CHAPTER – 2
REVIEW OF LITERATURE
Kamerlingh Onnes (1911) discovered superconductivity when he showed that the electrical resistance for Mercury drops to the order of $10^{-5}$ ohms at 4K which he considered an equivalent to zero dc resistance.

W. Meissner and R. Oşchenfeld (1933) came up with the Meissner Effect. The Meissner effect showed that when a metal is cooled in the presence of a magnetic field, there occurs an expulsion of magnetic field below the transition temperature of the superconducting metal. Hence it was concluded that a superconductor is a perfect diamagnetic material.

F. London and H. London (1935) gave the famous London equation

$$B(x) = B_0 e^{-x/\lambda_L}$$

where $B(x)$ represents that magnetic field inside the superconductor, $B_0$ is the magnetic field at the boundary, $\lambda_L$ represents the London penetration depth. This equation also gave an explanation to the Meissner effect.

V.L. Ginzburg and L.D. Landau (1950) gave the Ginzburg-Landau theory based on the concept describing the superconducting state in terms of a complex order parameter that vanished at $T_C$. The order parameter is viewed as a single particle wavefunction $\psi(r)$. 
C A Reynold et. al. (1951) found that the critical magnetic field at any temperature decreases with increasing average mass and the critical temperature also decreases with increasing average mass. They established the relation $M^{1/2}T_c = \text{constant}$, between critical temperature ($T_c$) and mass number ($M$).

Leon N. Cooper (1956) explained that a pair of electrons that interact above a quiscient Fermi surface can have a net attraction where they form a bound state such that their total energy is greater than zero. He suggested that such bound electron pair can be responsible to fabricate superconducting state.

Bardeen, Cooper and Schrieffer (1957) came up with the BCS theory. This theory gave a successful explained for low $T_c$ superconductors. The conceptual element of pairing of electrons was already given by Cooper, which became instrumental in explaining superconductivity. The electron-phonon-electron interaction was confirmed as the cause of superconductivity in liquid He.

Moskalenko et al. (1991) showed in two band superconductors near $T_c$ the upper critical field $H_{c2}$ as a function of temperature has positive curvature, due to the relation $\nu_{F1} \neq \nu_{F2}$ ($\nu_{F_n}$ – the velocity of electron on n-th cavity of Fermi surface). In one band case we have negative curvature. On the basis of the theory of superconductivity with overlapping energy bands one can explain a great number of experimental results in High- $T_c$ materials.
Palistrant & Kochorbe (1992) adapted the generalized Moskalenko model for the investigation of thermodynamical properties and collective oscillations in multi-band systems with the lowering density of charge carriers. Palistrant & Kochorbe found that in two band systems high temperature superconductivity is possible not only in the case of attractive interaction between the electrons, but even if the interaction between the electrons has repulsive character ($\lambda_{nm} < 0; n; m = 1-2$), but relation $\lambda_{11}\lambda_{22} - \lambda_{12}\lambda_{21} < 0$ is fulfilled.

Ravi P. Singh, Z. C. Tao, and M. Singh (1992) showed the role of interlayer coupling on the Néel temperature of YBa$_2$Cu$_3$O$_{6+x}$. They used the expression for Neel temperature derived from the three-dimensional anisotropic Heisenberg model. With the help of numerical calculations we have obtained an analytical expression for the Neel temperature. This expression shows that $T_N \to 0$ as $J_\perp \to 0$. They showed that a good agreement between theory and experimental results was achieved provided that the ratio of interplanar to intraplanar coupling strengths depend linearly on the doping concentration $x$.

Palistrant & Kochorbe (1997) In two band superconductors they also found collective oscillations of exciton-type Leggett mode appears, caused by the fluctuations of phase of order parameters for different bands. In the three band systems, and also in the two-band with lower density of charge carrier, which reduces to the three-band model, such oscillatory modes can be two.
**Shugla & Drechsler (1998)** The interest to the two band model for superconductivity was renovated with the discovery of MgB$_2$. This compound is a many-band superconductor and anomalies of its properties are described by them for the two band theory.

