IOSR Journal of Applied Physics (IOSR-JAP)
e-ISSN: 2278-4861.Volume 9, Issue 4 Ver. IV (Jul. – Aug. 2017), PP 01-03
www.iosrjournals.org

High-Temperature Superconductivity: Milestone in the Field of Electronics

Mukesh Kumar[a],
A-Head, Deptt. of Physics, Shivpati Post Graduate College,Shohratgarh, Siddharth Nagar, U.P.
*Corresponding Author: * Mukesh Kumar[a]*

Abstract:- *In 1986, High-Temperature Super conductivity was discovered. The superconducting materials display novel or enhanced properties compared to traditional materials & thus open up possibilities for new technological applications. One the property like the penetration depth of layer superconductors of some materials is studies theoretically the study can be implemented in the systems for various practical applications. e.g. in developing high quality thin films, wires, tapes, bulk materials etc.*

Date of Submission: 17-07-2017 Date of acceptance: 14-08-2017

I. Introduction

High-temperature superconductors (abbreviated **high-T_c** or **HTS**) are materials that behave as superconductors at unusuallyhigh temperatures. The first high-T_c superconductor was discovered in 1986 by IBM researchers Georg Bednorz and K. Alex Müller, who were awarded the 1987 Nobel Prize in Physics"for their important break-through in the discovery of superconductivity in ceramic materials".Bednozencountered a barium-doped compound of lanthanum and copper oxide whose resistance dropped down to zero at a temperature around 35 K (−238.2 °C). Their results were soon confirmed by many groups, notably Paul Chu at the University of Houston and Shoji Tanaka at the University of Tokyo.

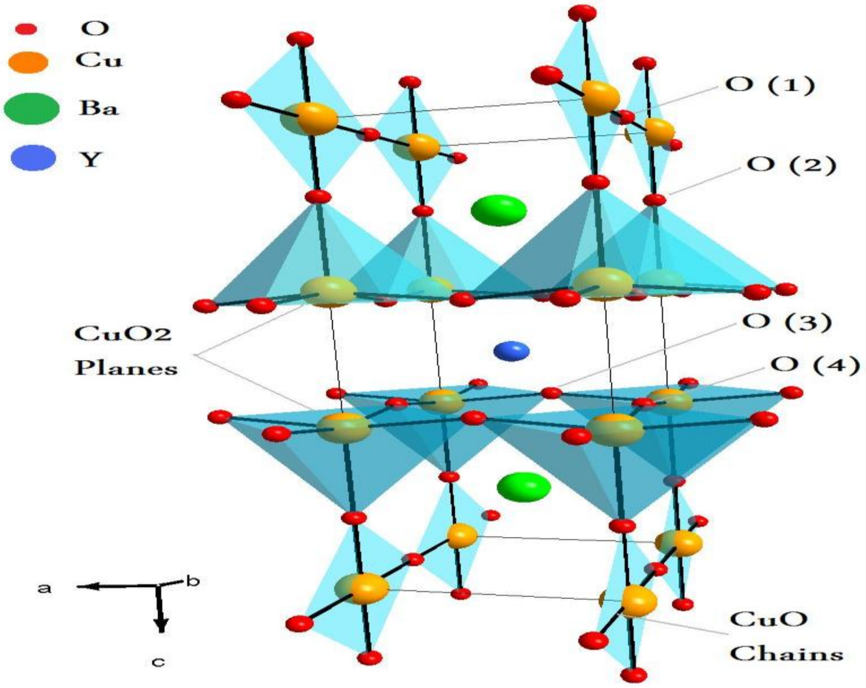
Theory-Shortly after, P. W. Anderson, at Princeton University came up with the first theoretical description of these materials, using the resonating valence bond theory,[but a full understanding of these materials is still developing today. These superconductors are now known to possess a d-wavepair symmetry. The first proposal that high-temperature cuprate superconductivity involves d-wave pairing was made in 1987 by Bickers, Scalapino and Scalettar, followed by three subsequent theories in 1988 by Inui, Doniach, Hirschfeld and Ruckenstein, using spin-fluctuation theory, and by Gros, Poilblanc, Rice and Zhang and by Kotliar and Liu identifying d-wave pairing as a natural consequence of the RVB theory. The confirmation of the d-wave nature of the cuprate superconductors was made by a variety of experiments, including the direct observation of the d-wave nodes in the excitation spectrum through Angle Resolved Photoemission Spectroscopy, the observation of a half-integer flux in tunneling experiments, and indirectly from the temperature dependence of the penetration depth, specific heat and thermal conductivity.

