Effect of Orbital Pair Breaking on Triplet - FFLO Competition in Bechgaard salts Quasi-1d Organic Superconductors

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The superconducting critical fields in quasi-1d organic Bechgaard salts $(TMTSF)_2X$, where X is an inorganic anion (X= ClO_4 or PF_6) are very large, three to for times larger than the Clogston-Pauli limit (about 2 T in these compounds). Such large values are obviously not compatible with a uniform singlet phase. Therefore, two different order parameter symmetries have been proposed to account for these large values of the critical fields: (i) a non-uniform singlet FFLO phase or (ii) a triplet phase. The field induced non-zero momentum of the FFLO Cooper pairs, indeed, enlarges the stability of the superconducting order, compared to that of the uniform phase. However, the real three dimensional character of the crystal structure has to be taken properly into account. Experimental data indicate the following orders of magnitude for the three transfer integrals along the main crystal axis: t_a = 3000 K, t_b = 300K and t_c in the 5-10 K range. We have calculated the gap equation for the superconducting order parameter in such a crystal structure. The spin effect has been taken into account by including the Zeeman effect in the electron dispersion relation. The orbital effect has been taken into account by doing the Peierls substitution in the gap equation. The critical field is calculated by writing the condition for a vanishing order parameter when a magnetic field is applied. We find that the critical field strongly decreases as a function of t_c, as a result of a strong orbital pair breaking. A value of t_c = 5 K is enough to reduce the FFLO critical field to about 0.3 T. Therefore, a finite and even not very large Pauli limit exists in the FFLO phase. On the contrary, a re-entrant superconductivity is still present in the triplet phase. Thus, we expect that, in large enough applied field, a singlet-triplet field induced phase transition should occur. The NMR experimental data of Shinagawa et al. seem a good indication of this phenomenon.

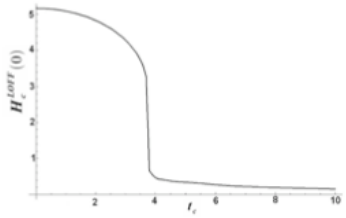

Figure caption
zero temperature critical field (in Teslas) of the FFLO phase in $(TMTSF)_2ClO_4$ as a function of t_c (in Kelvins), after optimization of the FFLO wave vector