Reference: https://nsb.wikidot.com/pl-9-4-4-5

BCS Theory

BCS stands for Bardeen, Cooper and Schrieffer. The BCS theory explains the super conductivity of only TYPE I superconductors and DOES NOT explain TYPE II superconductors. The aim of BCS theory is to provide a satisfactory explanation to the superconductivity of TYPE I superconductors.

Advantages:

- Provides an explanation of the superconductivity of Type I superconductors.
- Explains superconductivity within the realms of classical mechanics.
- Explains the relative difference in superconductivity between metals, better conductors at normal temperatures are terrible superconductors.

Disadvantages:

- Does not explain the superconductivity of Type II superconductors.
- Does not predict the effects of superconductivity.

The Formation of Cooper Pairs

Cooper pairs are formed due to interaction between electrons and a phonon. A phonon is quanta of vibrational energy. Normally, electrons will have too much energy to stay in a Cooper pair, however as the temperature is lowered sufficiently, electrons may be able to form Cooper pairs, as thermal vibrations will freeze and resistance will go to zero.

Normally an electron would never be able to interact with another electron due to the repulsive effect of the Coloumb force. (The Coulomb force is the repulsive force between like charges). The idea of superconductivity being intrinsic to the structure was lead by several discoveries to do with the property of superconductors:

- The Meissner effect showed that the magnetic field inside a superconductor was exactly ZERO.
- The critical temperature was dependent on the mass of the ions in the lattice (the isotope effect).
- An energy gap between the repulsion of electron is 10^{-8} per atom.

As an electron moves through a crystal lattice the positive crystal lattice bends towards it forming a 'trough' of positive charge. This charge may be sufficient to attract an electron and form a 'Cooper pair'. The importance of linking electrons into Cooper pairs is the fact that electrons are fermions (particles with non-integer spins), fermion must obey Pauli's exclusion principle which states that no two fermions with the same spin can occupy the same state. However electrons with opposite spins in a Cooper pair add up to an integer spin of 0. This promotes the electron pair into the Boson state. Roughly 10^6 or 10^7 pairs can all be in the same state, importantly the Cooper pairs provide the energy gap required to be broken/formed in order to transition in and out of the superconducting state.

Problems encountered during the creation of the BCS theory:

Dr. Cooper realised that he was not able to resolve the formation of Cooper pairs mathematically for millions of electrons. Instead he opted to apply mathematics of the formation of one Cooper pair at a time. Schrieffer was then able to contribute through treating the problem statistically. He realised that the Cooper pairs seemed to all move in one group. An analogy to which he described: "Ice skaters who are linked arm in arm. If one was pushed then the rest would move along in the line".