Role of quenched disorder in the phase diagram of cuprates

R. De Renzi, F. Coneri, S. Sanna, K. Zheng

Dipartimento di Fisica and Unità CNISM, Viale G.P. Usberti, 7A, I-43100 Parma, Italy

The effect of quenched disorder on the phase diagram of cuprates has been extensively studied in the $Y_{1-x}M_xBa_2Cu_3O_{6+y}$ structure, in the undoped-to-heavily underdoped regime that spans from the parent antiferromagnetic insulator $YBa_2Cu_3O_6$ to the marginal-Fermi-liquid or non-Fermi-liquid superconductors. We have investigated both the charged eterovalent (M=Ca) substitutions and the neutral isovalent (M=Eu, Nd) ones. Their hole concentration h, by thermopower, has in general two sources, eterovalent substituent cations and oxygen, $h = h_{Ca} + h_O$. The metal to insulator transition is governed by the hole concentration. The well known sudden reduction of $T_N(h)$ takes place at lower oxygen content in samples with increasing Ca substitution, indicating that all holes contribute to the disruption of the Neel state. The T_N drop gives way to a cluster spin glass state with much lower freezing temperatures T_g. Surprisingly, however, the carrier concentration that give rise to superconductivity coincides *exactly* [1] with the sole charges provided by oxygen (the y fraction in the chemical formula).

Another clear feature is the opening of a compositional window where short range magnetic order of the cluster spin glass type is the only ordered state, appearing at very low temperatures ($T_g \leq 20$ K). This window enlarges progressively with increasing degrees of disorder. The disorder itself may be quantified to a first degree by the variance of the ionic radii, $\sigma^2 = \langle r^2 \rangle - \langle r \rangle^2$, which is shown to behave as a third axis in the phase diagram. These findings agree with MonteCarlo simulations [2,3] in pointing out a transition from a clean to a dirty limit for the Mott-Hubbard treatment of the CuO_2 layers.

[1] S. Sanna et al., arXiv:0708.0710.
[2] E. Dagotto, Science 309, 257 (2005).
[3] G. Alvarez et al. Phys.Rev.B 71, 014514 (2005).