DETERMINATION OF $\lambda$ AND $\kappa$ IN A MOSAIC OF SINGLE CRYSTAL $\text{YBa}_2\text{Cu}_3\text{O}_{6.95}$


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We present transverse field $\mu$SR measurements of the magnetic field distribution in a mosaic of single crystal $\text{YBa}_2\text{Cu}_3\text{O}_{6.95}$ in high fields (1.9–6.5 T) applied parallel to the crystallographic $\tilde{c}$-axis. The $\mu$SR lineshapes are shown in detail and the results of fits to the lineshapes are summarized.

As discussed theoretically in another paper in these proceedings, [1] the vortex state of a type II superconductor produces a distinctive $\mu$SR lineshape with features determined by the magnetic penetration depth $\lambda$, the superconducting coherence length $\xi$ and the average internal field $B_0$. Only in the high field regime ($\lambda \gg L > \xi$, where $L = \left\{ (2\phi_0)/(\sqrt{3}B_0) \right\}^{1/2}$ is the intervortex spacing) do the vortex cores (of radius $\sim \xi$) occupy a large enough area that the field there is observable as a high field cutoff in the lineshape. Figs. 1 through 4 are the first measurements by any technique to date in a high temperature superconductor of this characteristic of the high field regime.

In the type II superconductor Vanadium, the fundamental superconducting properties such as $\lambda$ and the Ginzburg-Landau parameter $\kappa = \lambda/\xi$ are well known from other kinds of experiments, so Vanadium lineshapes measured by NMR [3] and $\mu$SR [4] are used to determine other things, such as the symmetry of the vortex lattice or whether muons diffuse in

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Vanadium. The high temperature superconductor YBa$_2$Cu$_3$O$_{6.95}$ has an extremely high value for $H_{c2}$ and an irreversibility temperature close to $T_c$, which makes determination of $H_{c2}(T)$, $\xi(T)$ and $\kappa(T)$ by many techniques, such as magnetization, extremely difficult. The penetration depth is determined as well, if not better, by $\mu$SR than by any other technique. Therefore, we chose to use the lineshapes in YBa$_2$Cu$_3$O$_{6.95}$ to measure the fundamental parameters $\lambda(T)$ and $\kappa(T)$. When fitting $\mu$SR lineshapes with the modified London model suggested by Brandt, [2] the determination of both $\lambda(T)$ and $\kappa(T)$ is only possible by simultaneously fitting data taken at multiple fields and the same temperature. [1] The solid curves in Figs. 1 through 4 are the results of these fits.

We will only summarize the results here; a more detailed description will be published elsewhere. In a mosaic of single crystal YBa$_2$Cu$_3$O$_{6.95}$ in high fields (1.9–6.5 T) applied parallel to the crystallographic $c$-axis, the parameter $\kappa(T)$ is found to be temperature independent with a value of $70 \pm 6$ (including both statistical and estimated systematic errors), over the temperature range 30 K to 75 K. This is the first measurement to date of $\kappa$ in the high temperature superconductor YBa$_2$Cu$_3$O$_{6.95}$ below the irreversibility temperature.

The low temperature value of $\lambda(10 \text{ K})$ is $1490 \pm 120$ Å (including both statistical and estimated systematic errors). The disorder in the vortex lattice, i.e. the root mean square displacement of each vortex from its position in the perfect lattice, is on the order of 5.5% of the distance between vortices, and does not appear to have a field dependence.

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References