Non-Linear Hall Effect in PCCO Electron-Doped Cuprate

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The Hall effect has been one of the most important tools used to explore the numerous differences between the p-type and n-type cuprates. In the conventional transport theory of metallic materials, the Hall resistivity is simply linear in field with the slope, the Hall coefficient, related to the density of charge carriers. Studying the evolution of the Hall coefficient as a function of temperature and doping in cuprates gave some crucial information on their major trademarks, about the charge carrier sign, the density but also the presence of major changes in their Fermi surface morphology. The Hall effect in electron-doped cuprates shows non-trivial behavior as a function of doping and temperature with a marked transition at x* ~ 0.17[1]. Another intriguing feature is the observation of two sign changes in $R_H(T)$ at two different temperatures of 40 and 260 K for $Pr_{2-x}Ce_xCuO_4$ (PCCO) at x = 0.17. One can use a two-carrier model to explain minimally, but not accurately, this temperature dependence of the Hall coefficient [2-4].
To extract even more information from the transport properties, we present a quantitative analysis of the non-linear field dependence of the Hall effect for PCCO thin films as a function of doping. High quality PCCO thin films are deposited by pulsed laser deposition and Hall bars are fabricated by photolithography. The structural characterization is done mostly using X-ray diffraction while the transport properties are carried out using a resistivity option of a PPMS. Hall resistivity as a function of magnetic field shows a non-linear behavior, easily evidenced at temperatures where R_H ~ 0, but present also at all temperatures. This non-linear contribution grows rapidly with decreasing temperature and is present for several doping levels around x = 0.17. By considering higher orders in the field dependence of $\rho_{xy} = AH + BH^3 + CH^5 + \ldots$ we extract *B* as a function T and doping and relate it to parameters of the two-carrier model. Results show that one needs to go beyond this simplistic model to improve our understanding of the band structure of these materials and the impact of the Fermi surface transformation as a function of doping.

References

[1] Armitage, N. P., Fournier, P. & Greene, R. L. (2010). Progress and perspectives on electron-doped cuprates. Rev. Mod. Phys. **82**, 2421-2487.
[2] Fournier, P., Jiang, X., Jiang, W., Mao, S. N., Venkatesan, T., Lobb, C. J. & Greene, R. L. (1997).Thermomagnetic transport properties of $Nd_{1.85}Ce_{0.15}CuO_{4+d}$ films: Evidence for two types of charge carriers. Phys. Rev. B **56**, 14149.
[3] Wang, Z. Z., Chien, T. R., Ong, N. P., Tarascon, J. M., & Wang, E. (1991). Positive Hall coefficient observed in single-crystal $Nd_{2-x}Ce_xCuO_{4-\delta}$ at low temperatures. Physical Review B, **43**(4), 3020.
[4] Greene, R. L., Mandal, P. R., Poniatowski, N. R., & Sarkar, T. (2020). The strange metal state of the electron-doped cuprates. Annual Review of Condensed Matter Physics, **11**, 213-229.