

Imaging power law distribution of mobile dopant ordering favoring high temperature superconductivity

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The control of multiscale phase separation near first order phase transitions is a paradigm for developing smart materials and complex functionality. HTcS cuprates are made of stacks of CuO₂ layers, intercalated by spacer layers hosting chemical dopants that contribute mobile carriers to the CuO₂ planes. Misfit strain between the spacer and CuO₂ planes lead to intrinsic lattice disorder. Electronic phase granularity at the nanoscale is well established but little was known at the micron scale, even while evidence is accumulating for control of superconductivity via dopant rearrangement at constant doping. A key limitation is that experimental probes of wave-number-resolved spectra such as photoemission and neutron diffraction do not provide spatially resolved information, while local probes like STM, and EXAFS do not provide wave-number-resolved information. We have investigated the prototypical, optimally doped layered cuprate with mobile dopants, La₂CuO_{4.1} using scanning synchrotron radiation x-ray microdiffraction, an emerging technique that reveals micron-scale fluctuations. The technique combines high wave-number resolution with micron-scale spatial resolution. The data reveal an unexpected type of heterogeneity following from the coexistence of 3D ordered and disordered domains of interstitial oxygen (i-O) in the La₂O₂ spacer layers. We discover a power law distribution, up to a maximum limiting size, of ordered i-O Q₂ domains, and that the limiting size is largest and hence the scale invariance of the distribution is optimized for a 40K superconductor among La₂CuO_{4.1} materials. The paradigms, which we employ for the first time within the rapidly developing field of x-ray microscopy, should also be applicable to the vast range of heterogeneous systems, from quantum matter to complex biological materials.

Reference:

M. Fratini, N. Poccia, A. Ricci, G. Campi, M. Burghammer, G. Aeppli, and A. Bianconi, Nature 466, 841 (2010). URL <http://dx.doi.org/10.1038/nature09260>