**Govind et al. (1999)** performed calculations on thermodynamic properties of bilayer cuprate superconductors using an extended Hubbard model that includes the various intra-planar and inter-planer contributions. It is shown that various thermodynamic properties namely transition temperature, density of states (DOS) and electronic contribution to specific heat depend on the intrabilayer interactions as well as on doping level in an essential way. The theoretically evaluated result was found to be in qualitative agreement with the existing experimental observations.

**Govind, Ajay and Tripathi (2000)** used a model Hamiltonian that incorporates the intra-bilayer, inter-bilayer and bilayer-chain interactions. The expressions of the superconducting order parameter, transition temperature, density of states and electronic specific heat was obtained using Green’s function technique. The numerical results they got showed that these properties were sensitive to the chain contributions.

**Govind et al. (2001)** reported the interplay of single particle hopping and cooper pair tunneling for layered high $T_C$ cuprate superconductors. The model
Hamiltonian used bilayer interaction consisting of interlayer and intralayer interactions. They found that superconducting order parameter at zero temperature is robust for single particle hopping. The cooper pair tunneling was found to increase the superconducting order parameter. This helps in formation of cooper pairs within the planes by providing favourable conditions.

Govind et al. (2001) studied the magnetic properties of bilayer cuprate antiferromagnets. the double time Green's function technique has been employed in the random phase approximation (RPA). Expressions for spin-wave dispersion, sublattice magnetization, Neel temperature were established. The spin wave dispersion curve for a bilayer antiferromagnetic system was found to consist of two branches, one acoustic and one optic branch. Their results showed that the Neel temperature ($T_N$) of the bilayer antiferromagnetic system increases with increasing $J_z$ and a small change in $J_z$ gives rise to a large change in the Neel temperature of the system.

Kristoffel & Rubin (2001) explained a simple model of interband superconductivity, incorporating a basic band and a doping created one, is considered, keeping in mind the two-component scenario of high - $T_C$ superconductivity. Diminishing gap ratios with hole doping was found.

Nagamastu et al. (2001) discovered superconductivity in MgB$_2$ with $T_C$ =39K. Study of MgB$_2$ superconductor showed these uncommon characteristics: a small
electronic density of states at the Fermi level, high phonon frequencies and a two-gap structure. After intensive effort, it has emerged that MgB$_2$ may be a fairly conventional superconductor, with the electron pairing mediated by unusually strong coupling with the phonons. However, in one respect it is unusual: There are two superconducting gaps or a highly anisotropic single gap; arising from different parts of the Fermi surface. We have been studying this rather fundamental aspect using tunnelling spectroscopy and high frequency techniques to look at how the density of states of quasiparticles and Cooper pairs evolve as a function of temperature.

**Sharma et al. (2001)** reported the role of dipole–dipole interaction on the magnetic dynamics of single layer antiferromagnets. They used the double time Green’s function technique to obtain expressions for the spin wave dispersion, sublattice magnetization and the magnetic contribution to specific heat as a function of various parameters of the model Hamiltonian.

**Govind et al. (2001)** they studied the magnetic properties of bilayer cuprate antiferromagnets. To evaluate the expressions for spin-wave dispersion, sublattice magnetization, Neel temperature and the magnetic contribution to the specific heat, they used the double time Green’s function technique. Their numerical calculations showed that the Neel temperature ($T_N$) of the bilayer antiferromagnetic system increased with the $J_z$ and a small change in $J_z$ gives rise to a large change in the Neel temperature of the system.
Mishonov et al. (2002) calculated the heat capacity using two-band model with the consideration of gas anisotropy. These results in a good way describe experimental data on heat capacity in MbG$_2$ in ordered and non-ordered samples of this compound.

Kristoffel & Rubin (2003) gave a descriptive interband model with two-subbands of the defect-component. Two pseudogaps appear as the minimal quasiparticle excitations energies. At critical overdoping concentration the larger pseudogap transforms into the defect component superconducting gap. The presence of two pseudogaps in the under doped state and the extension of the larger pseudogap to overdoping agree with the recent experimental data.

