PHONON SUPERCONDUCTIVITY AND KONDO SCREENING IN MIXED VALENCE AND HEAVY FERMION SUPERCONDUCTORS

V.V. Barzykin (University of Tennessee, Physics); L.P. Gor`kov (FSU, NHMFL)

Introduction

Scattering on paramagnetic impurities destroys phonon (s-wave) superconductivity (SC). However, it has been shown [1] that the Kondo screening of a local spin embedded into the metallic matrix may compete in the dilute limit with the time-reversal breaking scattering process, even resulting in the re-entrant SC regime. There are no scattering processes in Kondo lattices. Instead behavior is coherent. We considered competition between the Kondo effect and s-wave SC in dense heavy fermions and mixed valence superconductors using the phenomenological approach for the periodic Anderson model [2].

Results and Discussion

Similar to the well known results for the single-impurity Kondo effect in superconductors [1], we have found the principal possibility of a re-entrant regime of the SC transition temperature, Tc, in heavy fermion superconductors, although in a narrow range of *model parameters* and concentration of f-electrons. Suppression of Tc in mixed valence superconductors is much weaker. Our theory has the most validity in the low-temperature Fermi liquid regime. To check its applicability, we performed the fit for the x dependence of Tc on $Ce_{1-x}La_xRu_3Si_2$ and obtained an excellent agreement with the experimental data, although no re-entrance does appear at all in this case. We relate the good agreement to the fact that in the mixed valence compounds the added f-electrons just spill over into the conduction bands without forming scattering centers. Other experimental data are discussed in the light of our theory analysis. In particular, we compare temperatures of the SC transition for some known homologs, i.e., the analog periodic lattice compounds with and without f elements. For a few pairs of homologs, superconductivity exists only in the heavy fermion materials, thus confirming the uniqueness of SC-mechanism for the latter. We suggest that for some other compounds, the value of Tc may remain of the same order of magnitude in the two homologs, if superconductivity originates mainly on some light Fermi surface, but induces a sizable SC gap on another Fermi surface, for which hybridization or other heavy fermion effects are more significant. To that effect, we cite the old results that show that the ***jump in the specific heat at the transition reflects the heaviness of carriers on this Fermi surface independently of mechanisms responsible for superconductivity.***

Conclusions

To judge whether the phonon mechanism for SC may preserve in heavy fermion and mixed valence compound, we compared experimental Tc's for a number of homolog superconductors. Thus, $LaCu_2Si_2$ is not a superconductor, while $CeCu_2Si_2$ is. Also, there is no superconducting homologs without f electrons known for Ube_{13}, confirming the non-trivial SC in these two materials. Unfortunately, the experimental data for Tc's in non-f materials are scarce, obviously due to the absence of efforts and interest in the past in low temperature experiments for the latter. At the same time, one can enumerate numerous pairs (e.g., $CeRu_2$ (Tc=6K) and $LaRu_2$ (Tc=4K)) for mixed valence materials, thus confirming the common SC mechanisms for them. More experiments are needed.

Acknowledgements

The work (V.B.) was supported by TAML at the University of Tennessee and (L.P.G.) by NHMFL through the NSF Cooperative Agreement No. DMR-008473 and the State of Florida, with the partial support from the Alexander von Humboldt Foundation.

References

[1] Mueller-Hartman, E., *et al*., Phys. Rev. Lett., **26**, 428 (1971).
[2] Barzykin , V.V., *et al*., Phys. Rev. **B 71,** 214521 (2005).