The Gap Symmetry in Cuprate Superconductors and MgB_2 Due to Interband Pairing

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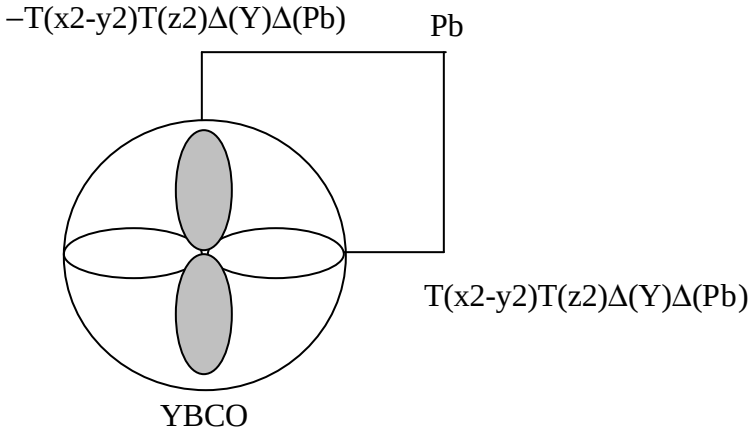
Abstract: In the Bardeen, Cooper, Schrieffer (BCS) theory of superconductivity, electron pairs are formed near the Fermi level comprised of $k\uparrow$ and $-k\downarrow$ electron pairs from the same band. We propose the existence of an additional type of Cooper pair consisting of $k\uparrow$ and $-k\downarrow$ electrons from *different* bands (Interband Cooper pairs). Interband Pairs (IBP) are only energetically possible in the vicinity of a band crossing at the Fermi level where two bands become degenerate for some k point on the Fermi surface. In general, bands repel unless there is some symmetry that forbids mixing. Thus, band crossings can only occur at special k points in the Brillouin zone. In the preceding paper, we argued that such band crossings occur at the Fermi level for the cuprate superconductors, the recently discovered 39K intermetallic superconductor MgB_2, and additionally in the 18K A15 superconductor, Nb_3Sn.

In this paper we show the following:

1.) Band crossings at the Fermi level are not precluded by Jahn-Teller distortion type arguments that would imply a crystal distortion to eliminate the oribital degeneracy at the Fermi level. This is due to the crossing phase space having measure zero.

2.) With IBP pairs, the *orbital* character of the bands also contributes to determining the symmetry of the superconducting gap. This is due to the fact that IBP pairs are not time-reversal (complex conjugate) invariant with themselves in contrast to traditional BCS-like Cooper pairs. IBP can explain the d-wave gap symmetry observed for the cuprates and suggests an "f-wave" type of gap for MgB_2. Thus, it is possible to have a non s-wave gap symmetry although the pairing arises from phonons or Coulomb repulsion.

The figure below shows how a dx2-y2 gap arises for Josephson tunneling of 92K cuprate superconductor $YBa_2Cu_3O_7$ to BCS superconductor Pb.



3.) For BCS-like pairs, even a small amount of impurities will smear any non s-like pairing into an isotropic s-wave gap. Since the symmetry of the gap is tied to the orbital character of the band wavefunctions for IBP, the smearing out of the pairing due to impurities does not affect the overall measured gap symmetry.

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