Kamihara et al. (2006) reported superconductivity with $T_C \sim 5$K in a compound of stoichiometry originally La(O$_{1-x}$F$_x$)FeP, consisting of alternating layers of lanthanum-series oxyfluorides and tetrahedrally coordinated ferrous pnictide. By January 2008, the same group had lifted $T_C$ to 26K on substituting arsenic for phosphorus, and in April that was raised to 43K, albeit under an applied pressure of 4 gigapascals.

Coldea et al. (2008) reported extensive measurements of quantum oscillations in the normal state of the Fe-based superconductor LaFePO, ($T_C \sim 6$K) using low temperature torque magnetometry and transport in high static magnetic fields (45 T). They found that the Fermi surface is in broad agreement with the band-
structure calculations with the quasiparticle mass enhanced by a factor ~2. The quasi-two dimensional surface consists of nearly-nested electron and hole pockets, suggesting proximity to a spin/charge density wave instability.

Yamamoto et al. (2008) found quasi-reversible magnetization curves in polycrystalline bulk rare-earth iron oxypnictides that suggest either widely spread obstacle to intergranular current or very weak vortex pinning. Study of polycrystalline samarium and neodymium iron oxynitride samples made with high pressure synthesis yielded that hysteresis magnetization is significantly enhanced. Magneto-optical imaging and study of the field dependence of the permanent magnetization as a function of particle size both show that global currents over the whole sample do exist but that the intergranular and intragranular current densities have distinctly different temperature dependencies and differ in magnitude by about 1000.

Cruz et al. (2008) stated that superconductivity in the newly discovered rare-earth iron-based oxide systems ROFeAs (R, rare-earth metals) arises from either electron or hole doping of their non-superconducting parent compound. The parent material LaOFeAs is metallic but shows anomalies near 150K in both resistivity and d.c. magnetic susceptibility. They performed neutron-scattering experiments that demonstrate that LaOFeAs undergoes an abrupt structure distortion below 155K, changing the symmetry from tetragonal (space group P4/nmm) to monoclinic (space group P112/n) at low temperature, and then, at
~137K, develop long range SDW-type antiferromagnetic order with a small moment but simple magnetic structure.

The mechanism and manifestation of unconventional superconductivity in the family of oxypnictides ROTMPn (R: La, Pr, Ce, Sm; TM: Mn, Fe, Co, Ni; Pn: P, As), because many features of these materials set them apart from other known superconductors.

Nekrasov et al. (2008) made calculation of electronic structure of superconducting series RO_{1-x}F_xFeAs. In all cases they obtained identical electronic spectrum in rather wide energy interval (about 2 eV) around the Fermi level. They debated that this fact is unlikely to be changed by the account of strong correlations. They argued that the experimentally observed variations of $T_C$ for different rare-earth substitutions are either due to disorder effects or less probably because of possible changes in spin fluctuation spectrum of FeAs layers caused by magnetic interactions with rare-earth spins in RO layers.

Hunte et al. (2008) performed resistance measurements of LaFeAsO_{0.89}F_{0.11} at high magnetic fields, up to 45 T, that show a remarkable enhancement of the upper critical field $B_{c2}$ compared to values expected from slopes $d B_{c2}/dT \approx 2$ TK-1 near $T_C$, particularly at low temperatures where the deduced $B_{c2}(0) \approx 63-65$ T exceeds the paramagnetic limit. They argued that oxypnictides represent a new class of high-field superconductors with $B_{c2}$ values surpassing those Nd$_3$Sn,
MgB$_2$ and the Chevrel phases, and perhaps exceeding the 100 T magnetic field benchmark of the high- T$_C$ cooper oxides.

