ELECTRONIC TRANSPORT MEASUREMENTS UNDER UNIAXIAL PRESSURE IN CUPRATE SUPERCONDUCTORS

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INTRODUCTION

Despite the cuprates (copper-oxide superconductors) being under close scrutiny by the scientific community since their discovery thirty years ago, the phenomenon of high-transition-temperature (high-T_c) superconductivity arising in this class of materials remains unresolved. [1] The richness of the phase diagram originates from strong electron correlation effects, and an intrinsic complexity of these materials. Several coexisting (in some cases competing) phases, and differences in the crystal structures between individual compounds, make it difficult to ascertain the intrinsic and universal properties of the cuprates. One important problem to resolve is the nature of the pseudogap (PG), a regime at moderately low doping, where partial gaps open at the Fermi level, transforming a large hole-like Fermi Surface (FS) into disconnected Fermi arcs.

PHASE DIAGRAM OF THE CUPRATES – REVISITED

The cuprates are a group of compounds in which the common building block, the CuO_2 layers, are separated by material specific charge reservoir layers. The parent compounds are charge-transfer insulators, while various phases and regimes emerge upon doping, in particular superconductivity (Fig.1). In the hole-doped cuprates, superconductivity exists in a doping range between $p_{\min} \approx 0.05$ and $p_{max} \approx 0.3$. In the heavily overdoped regime, above $p_{\max}$, the cuprates exhibit characteristics of a conventional Fermi liquid (FL). For example, the electrical resistivity follows a quadratic temperature dependence, and a large, hole-like Fermi surface is experimentally well documented [2,3] and consistent with band structure calculations. [4] Upon decreasing the doping (below $p_{\max}$), T_c first increases to its highest value at optimal doping ($p_{opt} \approx 0.18$) and then decreases on the underdoped side of the phase diagram, to vanish below p_{min}. [1] In recent work, the electronic scattering rate $1/\tau$ was demonstrated to be quadratic in temperature, and universal (compound and doping independent). [5–7] This result implies that the PG emerges as an effect of a gradual localization of one carrier per unit cell, upon decreasing the doping and/or temperature, marked by T^{**} in Fig. 1. [8–10] This allows for a simple description of the evolution of the carrier density from $n = 1 + p$ at the overdoped side, to $n = p$ on the underdoped side. [3,11] The strange-metal (SM) regime, where the resistivity exhibits a linear temperature dependence, can be explained by evoking thermally excited charge carriers contributing to the electronic transport, effectively masking the underlying Fermi-liquid scattering rate.

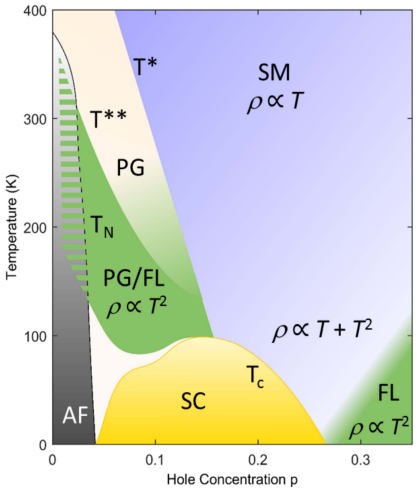

Figure 1: Generic resistivity phase diagram of the cuprates. [5]

SPATIALLY INHOMOGENEOUS LOCALISATION OF ONE CARRIER

The proposed phenomenological model is in its essence percolative, with small patches of the material becoming superconducting a few Kelvin above the actual T_c. Superconductivity results

from a coexistence of two electronic subsystems – itinerant holes and holes which are localised (in the PG regime one carrier per unit cell). [10] The latter subsystem is separated from the Fermi level by an energy gap which is inhomogeneous, both in real and momentum space. As the charge becomes localised (when traversing the phase diagram from high to low temperature/doping), the corresponding states at the Fermi level are being supressed, giving rise to the transformation of the large hole-like FS into Fermi arcs. Moreover, the localized carrier serves as the superconducting pairing "glue" for the itinerant electrons. However, the details of the microscopic mechanism responsible for the pairing/localization, where presumably the intrinsic structural inhomogeneity of the cuprates plays an important role, are still under investigation [12]. Therefore, our goal is to establish the relation between T_c and the details of the crystal lattice and its symmetry. To control these parameters, we developed a novel uniaxial pressure setup, which permits performing various measurements on a single sample while modifying its lattice symmetry. Results obtained from these measurements will be compared with the results from various compounds exhibiting distinct structures and distinct T_c's.

RESISTIVITY UNDER UNIAXIAL PRESSURE

I will present preliminary results of electronic transport measurements performed under uniaxial pressure in single crystals of $Nd_{2-x}Ce_xCuO_4$. This material has a tetragonal crystal structure, which we distort by applying uniaxial pressure within the *ab*-plane. According to the discussed phenomenological model, we expect this distortion to lower the T_c, as the tetragonal symmetry is lost. At room temperature, the *c*-axis resistivity decreases linearly with pressure, reverting to its original value upon releasing pressure. The superconducting transition shifts towards lower temperatures, in contrast to a general increase of T_c under isotropic pressure (Fig. 2). Thus, it is successfully demonstrated that superconductivity is affected by the structural changes of the lattice symmetry.

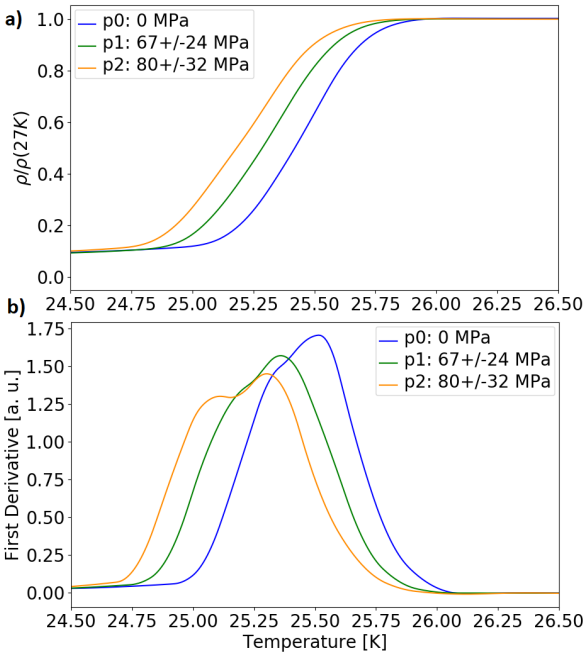

Figure 2: Variation of Tc with uniaxial pressure applied along the [100] crystallographic direction. (a) In-plane resistivity and (b) first derivative.

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