SESSION 13

(September 29, 2000)

Stripes and electron-lattice interactions

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High-temperature superconductors: The magnetism mantra and the lattice litany

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A radical change of philosophy from traditional solid state and manybody approaches appears necessary to describe many classes of complex electronic materials, both inorganic and organic. This is evident from more than a decade of improving experimental data and failures of traditional interpretative frameworks. We conclude that multiscale complexity is fundamental to the science of synthesis-structure-property relationships in many complex electronic materials, including the transition metal oxides--high-temperature superconductors, colossal magnetoresistance manganites, and ferroelectrics. Measuring, modeling and using this complexity will be the basis for a new generation of technology.

Intrinsic, nanoscale patterning of spin, charge and lattice (and orbital) degrees-of-freedom (including filamentary “stripe” patterns) are key indicators of the complexity and the functionalities it carries. We describe: (1) several mechanisms responsible for this nanoscale patterning; (2) experimental signatures of these fibrillar “skeleton” patterns; and (3) possible macroscopic consequences, including inhomogeneous superconductivity and coexisting magnetism. We emphasize the collusion of magnetic and lattice fluctuations in this scenario, and the inescapable considerations of nonlinear, nonadiabatic and nonequilibrium properties.

Finally, we describe mesoscopic structural patterns intrinsic to the elastic nature of the these materials (twinning, tweed, etc.) We suggest that these scales and the stripe scales are intimately coupled through the same competitions of anisotropic short- and long-range interactions, arising from the directional bonding and polarizability at unit cell scales. This coupling of scales controls both the electronic polarizability and elasticity, and defines novel classes of “electroelastic” materials with essential relationships between multiscale complexity and function.

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LO phonon signature of charge inhomogeneity in cuprates observed by inelastic neutron scattering

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The results of neutron inelastic scattering measurements on cuprates, $La_{2-x}Sr_xCuO_4$ and $YBa_2Cu_3O_{7-\delta}$, indicate that the high-energy LO phonon branch shows an unusual dependence on composition and temperature. We found that the high-energy LO phonon along the Cu-O bond is split into two nearly dispersionless branches, one at a higher energy with intensity around the zone center, and the other at a lower energy with the intensity around the zone-edge. As the charge density in YBCO is increased the split dispersion stays unchanged, but the spectral weight shifts from the high-energy branch to the low-energy one. This behavior is best explained by invoking atomic-scale charge inhomogeneity in the sample. The inhomogeneity, however, may be different from that in the static stripe phase. The splitting becomes weaker at high temperatures. For the optimally doped YBCO the modification starts at T_C, while in the underdoped YBCO it starts around the pseudo-gap temperature. This observation suggests that the paired holes are inhomogeneously distributed in space. It also suggests that phonons are strongly interacting with the paired charge, and may be involved in causing pairing. The results of density matrix renormalization group (DMRG) calculations are presented to support this view.

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From incoherent to coherent long range atomic vibrations in the HTS phase diagram

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In spite of numerous experimental indications that the crystalline lattice should be involved in the physics of HTS, decisive features proving its relevance in the pairing mechanism remain to a large extent illusive. Most likely the coupling of the electrons to dynamical lattice deformations in these materials are in a cross-over regime between weak and strong coupling as well as between the adiabatic and antiadiabatic limit. It is for this crossover regime that the Boson-Fermion model was initially proposed. We review a number of experiments (optical, EXAFS, µsr, etc.), which clearly demonstrate that the lattice is involved in the formation of dynamically preformed electron pairs and their ultimate condensation which can be expected to trigger a long range coherence of the atomic motions. These features are studied on the basis of a generalization of the Boson-Fermion model in which the internal phononic degrees of freedom of the charge carriers are taken into account.

Keywords: *Polaronic effects, long range coherence of atomic vibrations, boson-fermion scenario.*

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Resonant inelastic X-ray scattering in cuprates

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Angle-resolved photoemission spectroscopy (ARPES) has been successful in studying the dispersion and other properties in the hole state below the Mott gap. On the other hand, the experimental methods to study the dispersion in the electron state above the gap, i.e., the upper Hubbard band (UHB), have been very much limited, and thus the momentum dependent properties in the electron state remain to be clarified.
Resonant inelastic X-ray scattering (RIXS) is developing very rapidly into a powerful technique to investigate elementary excitations in the strongly correlated electron systems. In the K-edge RIXS process, an incident photon with energy ω_i, momentum K_i and polarization_ε_i causes the dipole transition of an electron from 1s to 4p orbital in a transition metal ion. In the intermediate states, 3d electrons interact with a 1s core hole and a photoexcited 4p electron via the Coulomb interactions. Then, the 4p electron goes back to the 1s orbital again and a photon with energy ω_f, momentum K_f and polarization ε_f is emitted. The differences of energies ω_f-ω_i and momenta K_f-K_i together with the polarization dependence between incident and emitted photons are transferred to the 3d electron systems. Then, the information of the 3d electron systems such as the dispersion of UHB and the orbital states of 3d electrons is obtained.
Here, we would like to examine theoretically the processes of RIXS and the spectra in cuprates. The theoretical results are compared with the recent experimental data.

*This work has been done in collaboration with K. Tsutsui, H. Kondoh, S. Ishihara and T. Tohyama.

Keywords: *cuprates, Mott gap, resonant X-ray scattering.*

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