# *SESSION 12*

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# CuO chains in YBCO: Nature's 1D metal coupled to a 2D superconductor

A.L. de Lozanne[1,2], D. J. Derro[1], E. W. Hudson[3], K. M. Lang[3], S. H. Pan[3], J. C. Davis[3] and J. T. Markert[1]
[1]Department of Physics, University of Texas, Austin TX 78712-1081, [2]Texas Materials Institute, [3]Department of Physics, University of California, Berkeley, CA 94720.

We present detailed spectroscopic studies of the surface CuO chains in YBCO taken with a low temperature scanning tunneling microscope. Due to its one dimensional (1-d) character this surface is rich in nanoscale electronic phenomena. The 1-d nature of the electronic structure responds strongly to the local environment, including the presence of the superconducting $CuO_2$ planes, defects such as vacancies, twin boundaries, and steps. At low energies, the most striking spectroscopic feature in the local density of states is surprisingly *not* the gap (which is clearly present) but rather sharp resonances in the LDOS. Furthermore, the modulations in the LDOS that we have reported earlier have a characteristic wavelength and spatial coherence, both of which depend on energy in a non-trivial fashion. Some of this behavior may be consistent with the presence of stripes in the $CuO_2$ planes. The wealth of information we have obtained is also important for the interpretation of data obtained by ARPES, INS, NMR and other nonlocal probes in YBCO.

Keywords: *STM, spectroscopy, local electronic structure.*

A. de Lozanne
Department of Physics
University of Texas
Austin, TX 78712-1081, USA
phone: +1 512 417 6108/5544
fax: +1 512 471 6518/9637
e-mail: lozanne@Physics.utexas.edu

# STM measurements of the nanoscale spatial inhomogeneities in the quasiparticle spectrum of $Bi_2Sr_2CaCu_2O_{8-\delta}$

J. C. S. Davis[1], S. H. Pan[2], E. W. Hudson[3], K. M. Lang[1], V. Madhavan[1], H. Eisaki[4,5] and S. Uchida[4]
[1]Department of Physics, University of California, Berkeley, CA 94720, USA. [2]Department of Physics, Boston University, Boston MA 02215, USA. [3]Electron Physics Group, NIST, Gaithersburg MD 20899, USA. [4]Department of Superconductivity, University of Tokyo, Tokyo, Japan. [5]Department of Applied Physics, Stanford University, Stanford CA 94205, USA.

We present scanning tunneling spectroscopy measurements taken on the BiO surface of weakly impurity-doped cryo-cleaved $Bi_2Sr_2CaCu_2O_{8-\delta}$. The samples are near optimal O-doping with a typical $T_c$ ~ 85 K due to the impurity atoms. The differential tunneling conductance dI/dV is mapped for 50 nm square fields of view at energies ranging between –100 MeV and +100 MeV from the Fermi level. These dI/dV maps represent the spatial distribution of the local density-of-states (LDOS) at each energy. At low energy the LDOS is spatially quite homogeneous except for the effects of the impurity atoms. As the energy approaches the gap energy scale $\Delta \approx \pm 40$ MeV, the spatial distribution of LDOS becomes highly inhomogeneous with rapid changes occurring on the nanometer scale. Far above $\Delta$ the LDOS distribution returns to spatial uniformity. We discuss potential explanations for these nanoscale spatial inhomogeneities in the quasiparticle spectrum and their implications for the mechanism of superconductivity.

Keywords: *STM, spectroscopy, local electronic structure, inhomogeneity*.

J. C. Séamus Davis
[1]Department of Physics
University of California
Berkeley, CA 94720, USA
phone: +1 510 643 9090/4505
fax: +1 510 643 8497
e-mail: icdavis@socrates.berkeley.edu

# Possible charge and/or spin ordering in the Bi-2212, Y-123 and La-214 phases

Y. Koike[1], M. Akoshimat[1], M. Aoyamat[1], K. Nishimakit[1], T. Kawamatai[1], T. Adachi[1], T. Noji[1], I. Watanabe[2], S. Ohira[2], W. Higemoto[3] and K. Nagamine[23]
[1]Department of Applied Physics, Tohoku University, Sendai, Japan. [2]The Institute of Physical and Chemical Research (RIKEN), Wako, Japan. [3]Institute of Materials Structure Science, High Energy Accelerator Research Organization (KEK-MSL), Tsukuba, Japan.

