The Quest for Underdoping

ARPES and resistivity measurements on $(Pb,Bi)_2Sr_2CaCu_2O_{8+\delta}$

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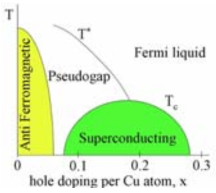
Introduction

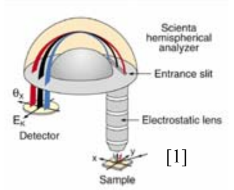
In this MSc. research project, the search for a reproducible method to underdope our TSFZ-grown Pb-doped Bi-2212 single crystals (see below) begun. With ARPES, resistivity and SQUID magnetometry measurements, post-anneals in different environments have been investigated. The underdoped state might shed light on the coupling mechanism that mediates superconductivity.



Phase diagram of a high T_c superconductor

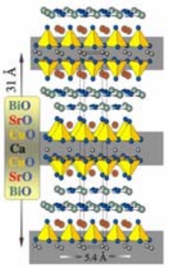
ARPES on $(Pb,Bi)_2Sr_2CaCu_2O_{8+\delta}$

- ARPES: k-resolved energy detection of photoelectrons
- HeI-α line (21,2 eV) excitation energy
- Measuring temperature: 25 K

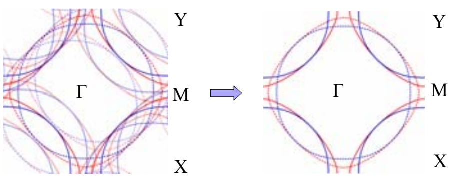


[1]

- Pb substitution of Bi (20%) lifts modulation in crystallographic b-direction:



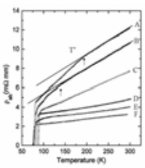
[2]



Fermi surface of Bi-2212 and (Pb,Bi)-2212

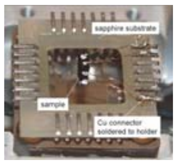
Resistivity

- Kink in ρ vs T due to opening of pseudogap



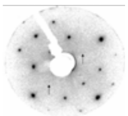
[3]

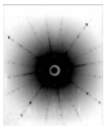
- Au evaporated pads (l) to contact (Pb,Bi)-2212 more stable than silver paste contacts (r)



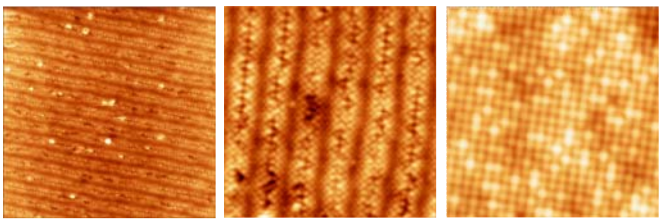
Crystal quality

- Home grown TSFZ single crystals
- Characterisation with SQUID, LEED and LAUE



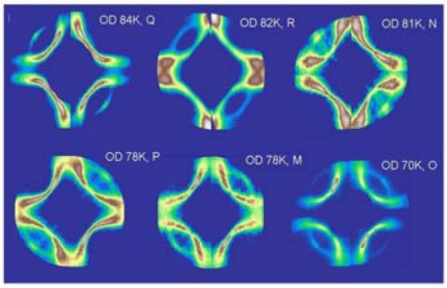


Typical LEED (l) and LAUE (r) image of (Pb,Bi)-2212

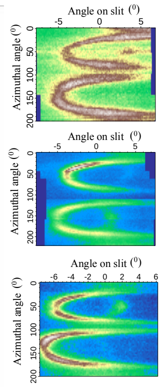


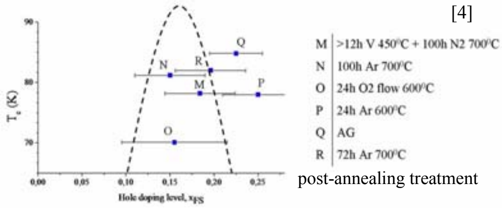
STM images (current research) of: Bi-2212 (left and middle) showing clear supermodulation and (Pb,Bi)-2212 (right) with a completely flat surface.

Results



[4]

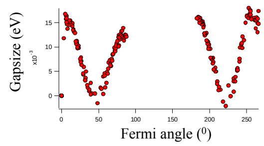




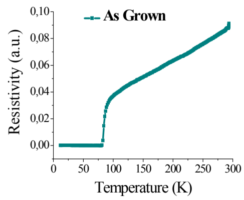
post-annealing treatment

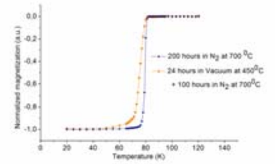
Uncorrected data of N (top), O (middle) and Q (bottom)

- Hole pocket area gives doping concentration
- SC gap analysis indicates absence of underdoping
- No kinks in ρ vs T observed

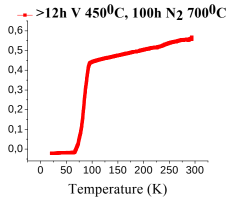


- Typical k-dependence of the gap (sample P)





- SQUID magnetometry curves for two different anneals. A very strong reducing anneal affects the crystal quality strongly.



- Resistivity curves, even a very strong vacuum anneal does not lead to a kink in resistivity above Tc.

Discussion

- Large error in doping concentration for some annealings due to very distorted as measured maps (i.e. large tilt)
- Trend points to overdoping of the samples
- Inability to underdope might be explained by self-doping due to dropping of Bi-O bands below Fermi energy – Hsin Lin et al., PRL **96**, 097001 (2006)
- 25% Pb doping used by Hsin Lin et al. in very good agreement with STM measurements and synchrotron data on our crystals

Conclusions

- Oxygen reducing anneals not sufficient to underdope our (Pb,Bi)-2212
- Pb doping might prevent easy reduction of hole content in CuO-planes
- Substitution of Y for Ca could be a solution: the first Y-doped crystals have already been grown

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[1] image from A.Damascelli, Physica Scripta **T109**, 61-74 (2004); [2] crystal structure of Bi-2212; [3] X.H.Chen et al., Phys.Rev.B **58**, no.21 14219 (1998); [4] Spectra are angle corrected and intensity normalised, T_c obtained from SQUID magnetometry measurement.