From Cuprate to Nickelate: Evolution of the Normal State Properties with Ni from $La_{1.85}Sr_{0.15}CuO_4$ to $La_{1.85}Sr_{0.15}NiO_4$

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The nickelates $La_{2-x}Sr_xNiO_4$ are a model stripe system. They are isostructural with cuprates $La_{2-x}Sr_xNiO_4$ (LSCO), but superconductivity has never been observed in them. In this context, a systematic examination of evolution of the normal state properties when Cu is replaced by Ni in LSCO may shed some light onto the problem of correlation between pseudogap in the normal state and superconductivity.

In this work we present results of the X-ray, the resistivity and the magnetic susceptibility measurements carried out on optimally doped cuprate with Ni impurity, $La_{1.85}Sr_{0.15}Cu_{1-y}Ni_yO_4$ (LSCNO), $0.00 \leq y \leq 1$. Over 40 ceramics samples were prepared with the use of a conventional solid-state reaction method. X-ray powder diffraction analysis have shown that all samples crystallize in tetragonal (SG *I*4/*mmm*) structure and include none additional phase. The lattice constants, *c* and *a*, change linearly with Ni content, y: *c* decreases with rate 6×10^{-3} Å (i.e. 0.05% *c*) per 1% of Ni and *a* increases with rate 8×10^{-4} Å (0.02% *a*) per 1% of Ni. The free atomic position and bond distances also show smooth variation with the Ni content.

The normal-state resistivity vs. temperature dependence evolves from the metallic-like for small y to a hopping behavior (described by Mott's law with the exponent ¼) for samples with y>0.07.

The susceptibility measurements were carried out in 1 kOe field and in the temperatures between 2 K and 400 K. Superconductivity disappears above y=0.054. For small y, the temperature-dependent part of magnetic susceptibility, $\chi(T)-\chi_0$, can be decomposed into two parts: χ_l describing the magnetic behavior of ½-spin antiferromagnetic lattice formed in the Cu-O plane and the Curie term C/T, which is attributed to a magnetic moment introduced by Ni ions. The analysis of the first part can be made in the terms of the universal empirical curve, proposed without parameterization independently by Johnston and Nakano long time ago, and below its maximum at T_{max} described quite well by G. Williams's model, as $\chi_l = A \cdot ([1-tgh^2(E_g/2k_BT)]$, where E_g is the energy below which the pseudogap in the spin excitation spectrum in the normal state opens up. The T_{max} increases with small Ni content, from 430 K for y=0 to about 480 for y=1.2%. At larger y the T_{max} remains almost constant and finally decreases abruptly above y=0.05 and disappears at around y=0.07. This is accompanied by simultaneous decreasing of the magnitude of the coefficient A. This indicates that the pseudogap closes at y only a bit larger than that at which superconductivity disappears. From y=0.09 to y=0.70 $\chi(T)$ is well described by Curie-Weiss function, $C/T+\theta$, with θ of the order of 10 K. Magnetic moment induced by Ni is constant for y>0.17 and equal to 1.65 μ_B per Ni.