Acta Ciencia Indica, Vol. XLII P, No. 3, 161 (2016)

THE HIGH TEMPERATURE SUPERCONDUCTIVITY PHENOMENA

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RECEIVED : 9 September, 2016

REVISED : 16 November, 2016

High temperature superconductors are materials that have a superconducting transition temperature (Tc) above 30 K. Earlier it was thought to be highest theoretically possible Tc. The observation of superconductivity in L_a-B_a-C_u-O system by Bednarz and Muller [1] has opened the flood gates for intense research activity in the highly competitive and challenging field and has rightly been awarded the Nobel prize for physics for 1987 for their innovative and starting break through Wu *et al* [2] has reported superconductivity at 95 k in Y-Ba-Cu-O system and the phase has been identified as Y_1 - Ba_2 - Cu_3-O_{7-x} an oxygen deficient yttrium barium copper oxide. Superconductivity has also been reported by Ovshinsky *et al* [3] for flurinated samples of Y-Ba-Cu-O system but this work has not been confirmed by other groups. Fe – based superconductors were discovered in 2008 [4] the term high temperature superconductor was used interchangeably with cuprate superconductors for compounds such as bismuth strontium calcium copper oxide (BSCCO) and yttrium barium copper oxide (YBCO). Two decades of intense experimental and theoretical research have discovered many common features in the properties of high temperature superconductors [5-6] but as of 2009, there is no widely accepted theory to explain their properties. Cuprate superconductors differ in many important ways from conventional superconductors. In 2009, the highest-temperature superconductor is mercury barium calcium copper oxide at 135K and is held by a cuprate -perovskite materials, which possibly reaches 164 K under high pressure. Recently, iron-based superconductors with critical temperature as high as 56K have been discovered [7-8] which referred to as high-temperature superconductors. The high Tc cuprate superconductors include $La_{1.85}Ba_{0.15}CuO_4$, and YBCO (Yttrium-Barium-Copper Oxide), which is famous as the first material to achieve superconductivity above the boiling point of liquid nitrogen. The transition temperatures of well known superconductors are 133 K of $Hg_2Ba_2Cu_3O_x$, 90 K of

237/P016

$YBa_2Cu_3O_7$ (YBCO), 55K of SmFeAs (O, F) and 26 K of LaFeAs (O, F). Iron based superconductors contain layers of iron and a pnictogen- such as arsenic or phosphorus-or a chalcogen. This is currently the family with the second highest critical temperature, behind the cuprates. Interest in their superconducting properties began in 2006 with the discovery of superconductivity in LaFePO at 4 K [9] and gained much greater attention in 2008 after the analogous material LaFeAs (O, F) [7]. In the conventional superconductors the phonon mediate electron cooper pairing which is evidenced by the presence of isotope effect in these systems. The near absence or marginality of isotope effect specially in Y-Ba-Cu-O system is puzzling both the experimentalists and theorists alike. The question that is being asked is whether these are phonon mediated BCS superconductors. Several possible mechanisms involving excitons, Charge transfer excitations, plasmons, polarons and bipolarons, and anti ferromagnetic excitations, have been proposed. The mechanisms involving quasi elastic structural excitations and instability have also been suggested .

KEYWORDS : Superconductivity, Phonon, Transition Temperature, Excitons, Magnetism.

Introduction

Before we briefly discuss various models employed by various workers let us recall some of the properties of the system. The pure compound $\mathrm{La_2\ CuO_4}$ is perhaps an insulator and the superconducting phase is $\mathrm{L}a_{2-x}(\mathrm{Ba/Sr})_x$ CuO_4 for $x \leq 0.2$. The superconductivity phase for high T_c oxide family of the Y-Ba-Cu-O system is $\mathrm{Y_1Ba_2Cu_3O_{7-Y}}$. The most important feature of these newly discovered systems is that they both certain Cu-O planes and this two dimensional nature of the structure is believed to be responsible for superconductivity behaviour. The magnetism of the system seems to play an important role in the establishment of the superconducting state.

