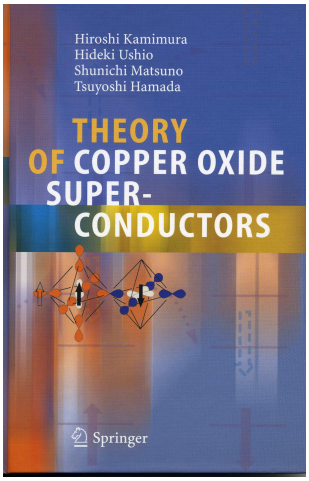
1 August 2005

Research on "Theory of Copper Oxide Superconductors"

Abstract

Whole results of the above research by Hiroshi Kamimura's group has been published in the book entitled "Theory of Copper Oxide Superconductors" by Hiroshi Kamimura, Hideki Ushio, Shunichi Matsuno and Tsuyoshi Hamada by Springer, Heidelberg, Germany in May of 2005. The cover of the book is shown below.



In this book the historical development of superconductivity, crystal structures of copper oxides (cuprates), anomalous properties of normal and superconducting phases and models of high temperature superconductivity (HTSC) are first reviewed for the sake of non-specialist readers. Then a special attention is paid to the Kamimura-Suwa (K-S) model among various theoretical models proposed for mechanism of HTSC. The following key features of the K-S model are explained in a comprehensive way: (1) Hole-carriers in the underdoped regime of cuprates form a metallic state, by taking the Zhang-Rice singlet and the Hund's coupling triplet alternately in the presence of the local AF order constructed by the localized spins. This creates the two-component theory of HTSC. In the formation of the metallic state in the K-S model it is pointed out that the local distortions of CuO_6 octahedrons or CuO_5 pyramids due to the anti-Jahn-Teller effect play an important role. (2) It is clarified that the appearance of superconducting as well as a metallic state in cuprates is inhomogeneous due to the finite size of a spin-correlation length. (3) By adopting the mean-field approximation for the exchange interaction between localized and carrier spins, the many-body effect included energy band, Fermi surfaces, the density of states, thermal, transport and optical properties can be calculated in a similar way to the case of a single-electron-type band structure. It is shown that a number of recent experimental results support the K-S model. In particular, the appearance of small Fermi surfaces thus calculated for LSCO is supported by recent results of the appearance of Fermi arcs in LSCO by ARPES experiments of Stanford group. Theoretical investigations for anomalous behaviour of electronic entropy reported by the Cambridge group clarify that hole-carriers in cuprates are anti-Jahn-Teller polarons", consistent with prediction by Bednorz and Müller who discovered HTSC in 1986 for the first time.

On the basis of the K-S model and the results of anti-Jahn-Teller polarons the mechanism of superconductivity in cuprates is discussed quantitatively. It is clarified that the characteristic phase difference of wave functions between up- and down-spin carriers in the K-S model leads to the selection rule that the electron-phonon coupling constants for up-spin and down-spin carrier can differ by a sign. As the direct consequence of this selection rule, the superconducting gap shows dx^2-y^2 symmetry for the homogeneous phase. Taking account of these facts the hole-concentration (x) dependence of Tc for LSCO is calculated by a strong coupling theory, and this result explains the experimental results quantitatively. The isotope effect of Tc is also calculated for LSCO. It is shown that the magnitude of the isotope effect varies with the hole-concentration.

References:

J.G. Bednorz and K.A. Müller, Z. Phys. B**64** (1986) 189

H. Kamimura and Y. Suwa; J. Phys. Soc. Jpn **62** (1993) 3368-3371

H. Kamimura, S. Matsuno, Y. Suwa and H. Ushio; Phys. Rev. Lett. **77** (1996) 723 – 726