Abstract

The origin of stable superconductivity in thin $YBa_2Cu_3O_{7-\delta}$ films and crystals is investigated by measering the dynamic resistivity $\rho'(\omega) - i\rho''(\omega)$ between 3 mHz and 2 GHz.

The critical temperature $T_c(\vec{B}\,)$ is very precisely determined from the intersection of isofrency phase angles ρ''/ρ'. The reduction of T_c by magnetic fields between 1 mT and 19 T is well described by the simple power law, $T_c(B)/T_c(0) = 1 - (B/B_0)^{1/\alpha}$. Both the exponent $\alpha = 1.33$ and the amplitude B_0 for $\vec{B} \parallel \vec{c}$ and $\vec{B} \perp \vec{c}$ agree well with the anisotropic $3D$-XY-model. The superconducting transition is presumably driven by topological fluctuations, i.e. thermal induced vortex-loops, which are below $T_c(B)$ smaller than the mean distance $a_0 \simeq \sqrt{\Phi_0/B}$ of field-induced vortices and reach a_0 at T_c.

Columnar defects with densities $B_\phi = n_\phi^* \Phi_0$ up to 2 T have no significant effect on the transition line $T_c(B)$. Only at higher defect densities the Bose-glass transition-line with $\alpha = 4$ predicted for linear-correlated pinning is found in fields $B \lesssim B_\phi$. Near B_ϕ the transition-line is well above the line of the pristine material. It is argued that in this case the density of columnar defects is higher than the density of defects which give rise to the XY-like transition-line with $\alpha = 4/3$.

In zero magnetic field the phase ρ''/ρ' at T_c is identical for films and crystals and indicates together with the continuous vanishing of the static resitivity $\rho_+(0)$ and of the superfluid density λ_-^{-2} by approaching T_c $3D$-ordering. The dynamic scaling function $\rho_+(\omega\tau)/\rho_0$ predicted by time-dependent Ginzburg-Landau-(GL)-theory considering $3D$-gaussian fluctuations of the superconducting order parameter is observed for $\omega\tau \leq 10^3$. For $\omega\tau > 10^3$ the scaling function deviates strongly from GL-dynamic, which indicates the effect of additional strong fluctuations. Surprisingly, the same scaling functions and critical temperature variations of $\rho_+(0)$ and λ_-^{-2} are found between 10^{-7} T and the highest applied field of 19 T. Together with the transition-line $T_c(B)$ this indicates the dominance of XY-like fluctuations.

Also in the presence of columnar defects the same gaussian scaling function is observed up to $\omega\tau \approx 10^3$. However, between 5 mT and B_ϕ the same power-laws of $\rho_+(0)$ and λ_-^{-2} are found as for the strongly twinned crystal, which were associated with correlated pinning at line-defects $\parallel \vec{c}$. The origin of the missing correlation between the transition-line and of the critical behavior of $\rho_+(0)$ and λ_-^{-2}, i.e. the combination of thermal fluctuations and intrinsic pinning, remains as a question.