Theory

The energy band structure calculations by Yu, Freeman and Xu [11] reveal that Cu-3d and O-2p states have sufficient overlap and that the density of states at the Fermi level is very small and the electron phonon coupling constant is quite large. Weber [12] has studies $\mathrm{L}a_{2-x}$ $(\mathrm{Ba/Sr})_x\mathrm{CuO_4}$ superconductors using energy band structure results and has found that the oxygen breathing mode compiles with cu 3d electrons very strongly and the electron phonon coupling parameter can be larger than 2. Allen and Dynes [12] have found on the basis of their numerical study that T_c is not limited by the value of but varies as T_c, and can be arbitrarily large. Using this fact and assuming that high frequency phonons of oxygen atoms are involved and span high Debye temperatures θ_p we find that it is possible to explain the range of T_c

values for appropriate values of the parameters [12]. The condensation of bipolarons has been studied and it is believed that the bipolarons are unlikely to push T_c Values to such a large extent. It has also recently emphasized the role of bipolarons in producing superconducting state. The absence of isotope effect specially in $Y_1Ba_2Cu_3O_{7-y}$ superconductors will rule out bi -polarons also as a mechanism of superconductivity.

Earlier a theory of high T_c superconductivity has developed in oxide superconductors. The charge carriers are holes in the O-2p states and the pairing is mediated by strong coupling to local spin fluctuations on Cu sites.

Later it has come out with a Novel idea of resonating valence bond (RVB) state according to which the compound La_2CuO_4 is in a anti ferromagnetic (RVB) state and only on doping with Ba or Sr do the pre existing magnetic singlet pairs become superconducting cooper pairs. But now that La_2CuO_4 has itself been found superconducting Anderson model will need re -examination. The T_c in this model is $4t^2/U$ where t and U are hopping integral and coulomb repulsion between opposite spin electrons. Plasmons have also been considered as candidates for high T_c superconductivity. It has shown that the 2-D character of the electronic structure of the oxide superconductors favours formation of "acoustic" plasmons and since their energies are orders of magnitude larger than phonon energy can lead to high T_c values because of the large prefactor. But plasmons are common occurrance in metals and the latter do not in general become superconductors and hence plasmons also do not seem to find favour as potential contenders for these systems.

The charge transfer excitations have also been considered as a mechanism for high T_c superconductivity Jagdish and Sinha [10].

In the following we argue that high T_c superconductivity in these ceramic oxide superconductors is perhaps induced by excitons in the spirit of Allender, Bray and Bardeen [13-14] (ABB) theory as proposed by them for planner and sandwich geometries. Following ABB the expression for the transition temperature can be expressed.

$$T_c = 0.7\ \theta_p \exp(-1/g)$$

Where

$$g = \lambda_p^* + \frac{\lambda_e^* - \mu^*}{1 - \left(\lambda_e^* - \mu^*\right)\ln\left(\omega_g / \omega_p\right)}$$

$$\lambda^* = 1/(1+\lambda)$$

and $\mu^*$is the screened coulomb interaction, $\lambda_e$is the energy gap and λ_P is the phonon energy.

With the choice appropriate to oxide superconductors we get the following T_c values (ω_g = 1000 K and ω_p = 300 K)

λ_P	λ_e	μ^*	θ_P	T_c (k)
1.0	0.2	0.2	300	44
1.0	0.5	0.1	250	84
1.5	1.5	0.2	300	101

Result and discussion

Thus we notice that excitons assisted by phonons can explain the entire range of observed Tc values. It is interesting to note that recently it has explained high T_c superconductivity in $Y_1Ba_2Cu_3O_{7-y}$ system using excitonic enhanced superconducting mechanism (14). It has been studied the optical absorption and neutron scattering in $Y_1Ba_2Cu_3O_{7-y}$ also find support for the exciton mechanism of superconductivity in these materials. More detailed experimental and theoretical work will be required to ascertain the real mechanism in these newly discovered oxide superconductors which unfortunately still seems to remain elusive.

Acknowledgement

The author is thankful to referee for his valuable comments.

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