Universal Behaviors and Cross-over from Non-fermi to Fermi Liquid in High Temperature Cuprate Oxides

aDepartment of Physics, Pohang University of Science and Technology, Pohang, Korea bDepartment of Physics, Joonang University, Seoul, Korea

aSung-HoSalk aSung-HoSalk aGwang-YongChoi

Earlier we proposed both U(1) and SU(2) gauge theoretic slave-boson theories of the $t-J$ Hamiltonian for the low dimensional systems of strongly correlated electrons. This theory has been successful in reproducing the dome-shaped phase diagram and consistently fits other physical properties involved with superfluid weight, spectral function and optical conductivity. In this talk, following brief reviews of both experiment and theories. we present studies of both spin and charge dynamics based on our proposed theory. In association we will discuss how the two different spin and charge degrees of freedom are coupled in revealing exotic physical phenomena thus far unseen in other than high temperature superconductivity such as the dome-shaped bose condensation temperature, the boomerang behavior of superfluid weight and peak-dip-hump structures of both spectral function and optical conductivity. Regarding the spin dynamics we unveil physics involved with both temperature and doping dependence of magnetic resonance and associated spin pairing correlations for high T_c superconductivity. We find that the onset temperature of magnetic resonance is the pseudogap (spin gap) temperature T^* and the resonance peak energy E_{res} is shown to have a linear scaling behavior with the superconducting transition temperature, T_c, $E_{res}/T_c \simeq const$, in agreements with observations. This indicates that the spin pairing correlations or the spin pairing order is responsible for the correlations between T_c and T^* or the spin gap phase and the superconducting phase in high temperature superconductivity. Further the universal scaling behavior in the ratio of T^* to T_c will be revealed and explained. Regarding the charge dynamics we find that the peak-dip-hump structure in optical conductivity is attributed to coupling between the spin and charge degrees of freedom but not to the spin-charge separation for the low (two-) dimensional Mott insulator of present interest. Using the present studies of both the spin and charge dynamics, quantum phase transition point will be located in association with the predicted phase diagram. We find that the spin-charge coupling is essential to reproduce all of the aforementioned physical properties. To put it otherwise, coupling between the charge pairing order and the spin singlet paring order, i.e. the spin fluctuations of the shortest possible correlation length plays a key role for the observed high temperature superconductivity including the universal scaling behaviors mentioned above. In addition, defining a proper supercharge operator we find that a supersymmetric quantum mechanical condition is met only in the vanishing limit of the spin-charge coupling or both the spin and charge pairing orders, at which hole doping a quantum critical point may appear in the phase diagram of high temperature cuprates. In short, coupling between the spin and charge degrees of freedom will be shown to be responsible for the above areas of physics.

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