Evidences of Static Stripe Order in $(RE)Ba_2Cu_3O_{6+x}$ Compounds

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Abstract

We have recently revealed that a stabilization of the orthorhombic crystal superstructure with 2a lattice period ($T_c = 50K$) in the $(RE)Ba_2Cu_3O_{6+x}$ compounds takes place at 300K within narrow interval 0,45 < x <0,65 and one is accompanied by jump of lattice parameter c and appearance of a plateau in the concentration dependences of electronic, magnetic and structural ptoperties versus x,connected evidently with pinning of dynamical stripe order of holes in CuO_2 layers with the hole concentration per Cu p=1/8 for x=0,5.We assume that 2a superstructure makes stripe order static,because this crystal structure is commensurable with period of the dynamic 1D space modulated spin-charge structures in the CuO_2 layers.

Key words: superstructure; static stripe; pinning; charge ordering

1. Introduction

Two mechanisms for producing stripe phases have been suggested the theories of doped Mott-Hubbard insulators: a Fermi-surface instability [1] and frustrated phase separation [2].The coupling to lattice distortions may also encourage the formation of stripes.Macroscopic charge phase separation has been observed in $high - T_c$ superconductors in many different experiments including direct high-resolution electron diffraction. The neutron- scattering experiments in $La_{1.6-x}Nd_{0.4}Sr_xCuO_4$, $La_{2-x}Sr_xCuO_4$, $La_{2-x-y}Sr_xNd_yCuO_4$ at x=1/8 have shown that the suppression of the superconductivity is associated with the formation of an ordered array of charged stripes.The plateau region around $T_c = 60K$ in the phase diagram of $YBa_2Cu_3O_{6+x}$ corresponds to a hole concentration of 1/8 for x=0,5 and may be also associated with charge ordering in the CuO_2 layers.Hence, the 1/8 anomaly could be an universal feature of the formation of an ordered array of charged stripes in cuprates.

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2. Experimental procedure and results

This complex study of electronic and magnetic properties of $(RE)Ba_2Cu_3O_{6+x}$ compounds was carried out at the temperature 300K and the frequency f=9GHz.Pellets of $(Y, Dy, Gd)Ba_2Cu_3O_{6+x}$ ceramics with various oxigen in indices 0,2 < x < 1,0 were obtained and calibrated by isobaric annealing of the initial homogeneous ceramic with y=7,0 in air at various annealing temperatures T_a in the range $400 - 950^oC$ until thermodynamic equilibrium was established and after which the ceramics was quenched in liquid nitrogen.The resonance method of the surface resistivity R(y) measurements was used.The pellets were placed in the centere of high-quality cylindrical cavity in the antinode of H_{011} mode magnetic component.The real part of the microwave dielectric susceptiblity χ_c was measured by the resonance method from the variation of the frequency of the cavity loaded with the powder sample.The EPR spectra were recorded on a "Radiopan" RX/E-2544 commercial apparatus.The imaginary part of the resonant paramagnetic susceptibility χ_{rm} is proportional to the integrated intensity of the EPR spectrum.

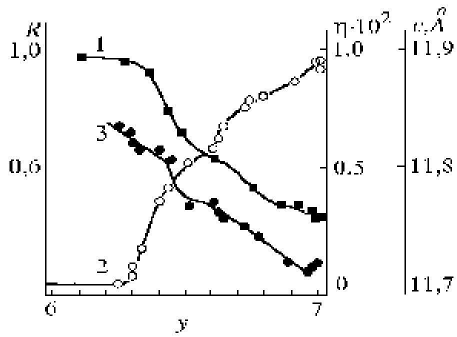

Fig. 1. The surface resistivity R(1), the orthorhombic lattice distortion parameter $\eta(2)$ and lattice parameter c(3) versus the oxygen index y=6+x in $YBa_2Cu_3O_y$.

As shown in Fig. 1 the crystal structure of $YBa_2Cu_3O_{6+x}$ at 0 < x < O.3 exhibits the tetragonal symmetry with lattice parameters a = b.The rhombic distortions, covered by parameter $\eta = (b - a)/(b + a)$, came into existence in the vicinity of x = 0.3 and then grew linearly with oxygen content increase until x = 0,45.The drop of surface resistivity R(y), the resonant paramagnetic susceptibility $\chi_{rm}(y)$ and lattice parameter c(y) was found near the critical value of oxygen index $y_{dm} = 6.4$.We suppose that these eleconic and structural singularities are connected with a dielectric-metal phase transition, which is induced by sharp buildup of free-carriiers concentration in CuO_2 layers.There is also intimate connection between the microwave resistivity changes and structural phase transitions in the dysprosium (Fig. 2) and gadolinium ceramics.

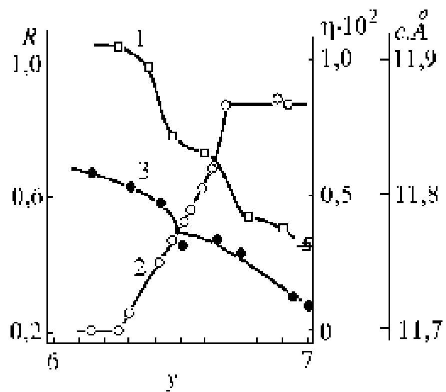

Fig. 2. The surface resistivity R(1), the orthorhombic lattice distortion parameter $\eta(2)$ and lattice parameter c(3) versus the oxygen index y=6+x in $DyBa_2Cu_3O_y$.

The stabilization of the orthorhombic crystal superstructure with 2a lattice period ($T_c = 50K$) in the $(Y, Dy)B_2Cu_3O_{6+x}$ compounds takes place according to Fig. 1, 2 at 300K within narrow interval 0.45 < x < 0.65 and one is accompanied by jump of lattice parameter c and appearance of a plateau in the concentration dependences of microwave resistivity R(y) and c(y).Such singularities are absent in the $GdBa_2Cu_3O_{6+x}$ samples.The same plateau was found in the vicinity of x=0,5 in $T_c(y)$, $\eta(y)$, dielectric and magnetic susceptibility versus y curves.We suppose that these singularities near x=0,5 are connected with dynamical stripe order of holes and spins in CuO_2 layers with the hole concentration per Cu p = 1/8.Evidently, that the superstructure with 2a = 7,68 A lattice period makes stripe order static, because this structure is favorable for pinning of the stripe order.

3. Discussion

According to the modern theories, a competition between phase separation and the long-range part of the Coulomb interaction leads to a charge-ordered phases, and especially stripe phases, which may be either ordered, quantum melted, or disordered by quenched randomness.The charge forms an array of metallic stripes, whose period is determined by the energetics of phase separation and is unrelated to any nesting vector of the Fermi surface.The charge structures, in turn, drive the modulation of the antiferromagnetic order.The assumption that in $(Y, Dy)Ba_2Cu_3O_{6+x}$ ceramics the static or slowly fluctuating stripe segments commensurated with the orthorhombic cristal superstructure with 2a lattice period exist at 300K for x = 0,5 provides a natural explanation for the unusual features of the concentration dependences of electronic, magnetic, and structural properties revealed in this paper.

References

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