After more than twenty years of intensive research, the origin of high-temperature superconductivity is still not clear, but it seems that instead of electron-phonon attraction mechanisms, as in conventional superconductivity, one is dealing with genuine electronicmechanisms (e.g. by antiferromagnetic correlations), and instead of s-wave pairing, d-waves are substantial. One goal of all this research is room-temperature superconductivity.

II. Crystal Structures Of High-Temperature Ceramic Superconductors

The structure of high-T_c copper oxide or cuprate superconductors are often closely related to perovskite structure, and the structure of these compounds has been described as a distorted, oxygen deficient multi-layered perovskite structure. One of the properties of the crystal structure of oxide superconductors is an alternating multi-layer of CuO_2 planes with superconductivity taking place between these layers. The more layers of CuO_2, the higher T_c. This structure causes a large anisotropy in normal conducting and superconducting properties, since electrical currents are carried by holes induced in the oxygen sites of the CuO_2 sheets. The electrical conduction is highly anisotropic, with a much higher conductivity parallel to the CuO_2 plane than in the perpendicular direction. Generally, critical temperatures depend on the chemical compositions, cations substitutions and oxygen content. They can be classified as superstripes; i.e., particular realizations of superlattices at atomic limit made of superconducting atomic layers, wires, dots separated by spacer layers, that gives multiband and multigap superconductivity.

YBaCuO superconductor-



The first superconductor found with $T_c > 77$ K (liquid nitrogen boiling point) is yttrium barium copper oxide ($YBa_2Cu_3O_{7-x}$); the proportions of the three different metals in the $YBa_2Cu_3O_7$ superconductor are in the mole ratio of 1 to 2 to 3 for yttrium to barium to copper, respectively. Thus, this particular superconductor is often referred to as the 123 superconductor.

The unit cell of $YBa_2Cu_3O_7$ consists of three pseudocubic elementary perovskite unit cells. Each perovskite unit cell contains a Y or Ba atom at the center: Ba in the bottom unit cell, Y in the middle one, and Ba in the top unit cell. Thus, Y and Ba are stacked in the sequence [Ba–Y–Ba] along the c-axis. All corner sites of the unit cell are occupied by Cu, which has two different coordinations, Cu(1) and Cu(2), with respect to oxygen. There are four possible crystallographic sites for oxygen: O(1), O(2), O(3) and O(4). The coordination polyhedra of Y and Ba with respect to oxygen are different. The tripling of the perovskite unit cell leads to nine oxygen atoms, whereas $YBa_2Cu_3O_7$ has seven oxygen atoms and, therefore, is referred to as an oxygen-deficient perovskite structure. The structure has a stacking of different layers: $(CuO)(BaO)(CuO_2)(Y)(CuO_2)(BaO)(CuO)$. One of the key feature of the unit cell of $YBa_2Cu_3O_{7-x}$ (YBCO) is the presence of two layers of CuO_2. The role of the Y plane is to serve as a spacer between two CuO_2 planes. In YBCO, the Cu–O chains are known to play an important role for superconductivity. T_c is maximal near 92 K when $x \approx 0.15$ and the structure is orthorhombic. Superconductivity disappears at $x \approx 0.6$, where the structural transformation of YBCO occurs from orthorhombic to tetragonal.

Some other examples-

1- **Bi-, Tl- and Hg-based high-T_c superconductors**
2-Tl–Ba–Ca–Cu–O superconductor
3-Hg–Ba–Ca–Cu–O superconductor

III. Magnetic Properties

All known high-T_c superconductors are Type-II superconductors. In contrast to Type-I superconductors, which expel all magnetic fields due to the Meissner effect, Type-II superconductors allow magnetic fields to penetrate their interior in quantized units of flux, creating "holes" or "tubes" of normal metallic regions in the superconducting bulk called vortices. Consequently, high-T_c superconductors can sustain much higher magnetic fields.

