

Recent Advances in High-Temperature Superconductivity

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After more than 15 years of intense research since the discovery of high-temperature superconductivity [1], many interesting physical phenomena unique to the cuprate superconductors are better understood, and various applications have been realized. However, the underlying mechanism for high-temperature superconductivity remains elusive, largely due to the complication of numerous competing orders in the ground state of the cuprates. We review some of the most important physics issues and recent experimental developments associated with these strongly correlated electronic systems, and discuss current understanding and possible future research direction.

1. INTRODUCTION

High-temperature superconducting cuprates are doped Mott insulators with numerous competing orders in the ground state [2-5]. Mott insulators differ from conventional band insulators in that the latter are dictated by the Pauli exclusion principle when the highest occupied band contains two electrons per unit cell, whereas the former are associated with the existence of strong on-site Coulomb repulsion such that double occupancy of electrons per unit cell is energetically unfavorable and the electronic system behaves like an insulator rather than a good conductor at half filling. An important signature of doped Mott insulators is the strong electronic correlation among the carriers and the sensitivity of their ground state to the doping level. In cuprates, the ground state of the undoped perovskite oxide is an antiferromagnetic Mott insulator, with nearest-neighbor Cu^{2+} - Cu^{2+} antiferromagnetic exchange interaction in the CuO_2 planes [6]. Depending on doping with either electrons or holes into the CuO_2 planes [6,7], the Néel temperature (T_N) for the antiferromagnetic-to-paramagnetic transition decreases with increasing doping level. Upon further doping of carriers, long-range antiferromagnetism vanishes and is replaced by superconductivity. As shown in the phase diagrams for the hole-doped (p-type) and electron-doped (n-type) cuprates in Fig. 1, the

superconducting transition temperature (T_c) first increases with increasing doping level (δ), reaching a maximum T_c at an optimal doping level, then decreases and finally vanishes with further increase of doping. Although the phase diagrams appear similar for both p-type and n-type cuprates, they are in fact not truly symmetric. For p-type cuprates in the under- and optimally doped regime, the normal state properties below a crossover temperature T^* are significantly different from those of Fermi liquid, and the electronic density of states (DOS) appear to be slightly suppressed [8]. These unconventional normal state properties are referred to as the pseudogap phenomenon [8]. Moreover, holes enter

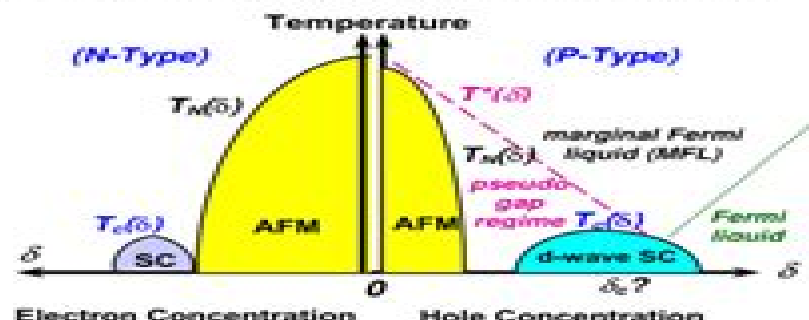


Fig. 1: Generic temperature (T) vs. doping level (δ) phase diagrams of p-type and n-type cuprates in zero magnetic field. (AFM: antiferromagnetic phase; SC: superconducting phase; T_N , T_c and T^* are the Néel, superconducting and pseudogap transition temperatures, respectively).

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