

METAL/SUPERCONDUCTOR-INSULATOR TRANSITIONS AND THEIR INFLUENCE ON HIGH-T_c SUPERCONDUCTIVITY IN UNDERDOPED AND OPTIMALLY DOPED CUPRATES

Metal-insulator transitions (MITs) in undoped and doped materials have long been a focus of condensed matter physics due to their inherent conceptual complexity, which has stimulated the development of many theories, and the possibility of controlling the (reversible) suppression of electrical conductivity in technological applications. The MITs in doped semiconductors and high-T_c cuprate superconductors are of particular interest. These materials at low dopings are insulators, but they contain two opposite phases: the metal phase consisting of mobile charge carriers (free electrons or holes and large polarons) and the insulating phase consisting of localized (immobile) charge carriers. In the simplest scenario, metal-insulator transitions can be distinguished based on the Wilson's picture of the filling of electronic bands [1]. Wilson's approach predicts the insulating properties of fully filled/empty d-band transition metal oxides. However, for partially-filled d-band transition metal oxides (especially for high-T_c superconducting cuprates), this approach is inadequate [2]. One of the seminal works of Mott resolved this limitation by considering the effect of electron-electron correlation and formulated the criterion for the Mott metal-insulator transition in solids, which was a subject of intense research during many decades [3]. After that, several mechanisms that localize conducting electrons and lead to the MITs were proposed. The most prevalent ones are the Mott–Hubbard (caused by an electron–electron correlation) and Anderson (caused by a disorder) mechanisms [4]. The Mott- and Anderson-type metal-insulator transitions were discussed as the basic mechanisms of the localization of charge carriers in crystalline and non-crystalline solids [4,5,6,7].

In this work we develop a new approach to the metal/superconductor-insulator transition in doped cuprates by studying the polaron formation in them and the possibility of transforming a metallic or superconducting system into an insulator. We examine the possible effects of the different disorders (e.g. polaron formation and charge-density-wave (CDW) transition) and the competing insulating and superconducting phases on the critical temperature T_c of the superconducting transition in underdoped and optimally doped cuprates. We determine the actual superconducting transition temperature T_c in these materials using the theory of Bose-liquid superconductivity, which is capable of predicting the relevant value of T_c in high-T_c cuprates. We find that the suppressing of the polaronic and CDW effects in optimally doped cuprates results in the enhancement of T_c, while some lattice defects (e.g., anion vacancies) in the cuprates can strongly affect on T_c and enhance high-T_c superconductivity in them.

References

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Section

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