PC6-1-INV

Pseudogap and Superconductivity in Cuprate Superconductors Solved by Ab initio and Machine Learning Studies

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We first summarize how the *d*-wave superconducting and stripe states are severely competing in the simple Hubbard models, which is elucidated by using combined variational Monte Carlo, tensor network and Lanczos methods [1,2]. The result is not consistent with the experimental indications. On the other hand, *ab initio* Hamiltonian of carrier doped cuprates recently derived without any adjustable parameters [3,4] well reproduces the experimental phase diagram.

We next discuss renewed understanding of the superconducting mechanism. An experimental long-standing puzzle was the featureless structure in the spectral function indicated by the angle resolved photoemission spectroscopy (ARPES) spectra, in contrast to the case of conventional strong-coupling BCS superconductors in the history. We discuss how the puzzle has been solved with the help of quantum-cluster dynamical mean-field studies of the Hubbard model [5,6] and a completely independent machine learning studies purely based on the ARPES data [7]. An emergent dark fermion theory is discussed in detail [8].

This series of work has been done in collaboration with S. Sakai, M. Civelli, K. Ido, T. Ohgoe, A.S. Darmawan, Y. Nomura, Y. Yamaji, M. Hirayama, T. Misawa, and T. J. Suzuki.

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PC6-2-INV

Exotic electronic properties revealed in a clean CuO_2 sheet of multilayered high-T_c superconductor

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The T_c value in cuprates is sensitive to the number of CuO_2 layers per unit cell, and it is maximized in triple-layer systems. Significantly, the cuprates are categorized into two kinds according to the chemical situation of CuO_2 layers in crystal. One is single- and double-layer systems, where the CuO_2plane is adjacent to the dopant layer, which possesses random atomic vacancies, thus generally causes spatially inhomogeneous state in the underlying conduction sheet. The situation is changed in the triple and more layered systems (the second category), where inner CuO_2 planes are sandwiched by outer CuO_2 planes, thus protected from the outermost dopant layers. The cleanness in CuO_2 plane seems to get improved with increasing the number of CuO_2 plane per unit cell. In this study, we have particularly selected a five-layered system with lightly doped inner CuO_2 planes, which are ideally flat and homogeneously hole-doped, thus provide an excellent platform to unveil inhere properties of the lightly doped electronic state in cuprates. The investigation of this compound is especially significant since the electronic properties would share those of triple-layer systems, which commonly have the highest T_c in homologous series of cuprate families. I will present recent results of multilayered cuprates investigated by laser-based angle-resolved photoemission spectroscopy (laser-ARPES) with high energy and momentum resolutions.

PC6-3-INV

Visualizing the Cuprate Pair Density Wave State

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When Cooper pairs are formed with finite center-of-mass momentum, the defining characteristic [1,2] is a spatially modulating superconducting energy gap $D(\mathbf{r})$. Recently, this concept has been generalized to the pair density wave (PDW) state predicted to exist in a variety of strongly correlated electronic materials such as the cuprates [3,4]. It is also the fact that a possible presence of a cuprate PDW state emerges from recent experimental studies. An example of the observed signature is a spatial modulation of the Josephson current detected in Cooper-pair tunneling that is established by Scanned Josephson Tunneling Microscopy [5]. Another indication is obtained by a simultaneous imaging of the local-density-of-states $N(\mathbf{r},E)$ that reveals electronic modulations with wavevectors $\mathbf{Q}$=(1/8,0);(0,1/8) and 2$\mathbf{Q}$=(1/4,0);(0,1/4) inside a vortex core when a high magnetic field is applied [6]. These signatures are indeed anticipated when the PDW coexists with homogeneous superconductivity. In this talk, I will present the recent development of the cuprate PDW studies as stated above and discuss a possible role of the PDW in the cpurate.

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