Our recent experimental work on the so-called 1/8 anomaly in the Bi-2212 and Y-123 phases and also on the new anomaly in the La-214 phase is reviewed. In the partially Zn-substituted Bi-2212 and Y-123 phases, the muon spin relaxation measurements have revealed that the Cuspin fluctuations exhibit slowing-down behavior at low temperatures singularly at p ~ 1/8, where the superconductivity is suppressed to some extent. This result suggests that the dynamical stripe correlations of holes and spins exist in the Bi-2212 and Y-123 phases as well as in the La-214 phase and that they tend to be pinned by a small amount of Zn at p ~ 1/8, leading to the 1/8 anomaly. If this tendency is the case in a wide range of p, it is possible to understand the universal experimental results in the high-TC cuprates that Zn is a strong scatterer in the unitarity limit and that the Zn substitution markedly suppresses superconductivity. Furthermore, we have succeeded in growing a large-scale single-crystal of $La_{2-x}Sr_xCu_{1-y}Zn_yO_4$ with x = 0.21 and y = 0.01, in which the superconductivity is anomalously suppressed as well as in the crystal with x = 0.115 and y = 0.01. In the crystal with x = 0.21 and y = 0.01, the slowing-down behavior of the Cu-spin fluctuations has also been observed at low temperatures from the muon spin relaxation measurements. This suggests that the dynamical stripe correlations of holes and spins in the overdoped region of the La-214 phase are pinned by a small amount of Zn, leading to the anomalous suppression of superconductivity as well as in the crystal with x = 0.115.

Keywords: *1/8 anomaly, x=0.21 anomaly, muon spin relaxation, stripe, substitution effect, Bi2212, Y-123, La-214.*

Y. Koike
Department of Applied Physics, Tohoku University
Aoba-yama 08, Aoba-ku, Sendai 980-8579, Japan
phone: +81-22-217-7974
fax: +81-22-217-7975
e-mail: koike@teion.apph.tohoku.acjp

# Analysis of the Knight shift data on Li and Zn substituted $YBa_2Cu_3O_{6+x}$

N. Bulut
Department of Mathematics, Koc University, Istanbul, Turkey.

The Knight shift data on Li and Zn substituted $YBa_2Cu_3O_{6+x}$ are analyzed using an itinerant model with short-range antiferromagnetic correlations. The model parameters, which are determined by fitting the experimental data on the transverse nuclear relaxation rate $T_2^{-1}$ of pure $YBa_2Cu_3O_{6+x}$, are used to calculate the Knight shifts for various nuclei around a nonmagnetic impurity located in the $CuO_2$ planes. The calculations are carried out for Li and Zn impurities substituted into optimally doped and underdoped $YBa_2Cu_3O_{6+x}$. The results are compared with the $^7$Li and $^{89}$Y Knight shift measurements on these materials.

Keywords: *Knight shift, nonmagnetic impurities, moment formation, anti-ferromagnetic correlations*

Nejat Bulut
Department of Mathematics
Koc University
Istinye, 80860 Istanbul, Turkey
phone: + 90 (212) 229 3006 (ext. 570)
fax: + 90 (212) 229 0680
e-mail: nbulut@ku.edu.tr

# Bose- versus Bragg-glass stripe phase

C. Morais Smith[1,2], A. H. Castro Neto[3] and N. Hasselmann[2]
[1]Institut de Physique Théorique, Université de Fribourg, Pérolles, Switzerland, [2]Institut für Theoretische Physik, Universitat Hamburg, Germany, [3]Dept. of Physics, University of California, Riverside, USA.

We show that the main experimental features of co-doping in cuprates can be understood within models of lattice-pinned or disorder-pinned stripes. We divide the co-dopants into two classes: those which produce correlated and and those which produce uncorrelated disorder. Correlated disorder is produced through rare earth co-doping. In this case the stripes are pinned in a flat phase and the fluctuations are strongly suppressed. The effective stripe width is reduced and consequently the incommensurate (IC) neutron scattering peaks become sharper after the introduction of the co-dopant. In analogy to the vortex-creep problem, we call this phase the Bose-glass striped phase. On the other hand, in-plane Znor Ni-doping provides randomly distributed point-like pinning centers. Within our model, in which the stripe is regarded as a quantum elastic string, the effect of the randomness is to "disorder" the string, increasing the effective stripe width and broadening the IC peaks. Due to the similarity of this problem to the pinning of vortices by randomly distributed point-like defects (oxygen vacancies), we call this phase the Bragg-glass striped phase. Moreover, we expect this kind of pinning to be relevant only at low doping, in agreement with the experimental results. In addition, we propose that the isotope and pressure effects can also be understood within the same phenomenological model. Isotope substitution leads to a buckling of the oxygen atoms (due to the higher mass of the isotope), therefore increasing the effective lattice pinning potential. Analogously, by applying tensile stress to a sample, the ab-lattice constants increase, the hopping parameter t reduces and consequently the effective stripe mass $m \propto t^{-1}$ increases. Assuming that superconductivity is associated with stripe fluctuations, we can explain the reduction of the critical temperature $T_c$ due to codoping, pressure and isotope effects within the same model of stripes pinned by an effective potential. The results are compared with the available data and a good overall agreement is obtained between theory and experiment.

C. Morais Smith
Institut de Physique Théorique
Université de Fribourg
Pérolles, CH-1700 Fribourg, Switzerland
phone: 41 26 300 9146
fax: 41 26 300 9758
e-mail: Cristiane.demorais@unifr.ch