that phonons contribute close to 90% of the thermal conductivity in $YBa_2Cu_30_{7\text{-}\delta}$ at Tc. Given the relatively large magnitude of Tc for $YBa_2Cu_30_{7\text{-}\delta}$ ($Tc/\ \theta_{Debye} \sim 0.25$) it is possible that the transition occurs in a region where the thermal conductivity is limited mainly by phonon phonon and carriers-phonon scattering. The enhancement of the thermal conductivity above the normal state conductivity for T < Tc in $YBa_2Cu_30_{7\text{-}\delta}$ in consistent with this interpretation. It indicates that the phonons make a major contribution to the thermal conductivity and that carrier-phonon scattering is important in limiting the phonon contribution to the thermal conductivity at Tc. On all the other hand the data for $La_{2\text{-}x}Sr_x\ Cu0_4$ are less conclusive. Although phonon make major contribution23 to the thermal conductivity at Tc, no clear enhancement is observed as for $YBa_2Cu_30_{7\text{-}\delta}$ only a slight change in shape is noticeable at Tc. It is possible that the enhancement effect is observed in $La_{2\text{-}x}Sr_x\ Cu0_4$ by scattering mechanisms other than phonon carriers scattering. The most likely scattering mechanisms limiting the phonon contribution to the thermal conductivity at Tc ($Tc/\ \tilde{}\theta Debye \sim 0.1$) are phonon defect, phonon carrier and phonon-phonon scattering. An understanding of the scattering mechanisms which lead to the law magnitude of the thermal conductivity for $LaCu0_4$ will be important for explains[24,25] the magnitude and temperature behaviour of the thermal conductivity of $La_{2-x}Sr_x$ $Cu0_4$.

Table 1. An Evaluation of Thermal Conductivity K ($WCm^{-1}K^{-1}$) as a function of temperature for $YBa_2Cu_30_{7-\delta}$ (Tc=90 K)

T(K)	Ohms	Graebener	Marelli
5	0.025	0.032	0.03
10	0.038	0.036	038
20	0.046	0.042	0.049
30	0.058	0.055	0.059
40	0.062	0.0360	0.061
50	0.068	0.069	0.070
100	0.072	0.074	0.0.75
150	0.075	0.078	0.080
200	0.082	0.083	0.086
250	0.096	0.095	0.092

Table 2. Evaluation of Thermal Conductivity K ($Wcm^{-1}K^{-1}$) as a function temperature T for $La_{2-x}Sr_x$ $Cu0_4$ T(K)

T(K)	K($WCm^{-1}K^{-1}$) X=015, Tc=38 K	K($Wcm^{-1}K^{-1}$) X=0.2, Tc = 30K
1	0.0052	0.0046
5	0.0067	0.0058
10	0.0072	0.0070
20	0.0087	0.0084
30	0.0097	0.0095
40	0.0127	0.0120
50	0.0138	0.0136
60	0.0252	0.0246
70	0.0286	0.0273
80	0.0329	0.0308
90	0.0468	0.0458
100	0.0587	0.0553

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Cite this article as :

Dr. Lav Kumar, "An Evaluation of Thermal Conductivity of High-Temperature Super Conductors", International Journal of Scientific Research in Science and Technology (IJSRST), Online ISSN : 2395-602X, Print ISSN : 2395-6011, Volume 6 Issue 3, pp. 392-396, May-June 2019. Available at Journal URL : http://ijsrst.com/IJSRST207487