ELECTRON-HOLE SYMMETRY AND PHASE SEPARATION IN ELECTRON-DOPED CUPRATES

L.P. Gor’kov (FSU, NHMFL); G.B. Teitel’baum (E.K. Zavoiskii Institute for Technical Physics, RAS, Kazan, Russia)

Introduction

Since 1987 it was known [1] that the hole-doped high Tc cuprates must experience a phase segregation into a magnetic and a metallic components that would differ by their charge densities. However, such phase separation cannot occur on the macroscopic scale. Instead, to compensate for the broken electroneutrality in the presence of rigidly embedded ions of dopants, the phase separation must bear a microscopic character. If the spatial scale for these inhomogeneities is small enough, phase separation acquires a dynamical character: sub-phases appear and disappear locally on a short time scale, especially at higher temperatures. Coexistence of two components in the so-called pseudogap regime for LSCO and some other cuprates has recently been firmly established from the analysis of existing data on the $^{63}$Cu-nuclear spin relaxation in [2].

To wit, it turned out that the $^{63}$Cu nuclear relaxation rate can be decomposed into two independent dissipation mechanisms:

$$1/^{63}T_1(x,T) = 1/^{63}T_1(x) + 1/^{63}T_1(T)$$

The first term comes about from the incommensurate stripes fluctuations, while the temperature dependent component turned out to coincide with the $1/^{63}T_1(T)$ of the double-chain stoichiometric YBCO124. In this project [3] we have analyzed whether the phase separation may take place in electron-doped materials as well. We applied the same method [2] of decomposition as in eq.(1) of the available $1/^{63}T_1(T)$ data for a few electron doped materials. The latter are not so numerous as for the hole-doped ones. (For references see in [3]).

Results and Discussion

There are actually two sides of the problem for electron-doped materials. Indeed, the common believe is that all phenomena related to unusual properties of cuprates take place in the CuO$_2$—plane. Therefore, beside the question regarding inherent inhomogeneities, the second question concerns the electron-hole symmetry in the properties and energy spectra in the two classes. Our point is that one would not expect such a symmetry because at the hole doping holes go primary onto oxygen sites, while doped electrons should go directly on the Cu sites (i.e., transforming d$^9$Æd$^{10}$). This is in the agreement with the fact that superconductivity in the electron-doped superconductor Nd$_{2-x}$Ce$_x$CuO$_4$, for instance, is observed only above $x=0.18$.

Returning to the analysis of the NMR data, where they are available, we have noted that in some cases( Pr$_{2-x}$Ce$_x$CuO$_4$, for example) one can again decompose the relaxation rate into two components, as in eq(1), except that the temperature in the second term has the linear slope, as the Korringa law for a metallic phase. We then ascribe the temperature independent term to antiferromagnetic (AFM) fluctuations, using the fact that the analogous term for the hole-doped materials was quantitatively explained in[3] in terms of incommensurate AFM fluctuations. Unlike the hole-doped cuprates, AFM fluctuations in the electron-doped materials (where it has been measured) take place at the commensurate AFM vector. Our main finding is that for the so-called “infinite layers” compounds, Sr$_{1-x}$La$_x$CuO$_3$, the temperature dependent term in the decomposition (1) coincides identically with $1/^{63}T_1(T)$ for the hole-doped stoichiometric YBCO124. This unexpected result says in favor of the electron-hole symmetry in the “infinite layers” compound. Accordingly, we suggest that the T-independent term for this material may come about due to “stripes”-like fluctuations. Therefore, in the neutron scattering experiments that have not been done yet for this material, one should expect appearance of fluctuations at an incommensurate antiferromagnetic vector.

Acknowledgements

The work of L.P.G. was supported by the NHMFL, that of G.B.T. through the RFBR Grant N 04-02-17137.

References