

# First-Order Phase Transition of the Vortex Lattice in $(\text{La}_{1-x}\text{Sr}_x)_2\text{CuO}_4$ single crystals

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## Abstract

The first-order vortex lattice phase transition in  $(\text{La}_{1-x}\text{Sr}_x)_2\text{CuO}_4$  (La214) single crystals ( $0.046 \leq x \leq 0.077$ ) was studied by means of magnetization and resistivity measurements for fields parallel to the crystal  $c$ -axis. Distinct stepwise changes corresponding to the vortex lattice phase transition were observed in magnetization measurements. Resistive transition took place in both components along the  $a(b)$ -axis and along the  $c$ -axis at the same temperature where the transition was observed in the magnetization measurements. A scaling law,  $H_{\text{pt}}(T)[\text{Oe}] = 2.85\gamma^{-2}s^{-1}(T_c/T - 1)$ , which is based on the *decoupling* theory, was found to universally hold for the phase transition lines not only in the present La214 system but also in Y123 and Bi2212 systems [Sasagawa *et al.*, Phys.Rev.Lett.**80**, 4297 (1998)]. Here  $\gamma^2(\equiv m_c^*/m_{ab}^*)$  and  $s$  are the anisotropy factor and the superconducting layer spacing. The obtained remarkable scaling feature of the  $H_{\text{pt}}(T)$  lines provide strong evidence that the first-order phase transition in the high-temperature superconductors manifests itself as the *sublimation* (simultaneous *melting* and *decoupling*) transition of the vortex-lattice rather than simple *melting*. In other words, at fields and temperatures above the phase transition, the vortex lines split up into pancake-vortex gases with no correlation along the  $c$  direction.