Correlated strain fluctuations in $BaPb_{1-x}Bi_xO_3$ promoting high temperature quantum coherence by novel Scanning-Micro-XANES

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Background

Although high temperature superconductors are complex materials it is an open question if complexity is detrimental or favors quantum coherence at high temperature. As a matter of fact, similar to cuprates, the bismuthate superconductors seem to be the archetypal systems to study the emergence of quantum coherence and lattice fluctuations. While the dimorphic composition of the $BaPb_{1-X}Bi_XO_3$ was found to be characteristic of the superconductive behaviour, the particular disorder, which promotes quantum coherence is not known.

In the present work we have used the specific feature of XANES spectroscopy to probe the local geometry at nanoscale of complex oxides [1-3] in order to get, for the first time, the statistical spatial distribution of the local lattice fluctuations in the $BaPb_{1-x}Bi_xO_3$ by using scanning micro XANES at the Bi and Pb L_3-edges.

Methods

Recently, novel experimental approaches, like scanning micro x-ray diffraction and scanning micro-XANES [4-6] have been developed to unveil the features of inhomogeneity extending from nanoscale to microscale. Since it is possible to map the spatial distribution of the sample surface using the scanning micro-XANES technique, our research has been focused to use this technique to investigate the real space distribution of the local lattice distortions as a function of doping and temperature. In particular, we used at ESRF in Grenoble, the ID24, a beamline equipped with an energy dispersive XANES spectrometer and a unique setup for real-space scanning and low temperature measurements with high quality data. Indeed, the lack of moving parts, due to the particular setup of the beamline, provides a small and stable focal spot ($\sim 5\times 5$ μm^2 at Pb and Bi L_3-edges and a photon flux of $\sim 10^{14}$ ph/s) necessary for the scanning micro-XANES [3].

Results

In order to span the superconducting dome three single crystals with x=0.19, 0.25 and 0.28 have been investigated as a function of temperature between 300 K and 5 K. Since XANES spectroscopy probes local structure around the photo-absorber, the Pb and Bi L_3-edge spectra of these crystals show clear differences of the bond length with picometer resolution going from one to another spot. By spatial mapping we have obtained the local strain fluctuations at the Pb and Bi sites. The chemical inhomogeneity and the strain inhomogeneity have been determined. We have found clear evidence for the coexistence of polaronic distorted and flat lattice portions [2,6] in the superconducting range. The key result of this work has been the evidence of a correlated disorder with a power law distribution in the low temperature superconducting case, which supports the emergence of the superconducting phase in a filamentary hyperbolic space. [4,7,8]

Conclusions

This work provides the clear evidence that micro-XANES represent a direct way to probe the statistical distribution of the local strain field in a superconducting crystal, with a picometer spatial resolution supporting the occurrence of lattice inhomogeneity in these systems [9,10].

1 A. Bianconi, S. Doniach, D. Lublin, Chemical Physics Letters 59 (1), 121 (1978)
2 A. Bianconi, M. Missori, Solid State Communications 91 (4), 287 (1994)
3 N. Poccia et al., Applied Physics Letters **104**, 221903 (2014)
4 G. Campi et al., *Nature* 525 (7569), 359 (2015)
5 N. Poccia et al., *Superconductor Science and Technology* 30 (3), 035016 (2017)
6 A. Bianconi, Nature Physics **9**, 536 (2013)
7 G. Campi et al., ACS Nano **12**, 729 (2018)
8 G. Campi, A. Bianconi, J Supercond. Nov. Magn. 29 (3), 627 (2016)
9 P. Giraldo-Gallo et al., J Supercond. Nov. Magn. 26, 2675 (2013)
10 P. Giraldo-Gallo et al., Nature Communications **6**, 8231 (2015).

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