Transport properties of superconducting electron doped $Pr_{2-x}Ce_xCuO_{4+\delta}$

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In contrast to hole doped cuprates, electron doped cuprates have smaller upper critical field H_{c2}. Therefore, superconductivity in electron doped cuprates is crucially influenced by scattering events. In electron doped cuprates, annealing process is responsible for the induction of superconductivity. Annealing is required to control the oxygen concentration δ. The occupation of excess oxygen at the apical site in the CuO_2 planes induces long range antiferromagnetic order even in optimally doped sample and destroys superconductivity [1]. Here, we reinvestigated superconducting and transport properties of so-called optimally electron doped cuprates. We synthesized high quality $Pr_{1.85}Ce_{0.15}CuO_{4+\delta}$ thin films on (100) $SrTiO_3$ substrates by molecular beam epitaxy. The films were annealed *in situ* under various conditions (temperature and time). We show that H_{c2} scales with residual resistivity ratio (RRR = ρ(300 K)/ρ(30 K)). Fig. 1 shows temperature dependence of magnetization for films with RRR = 10.5. The observed diamagnetic signal at 1.8 K is as large as −8.4 memu under ZFC condition, a suggestive of bulk superconductivity. Films with RRR ≥ 8 show reduced H_{c2} values as well as enhanced residual conductivity σ_{ab}. The evaluated superconductivity coherence length ξ_{GL} (= $(\Phi_0/2\pi H_{c2})^{0.5}$) and electron mean free path ℓ (= $h^2 d\sigma_{ab}(2\pi e^2 v_F m^*)^{-1}$, where d is distance between CuO_2 planes) significantly increase with RRR, as shown in Fig. 2. Since RRR can be controlled by annealing, these observations imply that intrinsic properties of electron doped cuprates suffer due to the occupation of apical oxygen even in optimally doped region.

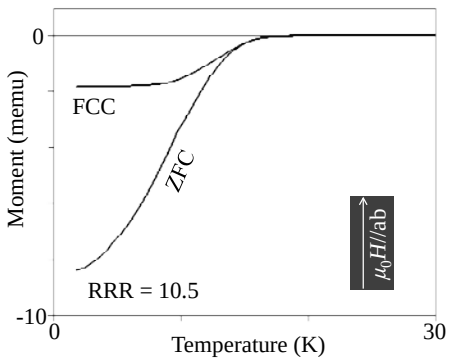

Figure 1. Magnetization as a function of T for film with RRR = 10.5. The external magnetic field (10 Oe) is applied parallel to the film surface.

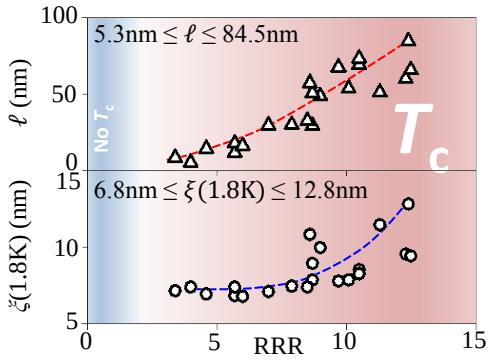

Figure 2. ξ_{GL} and ℓ as a function of RRR. ξ_{GL} and ℓ are estimated from H_{c2} and σ_{ab} at 1.8 K for $v_F = 4.3\times10^5$ m/s [2] and $m^* = m_e$.

[1] T.R. Thurston *et al.*, Phys. Rev. Lett. **65**, 263 (1990).
[2] N.P. Armitage *et al.*, Phys. Rev. B **68**, 064517 (2003).