Two-dimensional electron localization in bulk single crystals of Bi_2Sr_2Ca_1-xY_xCu_2O_8

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TWO DIMENSIONAL ELECTRON LOCALIZATION IN BULK SINGLE CRYSTALS OF $Bi_2Sr_2Ca_{1-x}Y_xCu_2O_8$

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Abstract. The temperature dependence of the electrical transport was investigated on a series of single crystal $Bi_2Sr_2Ca_{1-x}Y_xCu_2O_8$ samples with a wide range of yttrium content. The observed metal-insulator transition is discussed in terms of two dimensional localization. The Hall effect and thermopower results indicate that the driving force of the localization is the random impurity potential.

There is an increasing interest in studing ultrathin films because they have revealed many interesting aspects of quantum fluctuations, Coulomb interactions and various phase transitions. An important observation is that the onset of the zero resistance state in the ultrathin films of different metals occurs when the normal state sheet resistance is close to a threshold value $h/4e^2=6.45k\Omega$ /1/.

Cuprate-based high temperature superconductors are known to have quasi two-dimensional electronic structure. This is especially true for the BISCO family, where, for example in $Bi_2Sr_2CaCu_2O_8$, the normal state resistivity anisotrpoy is in the range of 10^4-10^5 /2/. Upon doping this material, the superconducting transition temperature shifts down and exhibits a transition to an insulating ground state, so it is a good candidate to study the electron localisation in 2D. The advantage of this system is that the measurements could be done on *bulk* single crystals insted of ultrathin films.

We have performed a dc electronic transport study, thermoelectic power and Hall-efect measurements on single crystals of $Bi_2Sr_2Ca_{1-x}Y_xCu_2O_8$. The yttrium concentration in the crystals has been measured by X-ray fluorescence . The effect of Y doping is expected to be twofold. First, the introduction of Y^{3+} in place of Ca^{2+}, in the immediate neighborhood of the CuO layers, will lead to a random potential felt by the charge carriers. Second, The Y^{3+} ions take away holes from the conduction band, and reduce the carrier density.

The results of the resistivity measurements are shown in fig.1. One can observe the suppression of the superconducting transition temperature as

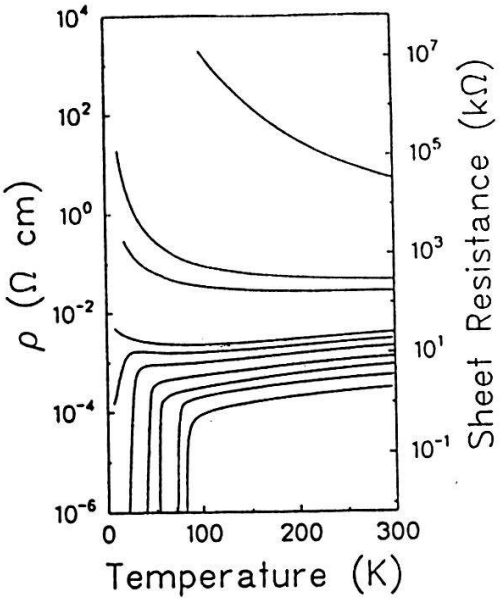

Fig. 1. Resistivity vs. temperature of $Bi_2Sr_2Ca_{1-x}Y_xCu_2O_8$ samples for x of 0, 0.20, 0.34, 0.38, 0.42, 0.44, 0.47, 0.51, 0.55, 0.80.

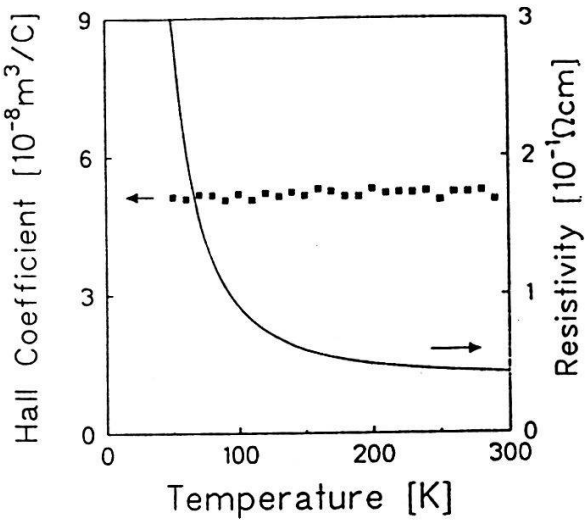

Fig.2. Hall coefficint and resistivity vs. temperature for the x=0.55 sample.

x was increased from zero to x=o.45. Above this concentration the samples are insulators at low temperature. The thermoelectric power of all samples approaches zero at low temperature, indicating that there is no gap or pseudugap at the Fermi energy. This is supported by the Hall coefficient (R_H) measurements. Fig.2 shows R_H for the x=o.55 sample: while the resistivity increases two orders of magnitude, R_H, that is the carrier density is constant.

We interpret the results in terms of electron localization, due the increase of impurity potential and the decrease of the hole bandwith upon doping. We argue that the structurally distinct copper oxide double layers (sandwiching the Ca(Y) layers) confine the electrons to two dimensions, and the localization is best characterized in terms of the sheet resistance of the sandwiches. The critical sheet resistance which separates the superconducting and semiconducting behaviour is at $8^{\pm}1\,k\Omega$.

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