Poster

Restoring superconductivity in hole-doped Pr_2CuO_4 via high-pressure phase transitions

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The hole-doped lanthanum cuprates, based on Ruddlesden-Popper n = 1 (RP1) La_2CuO_4, have attracted intense focus since the discovery of high-temperature superconductivity in $La_{2-x}Ba_xCuO_4$. The temperature vs doping level (x) phase diagram for these materials includes a region around x = 0.125 (1/8th) featuring a marked drop in superconducting critical temperature (Tc). This region is understood to coincide with both the emergence of charge density wave ordering, which seemingly competes with superconductivity, and a structural phase coexistence between the low temperature orthorhombic (LTO) and low temperature tetragonal (LTT) structures which arise from cooperative tilts of the CuO_6 octahedra present in the RP1 structure about the [110] (LTO) or alternating between the [100]/[010] axis (LTT). This structural phase coexistence is not observed in systems where the A-site cation size variance (σ_A) is low, e.g. $La_{2-x}Sr_xCuO_4$ [1], leading us to believe that σ_A acts as a chemical control parameter for tuning the phase separation. Thus, we have devised a model system, $Pr_{2-x}Ca_xCuO_4$, where σ_A is zero within the precision of the reported Shannon ionic radii, which should prove a promising candidate for gaining insights into the interplay of electronic properties and structure in these superconducting materials.

$Pr_{2-x}Ca_xCuO_4$ crystallises in the Nd_2CuO_4 type structure (T'), which differs from the K_2NiF_4 RP1 structure (T) adopted by the lanthanum cuprates most obviously in the lack of apical oxygen, leading to differing coordination of the Cu – four-fold in the T' and six-fold in the T (Fig. 1(a)) [2]. We have synthesised $Pr_{1.875}Ca_{0.125}CuO_4$ and shown by resistivity and susceptibility measurements that it is not superconducting but rather an antiferromagnetic insulator, similar to the undoped parent compound Pr_2CuO_4. This is not surprising as, typically, superconductivity is only induced in cuprates with the T' structure by electron doping, i.e. with Ce^{4+}. However, there are indications in the literature that Pr_2CuO_4 undergoes a high-pressure phase transition to the T phase at about 15 GPa [3] which, if we can replicate in our Ca doped system, should allow us to convert it to a structural symmetry where superconductivity can be stabilised.

Initial attempts to stabilise the T phase in our $Pr_{1.875}Ca_{0.125}CuO_4$ sample at high-pressure via *in situ* PXRD experiments have been undertaken. Using diamond anvil cells, we have measured up to 7 GPa with no transition observed, indicating higher pressures are required. Despite this there are several interesting features associated with the T' phase including neutron diffraction data showing the emergence of a single magnetic peak at low temperatures (Fig. 1(b)) which does not appear to have the same k-vector as the parent material which suggests the magnetic ordering has changed. High-resolution PXRD data shows increasing peak broadening with temperature suggesting unusual microstrain behaviour which could be indicating the onset of a phase transition.

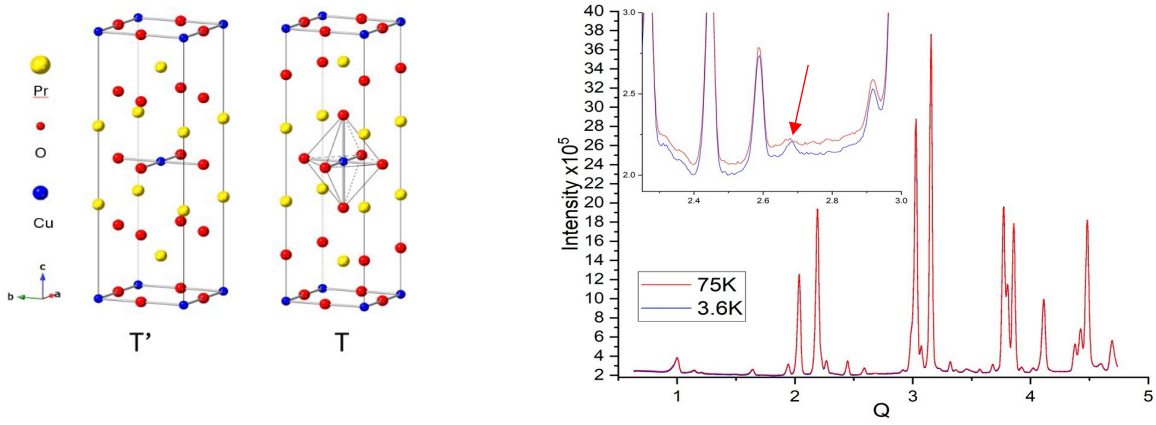

Figure 1. (a): schematics of the T' and T structures. (b): WOMBAT neutron data with inset highlighting the emerging magnetic peak.

[1] J. P. Tidey, E. -P. Liu, Y. -C. Lai, Y. -C. Chuang, W. -T. Chen, L. J. Cane, C. Lester, A. N. D. Petsch, A. Herlihy, A. Simonov, S. M. Hayden and M. Senn, Sci. Rep., 12, 14343 (2022)

[2] K. K. Singh, P. Ganguly and C. N. R. Rao, Mat. Res. Bull., 1982, 17, 493 - 500

[3] H. Wilhelm, C. Cros, E. Reny, G. Demazeau and M. Hanfland, J. Solid State Chem., 2000, 151, 231 – 240