Abstract

By measuring the dynamic conductivity parallel to the CuO_2-planes of single crystals and epitaxial films, the onset of superconductivity in the highly anisotropic high-temperature superconductor $Bi_2Sr_2CaCu_2O_8$ is investigated.

The temperature variation of the phase σ''/σ', measured between 3 mHz and 30 MHz, allows a precise determination of the superconducting transition T_c. The static conductivity and the frequency-dependence of the dynamical scaling function for $\sigma(\omega)$ provide strong evidence for 2D fluctuations occuring in a broad temperature range above T_c. At T_c a jump of the inverse penetration depth is found, which agrees with the prediction of the Kosterlitz-Thouless-theory for thin films, i.e. 2D-superconductivity. This leads to the assumption that the superconductivity is nucleated by the binding of thermally induced long vortex-antivortex strings piercing the samples. The finite value of the phase at T_c, $\sigma''/\sigma' = 13.5(2)$ differs from ideal 2D behavior and is tentatively associated with weak 3D-fluctuations in the layered structure of $Bi_2Sr_2CaCu_2O_8$. Columnar Defects, however, do not affect the 2D-ordering, but they reduce the phase at T_c to $\sigma''/\sigma' = 3.9(2)$. Since this value is identical to that found for $YBa_2Cu_3O_7$, which exhibits 3D-ordering, it is taken as evidence for 3D fluctuations on short lengthscales.

External fields as low as 1 mT applied parallel to the c-axis destroy the superconducting transition. A thermal activated vortex-dynamics characterized by plastic displacements in a highly viscous vortex-liquid is observed. At higher fields ($B > 2$ T) the vortex-lines dissociate in point-vortices. Interestingly, no phase-transition is found for $\vec{B} \perp \vec{c}$, which indicates that the intrinsic pinning of the CuO_2-planes can not stabilize the superconducting transition in a magnetic field. It is argued that this effect is caused by those fluctuations, which give rise to the finite phase-angle at $H = 0$.

Correlated pinning by columnar defects of density n_ϕ introduced by heavy-ion irradiation parallel to the c-axis, produces stable superconductivity for fields $\vec{B} \parallel \vec{c}$. Unlike the $H \rightarrow 0$ limit the superfluid density disappears continuously at T_g, and the critical singularities of the conductivity and relaxation time at T_g indicate 3D-ordering. As long as the density of the columnar defects is small, $B_\phi < B_{c1}$, the order-parameter fluctuations are isotropic and the temperature dependence of the phase-boundary $B_g(T)$ can be explained in terms of the 3D-XY model. At higher densities of defects, $B_\phi \gg B_{c1}$, the phase-boundary follows a prediction of the Bose-glass model for non-interacting vortices for fields between B_{c1} and B_ϕ. This is attributed to the strong localization of the vortices at the defects. Surprisingly, superconducting ordering is also observed for $\vec{B} \perp \vec{c}$ in the presence of the columnar defects, which signalizes a reduction of the local fluctuations in the CuO_2-planes, the origin of which is not known.