Spin Correlation in $La_{2-x}Sr_xCuO_4$ Studied by Neutron Scattering Measurement

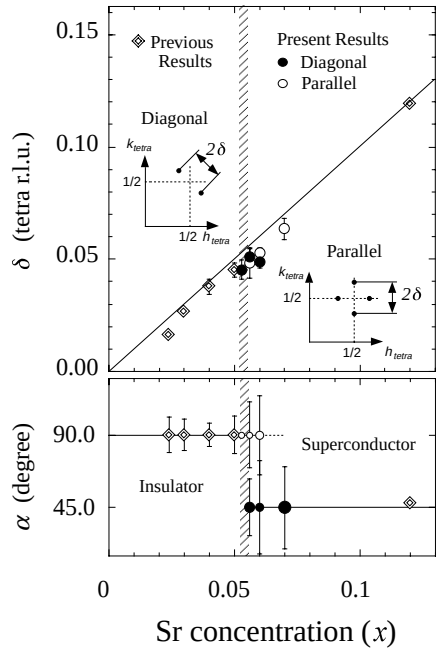
M. Fujita and K. Yamada

Systematic elastic neutron scattering study was performed on several single crystals of $La_{2-x}Sr_xCuO_4$ in the wide hole concentration. Incommensurate spin modulation in the CuO_2 plane exists in both the insulating and superconducting phases, however, the direction of modulaton vectors are different by 45degrees from each other. Both type of spin modulation possibly coexist around the lower critical concentration (x≈0.055) for superconductivity.

Keywords: static spin correlation/ neutron scattering/ high-Tc superconductor

The intimate connection between superconductivity and magnetism in the high-T_c copper oxide superconductors is one of the key issues to understand the mechanism of hith-T_c superconductivity. In order to clarify the relationship between the two, we have performed systematic elastic neutron scattering study on several single crystals of $La_{2-x}Sr_xCuO_4$ in the wide hole concentration range. Our recent research focusing on the spin correlation near the insulaor-superconductor phase boundary revealed a qualitative change in the direction of spin modulation.

In the insulating sample (x=0.053), we observed so-called diagonal magnetic component corresponding to the magnetic correlations modulated along the diagonal direction of the CuO_2 square lattice, consistent with our recent work.[1] On the other hand, all the superconductiong samples (x=0.056,0.06,0.07) show so-called parallel magnetic component corresponding to the modulation parallel to Cu-O-Cu line.[2-4] As a remarkable feature, the supercondunting sample in narrow concentration above the insulator-superconductor boundary exhibits the "diagonal" component in addition to the "parallel" one. For both the "diagonal" and "parallel" components, the incommensurability parameter δ, defined as the distance between the incommensurate the (π,π) positions in reciprocal lattice units of the "tetragonal" structure, follows a linear relation δ=x regardlessly of the insulator-superconductor boundary.



SOLID STATE CHEMISTRY — Quantum spin Fluids —

Scope of research

Quantum spin oxide system such as high-T_c superconducting cuprates, $La_{2-x}Sr_xCuO_4$ and $Nd_{2-x}Ce_xCuO_4$ are synthesized in the form of single crystals using traveling-solvent-floating-zone method. Detailed equilibrium phase diagram of Bi cuprate systems is investigated. Main subjects and techniques are: mechanism of high-T_c superconductivity: origin of quantum phase separation in strongly correlated electron systems: spin excitations in quantum spin systems: interplay between spin and charge flow in doped spin system: neutron scattering by using triple-axis as well as time-of flight techniques.

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Magnetic Excitations in the Electron-Doped Superconductor $Nd_{1.85}Ce_{0.15}CuO_4$

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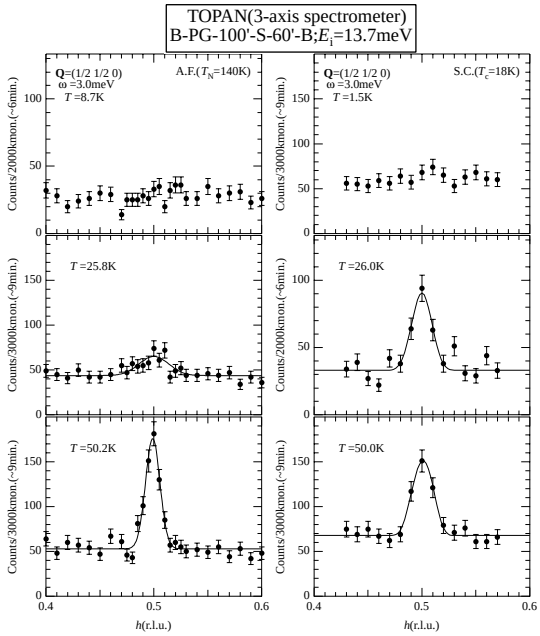
Neutron scattering on electron-doped high-Tc superconductor firstly observed well-defind spin flucations in the superconducting state. Similar to the hole-doped system, the spin excitations are gapped with the energy-gap of about 4 meV. However, the spacial spin correlation is commensurate in contrast to the incommensurate one in the hole-doped system.

Keywords: spin fluctuations/ neutron scattering/ electron-doping/ high-Tc superconductor

For the hole-doped high-T_c superconductor it is now established that the spin fluctuations coexist and closely correlate with the superconductivity. For the electron-doped system, however, many key experiments have been missing possibly due to the difficulty in growing single crystal and in preparing the superconducting sample by the post-growth heat treatment. In fact, previous neutron scattering measurements so far performed observed no well-defined magnetic signal in the superconducting (SC) phase.

We have succeeded in growing large single crystals of $Nd_{1.85}Ce_{0.15}CuO_4$ by using a TSFZ method. The as-grown crystal is antiferromagnetic insulator. With the heat treatment of the crystal bulk superconductivity appears below T_c=18 K. Neutron scattering experiments have been performed for both the antiferromagnetic (AF) insulating and the superconducting (SC) phases in (h k 0) zone. For the AF sample, we monitored (3/2 1/2 0) magnetic reflection in the tetragonal lattice to study the long range antiferromagnetic order. At low temperature below around 10 K the intensity of (3/2 1/2 0) reflection starts to increase rapidly due to the participation of Nd^{3+} spins in the magnetic order. As shown in Fig.1 (a), a sharp commensurate magnetic inelastic scattering peak was observed for AF sample at (1/2 1/2 0). For the SC sample, we newly observed a commensurate inelastic scattering peak at (1/2 1/2 0) . Compared with Fig.1(a) , the q-width of the peak is substantially broader than that of the AF phase. However, the q-integrated peak intensities of both samples are comparable except at low temperatures. Even in the SC phase, we observed a Bragg peak at (3/2 1/2 0) though the intensity is much weaker than that in the AF phase.

If the observed commensurate peak in the SC sample originates from the residual AF phase with the reduced volume and no magnetic intensity exists in the SC phase as in the previous work, it is very unlikely to observe comparable magnetic intensity as in the as-grown AF phase. Therefore, the commensurate peak is considered to be associated with the SC phase. However, the nature of the residual AF phase should be studied in more detail. The temperature dependence of the spin fluctuations is quite different between AF and SC phases. For the SC phase, *the energy as well as temperature dependence indicate an energy-gap of about 4 meV in the SC state.*



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