THE SEARCH FOR A 1D METALLIC STATE IN $PrBa_2Cu_4O_8$

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Introduction

$PrBa_2Cu_4O_8$ (Pr124) is the non-superconducting analog of the bilayer double-chain high-T_c cuprate $YBa_2Cu_4O_8$. Substitution of Pr for Y completely suppresses superconductivity whilst preserving the metallicity of the double chains. Though charge transport in Pr124 is extremely anisotropic (t_b^2: t_a^2: t_c^2 ~ 2500:2:1), Pr124 develops a quasi-1D Fermi-liquid ground state below 50K with both $\rho_c(T)$ and $\rho_a(T)$ proportional to T^2 [1]. In July 2001, we measured $\rho_c(T)$ and $\rho_a(T)$ of Pr124 crystals in the 30 Tesla dc field facility in Tallahassee. Remarkably, $\rho_c(T)$ was found to become insulating once $\boldsymbol{B}//a$ exceeded a certain crossover field B_{cr}^c (~ 10T) [2]. This *field-induced dimensional crossover* arises from the slightly warped nature of the Q1D Fermi sheets of the double CuO chains. For $\boldsymbol{B}//a$, the dominant Lorentz force is directed along the c-axis, giving rise to an oscillatory c-axis component to the real-space trajectory with an amplitude A_c which shrinks as B increases until eventually A_c ~ c (= 13.6 Δ), the c-axis lattice spacing, and all carriers become confined to a single plane of coupled chains [3]. The value of the crossover field B_{cr}^c gives directly an estimate for the c-axis warping $2t_c$ ~ 50K, consistent with the temperature at which ρ_c first deviates from T^2 [1], i.e. when c-axis hopping first begins to lose coherence.

A similar coherent/incoherent crossover is also expected to occur in the reciprocal configuration $\boldsymbol{I}//a$ and $\boldsymbol{B}//c$ once the amplitude of oscillation of the real-space trajectory *along the a-axis* $A_a \leq a = 3.8\Delta$. In our original measurements at Tallahassee, no crossover was observed up to 30T. Indeed, $\rho_a(B) \sim B^2$ for the entire experimental field range. However, by extrapolating this B^2 dependence to *higher* fields, we estimated a *second field-induced dimensional crossover* might occur above B ~ 60T. (Note that since $a \sim c/4$, a much higher field is required to decouple the chains in the a-direction, even though $t_a \sim t_c$.) In order to confirm this possibility, we measured $\rho_a(B)$ in the 65T pulsed field facility in Los Alamos in January 2004.

Results and Discussion

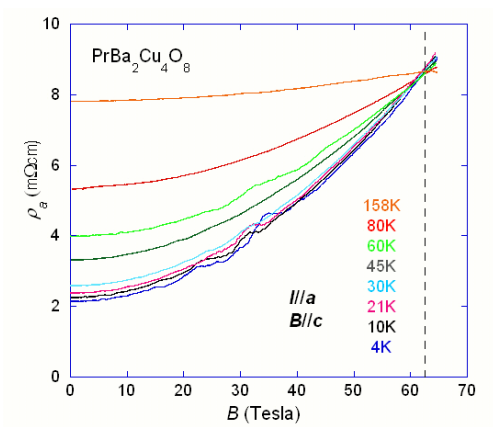

Figure 1. Pulsed field data for $\boldsymbol{I}//a$ and $\boldsymbol{B}//c$ at various T.

As one can see from the figure, *all* field sweeps eventually converge to a single point at B ~ 62T. $d\rho_a/dT$ is negative (positive) above (below) 62T respectively, indicating a *magnetic field-induced dimensional crossover* for $\boldsymbol{I}//a$. From the crossover field B_{cr}^a, we obtain an estimate for $2t_a$ ~ 70K. Again this is consistent with the onset temperature (T_{onset} = 75K) for incoherent transport along the a-axis (inferred from the deviation from T^2 resistivity) [1]. This result now establishes that a magnetic field can be used to tune the dimensionality of Pr124 and in a suitably tilted field (i.e. with $\boldsymbol{B}//a$ > 10T and $\boldsymbol{B}//c$ > 60T), a purely 1D state might be reached. We are planning to return to Los Alamos in 2005 to investigate the charge dynamics *along the chains* in this state of reduced dimensionality to look for signatures of Luttinger liquid behavior.

Acknowledgements

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References

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