IV. Ongoing Research

The question of how superconductivity arises in high-temperature superconductors is one of the major unsolved problems of theoretical condensed matter physics. The mechanism that causes the electrons in these crystals to form pairs is not known. Despite intensive research and many promising leads, an explanation has so far eluded scientists. One reason for this is that the materials in question are generally very complex, multi-layered crystals (for example, BSCCO), making theoretical modelling difficult. Improving the quality and variety of samples also gives rise to considerable research, both with the aim of improved characterisation of the physical properties of existing compounds, and synthesizing new materials, often with the hope of increasing T_c. Technological research focuses on making HTS materials in sufficient quantities to make their use economically viable and optimizing their properties in relation to applications.

References

[1]. George Rajna; Academia.edu, Superconductive Graphene
[2]. http://en.wikipedia.org/wiki/BCS theory
[3]. http://en.wikipedia.org/wiki/Superconductivity
[4]. http://en.wikipedia.org/wiki/high temperature superconductivity
[5]. http://en.wikipedia.org/wiki/Room-temperature superconductivity
[6]. http://phys.org/news/2015-05-linking-superconductity.html#jcp
[7]. Timmer, John (May 2011). "25 years on, the search for higher-temp superconductors continues". ArsTechnica.Retrieved 2 March 2012.
[8]. Ford, P. J. (2005). The Rise of the Superconductors.CRC Press.
[9]. Bednorz, J. G.; Müller, K. A. (1986). "Possible high T_C superconductivity in the Ba-La-Cu-O system".ZeitschriftfürPhysik B64 (2): 189–193. Bibcode:1986ZPhyB..64..189B. doi:10.1007/BF01303701.
[10]. The Nobel Prize in Physics 1987: J. Georg Bednorz, K. Alex Müller. Nobelprize.org. Retrieved 2012-04-19.
[11]. A. Leggett (2006). "What DO we know about high T_c?".Nature Physics2 (3): 134. Bibcode:2006NatPh...2..134L. doi:10.1038/nphys254.
[12]. Nisbett, Alec (Producer) (1988). Superconductor: The race for the prize (Television Episode).
[13]. Stuart A Wolf & Vladimir Z Kresin,Eds, Novel Superconductivity, Springer (October, 1987)
[14]. Tanaka, Shoji (2001)."High temperature superconductivity: History and Outlook"(PDF).JSAP International.Retrieved 2 March 2012.
[15]. Anderson, Philip (1987)."The Resonating valence bond state in la-2CuO-4 and superconductivity". Science 235 (4793): 1196–1198. Bibcode:1987Sci...235.1196A. doi:10.1126/science.235.4793.1196. PMID 17818979.
[16]. Bickers, N.E.; Scalapino, D. J.; Scalettar, R. T. (1987)."CDW and SDW mediated pairing interactions". Int. J. Mod. Phys. B 1 (3n04): 687. Bibcode:1987IJMPB...1..687B. doi:10.1142/S0217979287001079.
[17]. Inui, Masahiko; Doniach, Sebastian; Hirschfeld, Peter J.; Ruckenstein, Andrei E.; Zhao, Z.; Yang, Q.; Ni, Y.; Liu, G. (1988). "Coexistence of antiferromagnetism and superconductivity in a mean-field theory of high-Tc superconductors". Phys. Rev. B 37 (10): 5182. Bibcode:1988PhRvB..37.5182D. doi:10.1103/PhysRevB.37.5182.
[18]. 18-Gros, Claudius; Poilblanc, Didier; Rice, T. Maurice; Zhang, F. C. (1988)."Superconductivity in correlated wavefunctions".Physica C. 153–155: 543–548. Bibcode:1988PhyC..153..543G. doi:10.1016/0921-4534(88)90715-0.
[19]. Kotliar, Gabriel; Liu, Jialin (1988)."Superexchange mechanism and d-wave superconductivity".Physical. Review B 38 (7): 5182. Bibcode:1988PhRvB..38.5142K. doi:10.1103/PhysRevB.38.5142..
[20]. Mourachkine, A. (2004). Room-Temperature Superconductivity. Cambridge International Science Publishing. arXiv:cond-mat/0606187. ISBN 1-904602-27-4..21-Khare, Neeraj (2003). Handbook of High-Temperature Superconductor Electronics.CRC Press.ISBN 0-8247-0823-7.

IOSR Journal of Applied Physics (IOSR-JAP) is UGC approved Journal with Sl. No. 5010, Journal no. 49054.

Mukesh Kumar. “High-Temperature Superconductivity: Milestone in the Field of Electronics.” IOSR Journal of Applied Physics (IOSR-JAP) , vol. 9, no. 4, 2013, pp. 01–03.