SESSION 10

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A possible non-uniform crypto-superconducting state in the superconducting ferromagnets: Ru-1212 and -1222

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A systematic study has been carried out on the structural, electrical and magnetic properties of Ru-1212 and -1222, which undergo a magnetic transition at Tm followed by a superconducting transition at a lower temperature Ts. the transition temperatures (Tm, Ts) are (133K, 30-45K) for Ru-1212, and (80-90K, 30-50K) for Ru-1222. These structurally pure, chemically homogeneous and electrically uniform polycrystalline samples of Ru-1212 and -1222 are characterized by the absence of a bulk Meissner state, presence of only a negligible condensation energy and an unusually large effective penetration depth. A possible crypto-superconducting state is therefore proposed. Such a state appears to have a non-uniform fine grain structure beset by ferromagnetic walls betweenantiferromagnetic domains, similar to the case of $NdNi_2B_2C$, or a non-uniform filamentary structure existing in the less magnetic domain walls between the ferromagnetic domains. The results will be presented and contrasted with the recently reported Meissmer effect in Ru-1212 in terms of the various possible phase transition sequencespredicted.

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Experimental look to the stripes and high-T_c superconductivity

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The static stripes realized in Nd-substituted $La_{2-x}Sr_xCuO_4$ are unique in that they are one-dimensional metals as evidenced by recent transport and photoemission experiments. Each stripe contains one hole per two Cu sites (i.e., quarter-filled) for *x* lower than 1/8, but does not show any instability such as the Peierls transition at low temperatures, suggestive of strong quantum fluctuations and /or weak pinning of the LTT lattice deformation induced by Nd.
The static stripe order competes with high-T_c superconductivity, although both orders likely coexist for *x* larger than 1/8. Thus, it is possible to control high-T_c superconductivity by suppressing or promoting stripe order. We discuss several canditates for stripe-control parameters such as ii) rare-earth substitution ii) Zn doping iii) magnetic field iv) O^{18} isotope substitution v) pressure.

Keywords*: metallic stripes, stripe control parameters, high-T_c superconductivity.*

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Superfluid density and magnetic order in stripe HTSC systems studied by μSR

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Zero-field (ZF) muon spin relaxation (ZF-μSR) can probe static spin freezing in the stripe HTSC systems. The Bessel function line shape, corresponding to an incommensurate spin modulation, was observed in several representative systems [1,2]. The frequency indicates static Cu moment of ~ 0.3 μ_B, while the amplitude of this signal represents the fraction V_M of muon sites belonging to the region with static spin freezing. For systems with $V_M < 1$, the superfluid density n_s/m^* can be measured by transverse-field (TF) μSR using the signal from "non-magnetic'" muon sites. Here we report our recent ZF- and TF-μSR studies in $(La_{2-x-y}Eu_ySr_x)CuO_4$ (LESCO) [3] and stage-4 $La_2CuO_{4+\delta}$ with $\delta = 0.12$ [4].
In LESCO with y = 0.1, x = 0.15, which shows static stripe freezing with V_M ~0.5, the superfluid density decreases to about 50\% of the value for pure LSCO (y = 0, x = 0.15), following an approximate relationship $n_s/m^* \propto (1-V_M)$. In a plot of T_c vs. n_s/m^*, the points from LESCO lie on the "universal" trajectory of hole doped 214 system. These features indicate that the charge carriers in the static stripe regions do not contribute to the superfluid, while T_c is determined by the volume averaged superfluid density. This situation is analogous to the "Swiss cheese model" in Zn-doped HTSC [5], and also to overdoped HTSC, suggesting importance of Bose-Einstein condensation.
In the stage-4 $La_2CuO_{4.12}$, V_M gradually increases with decreasing temperature below T_N ~42 K, from 0 to ~ 0.5 at $T \rightarrow 0$. A rather large superfluid density observed in TF-μSR indicate robustness of superconductivity. We will compare this system with other 214 systems in the T_c vs. n_s/m^* plot.

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μSR study on the Cu-spin dynamics of high-T_c oxides

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Muon spin relaxation (μSR) measurements have revealed the appearance of anomalous slowing down behavior of Cu spin fluctuations around the hole concentration, p, of about 1/8 per Cu in La-214 systems [1], Zn-substituted Bi-2212 systems [2] and also Zn-substituted Y-123 systems [3]. In order to investigate the dynamics of Cu spins, dynamical depolarization behavior of the muon spin was measured in external fields which were applied in the initial muon-spin direction. It has been found that the dynamical depolarization rate of the muon spin in the Zn-substituted Bi-2212 system around p=1/8 per Cu at 0.3 K is proportional to minus-square-root of the external field. From the analogy of results of μSR measurements on low-dimensional materials [4], this field-dependence can be explained by assuming the existence of an excited state of Cu spins diffusing along the one-dimensional spin-domain which is expected to be formed by the spin/charge stripe correlations.
Recently, a possibility of the existence of a spin/charge ordered state in the Zn-substituted LSCO system around roughly p=l/4 per Cu (in an overdoped region) was reported by one of our co-authors Koike et al. μSR measurements were studied as well and found the existence of a static magnetically ordered state of Cu spins below about 3 K. The minus-square-root field-dependence of the dynamical muon-spin depolarization rate was also observed at 3 K which is just above a magnetic transition temperature, indicating a possibility of the existence of the spin/charge stripe correlations in the overdoped region in the LSCO system.

Keywords: *μSR, spin dynamics, La-123, substitution effect, stripe.*

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Conducting electron strings in oxides

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We found that insulating and conducting electron strings may arise in oxide materials with not very wide bands, like HTSC, Manganites, Nickelates and others oxides due to short and long-range electron-phonon and electron-electron interactions [1]. We estimate the string length and the number of particles self-trapped into a single string taking into account the typical parameters of cuprates, like La_2CuO_4 and obtain that 7 holes will be trapped into the string with the length equal to N=40 interatomic distances or *about 150 Angstrom*. At low temperatures the electron strings may be ordered in CuO planes creating a nematic liquid crystal discussed by Bianconi, Kivelson, Emery and others. The striped phase in HTSC observed in numerous experiments may correspond to such a liquid crystal of conducting strings. With the doping of the antiferromagnet there arises only the change in the distance between the strings while the strings structure (like, the string doping n or the length N) is not changed. The metallic stripe phase arises due to a percolation over these strings when a density of such strings will be larger than the percolation threshold. For square lattices this threshold is well known and it is equal to x=.5 . Then, using our estimation for the string doping in La_2CuO_4 as n=7/40 we may readily get the hole doping δ=n x= .09 of the antiferromagnet at which the metallic stripe phase may arise. The spin-spin and hole-spin correlations will slightly change this result.

Keywords: *electron strings, stripes, oxides, electron-phonon and electron-electron interactions.*

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