**Raghu et al. (2008)** studied the high transition temperature and the electronic structure of the Fe-pnictide superconductors. They suggested that band structure calculations in these materials are associated with iron-pnictide layers and the density of states gets its maximum contribution from the Fe-3d orbitals. There model consisted of two orbitals per site on a two-dimensional square lattice. By manipulating the one-electron hopping parameters and the chemical potential, they found out a Fermi surface which has the same topology as found from the band structure calculations. They proposed a minimal two band model for iron pnictides that reproduces the topology of the low density approximation (LDA) Fermi surface and shows both ferromagnetic and spin density wave fluctuations.

**Benfatto et al. (2008)** studied a four-band model for the iron oxypnictides, in which the superconducting properties are assumed to be determined by the interband coupling between hole-like and electron-like Fermi sheets. They showed that reasonable parameters can account for the angle-resolved photoemission spectra showing multiple gaps in Ba$_{1-x}$K$_x$Fe$_2$As$_2$, and for the temperature dependence of the superfluid density. At the same time, the zero-temperature value of the superfluid density shows a conventional scaling with the number of carriers.
Han, Chen and Wang (2008) suggested on the basis of experimental data of the newly synthesized iron-based superconductors a minimal two-band BCS-type Hamiltonian with the interband Hubbard interaction included. They showed that the two band model was able to attain the important features of unconventional superconductivity and spin-density-wave (SDW) ordering. They found that bound hole-electron pairs can be condensed to reveal the SDW ordering for zero and very small doping. The analytical formulas derived by them gave an almost identical symmetric phase diagram for electron and hole doping. These calculations were most likely to account for existing main experimental results.

Ishida et al. (2008) performed a temperature-dependent angle-integrated laser photoemission study of iron oxypnictide superconductors LaOFeAs:F and LaOFeP:F exhibiting critical transition temperatures ($T_C$'s) of 26 K and 5 K, respectively. They found that high- $T_C$ LaOFeAs:F exhibits a ~0.1-eV pseudogap similar to high- $T_C$ copper oxides, whereas low- $T_C$ LaOFeP:F does not. They also found ~20-meV pseudogap-like features and superconducting gaps both in LaOFeAs:F and LaOFeP:F. They discussed possible origin of the pseudogaps through comparison with the high- $T_C$ cuprates.

Lynn and Dai (2009) studied the neutron scattering and the changes in the crystal structure, magnetic structure and spin dynamics for iron based superconductor RFe (As,P)(O,F) (R=La, Ce Pr, Nd) , (Ba, Sr, Ca)Fe$_2$As$_2$. He observed magnetic correlation with magnetic resonance that is similar to
superconducting order parameter of the cuprates. On cooling all the undoped materials exhibit universal behavior, where a tetragonal-to-orthorhombic/monoclinic structural transition takes place. The application of pressure in CaFe$_2$As$_2$ transformed the crystals structure from ortho-rhombic to tetragonal.

Osborn et al. (2009) performed measurements of the spin and lattice dynamics on non-superconducting ‘parent’ compounds based on the LaFeAsO (‘1111’) and BaFe$_2$As$_2$ (‘122’) crystal structures, and on electron and hole-doped superconducting compounds, using both polycrystalline and single crystal samples. He found that when combined with estimates of the electron-phonon coupling, the predicted superconducting transition temperatures are less than 1K, making a conventional phononic mechanism for superconductivity highly unlikely. Below $T_C$, there is evidence in ‘122’ structured compounds that these fluctuations condense into a resonant spin excitation at the antiferromagnetic wavevector with an energy that scales with $T_C$ which has also been observed for high-$T_C$ copper oxides.

Weber et al. (2012) used first-principles calculations to extract two essential microscopic parameters, the charge-transfer energy and the inter-cell oxygen-oxygen hopping. These parameter correlate with the maximum superconducting transition temperature $T_C$, max across the cuprates. they found that the position of the apical oxygen tunes both parameters, but the strength of
superconductivity, $\Delta_{\text{max}}$, is mainly sensitive to charge transfer energy. Optimal superconducting order parameter $\Delta_{\text{max}}$ of LSCO was found to decrease with increasing oxygen-oxygen hopping.