# ANISOTROPY OF MAGNETIC PROPERTIES OF TEXTURED SUPERCONDUCTOR $Bi_2Sr_2CaCu_2O_{8-\delta}$

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This work was done with a sample prepared by vacuum induction zone melting /1/. The contamination of other phases was less than 1%. The sample was composed of 10 parallelepipeds $30\times7\times\times2.5\ mm^3$ in size. The average C axis direction was ortogonal to the parallelepiped plane and its dispersion was $\pm10°$ along the main parallelepiped axis and was $\pm17°$ along the direction perpendicular to it. The temperature of the transition to the superconducting phase was 84—85K and width of the transition region was about 7K.

The muon spin rotation experiments were carried out at the muon channel of the LNPI /2/. They were performed in the external magnetic field $H_{ext}=(0—33)$ mT which was directed either along the C axis ($H_{ext}\|C$) or parallels to the (a,b) plane ($H_{ext}\perp C$).

The results on the external magnetic field penetration into a sample volume /3/ showed that for ($H_{ext}\|C$) conditions the value of the first critical magnetic field was from 16 mT to 3.5 mT in the temperature interval (11—55) K. The value of $H_{c1}$ is less than 1 mT for $H_{ext}\perp C$. So $H_{c1}$ for $H_{ext}\|C$ is greater by 10 times than in the case of $H_{ext}\perp C$.

Orientation dependence is also seen in field-cooled measurements both for the value of a magnetic flux displacement (8 or 10 times) and for the dispersion of the magnetic field ($<\Delta B^2>$). As the precession damping rate (fig. 1) is caused by $<\Delta B^2>$ it is possible to calculate such a value as the penetration depth $\lambda$ of the magnetic field $2\sigma^2=\gamma^2<\Delta B^2>$ and $<\Delta B^2>=0.0037\Phi_0\lambda^{-4}$, where $\gamma$ is a gyromagnetic ratio of muon, $\Phi_0$ is a quantum of magnetic field $\Phi_0=2.07\cdot10^{-11}$ т $cm^2$. The penetration depth in the (a,b) plane is $\lambda_\perp(0)=3.4\cdot10^3$ Å (case $H_{ext}\|C$) and this data coincides with the results in reference /4/ where the sample was of ceramic origin. Since $\sigma_\perp\sim\lambda_\perp^{-2}$ pgv $\sigma_\|\sim(\lambda_\perp\lambda_\|)^{-1}$ then for our sample we get $\lambda_\|(0)/(0)\geqslant2.6$ and $\lambda_\|(0)>\geqslant8.8\cdot10^3$ Å.

It will be noted that unlike $\lambda_\|(T)$ the temperature dependence of $\lambda_\perp(T)$ is not in agreement with relation $\lambda(T)=\lambda(0)\,[1-(T/T_c)^4]^{-1/2}$ (fig. 1). This effect may be due to the strong pinning of the vortices. On the other hand a similar dependence $\sigma(T)$ was observed in reference /4/ where the external magnetic field was several times greater than in our measurements and the influence of pinning must be neglected. Therefore these properties may be the consequence of an anisotropy of superconductivity. There was also seen a declination of Abricosov's vortices about the external field direction as in the ceramic sample $YBa_2Cu_3O_{6,9}$ composed of large grains /2/. But in $Bi_2Sr_2CaCu_2O_{8-\delta}$ this effect takes place only in small external magnetic fields ($\leqslant5$ mT) because $H_{c1}$ is smaller and $\lambda$ is larger than in $YBa_2Cu_3O_{6,9}$.

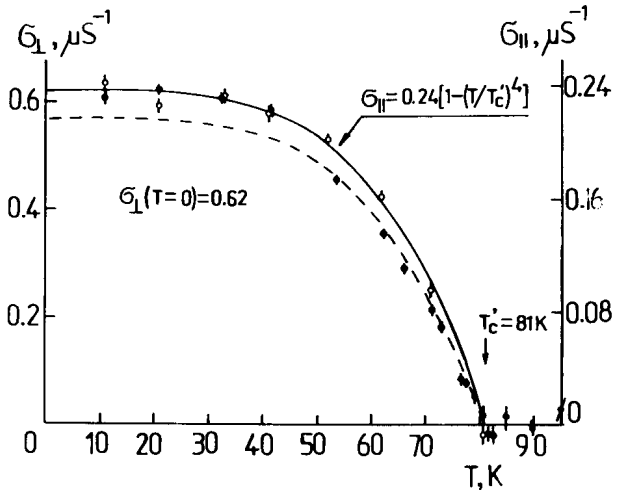


Fig. 1. Temperature dependence of $\sigma(T)$ due to magnetic field dispersion in vortice lattice:
$\sigma_\perp^2 = (\sigma^{Fc}(H\|C))^2 - \sigma_n^2$,
$\sigma_\parallel^2 = (\sigma^{Fc}(H\perp C))^2 - \sigma_n^2$,
$\sigma_\perp = 0.57(1-(T/T_c^*)^4)$

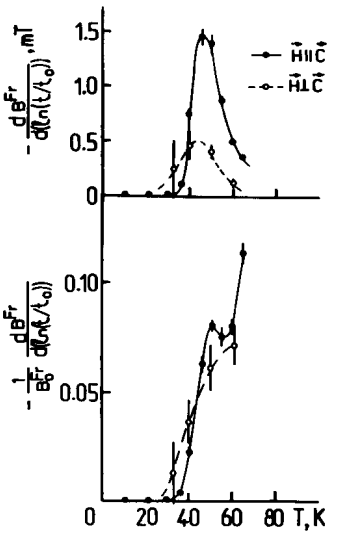


Fig. 2. Temperature dependence of absolute and relative rates of change of trapped field $B^{Fr}$.
$B_o^{Fr} = B^{Br}(t=t_0)$, $T_0=1$ min

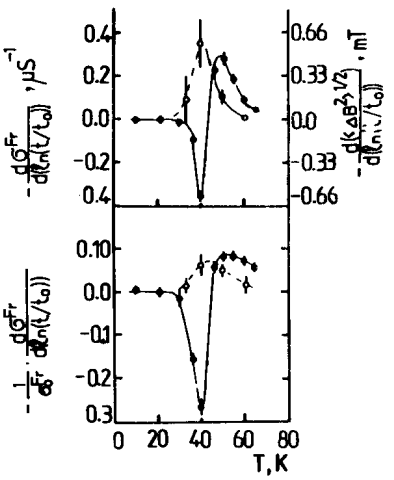


Fig. 3. Temperature dependence of absolute and relative rates of magnetic field dispersion $\sigma^{Fr}$.
$\sigma_o^{Fr} = \sigma^{Fr}(t=t_0)$, $t_0=1$ min

The anisotropy of superconductivity has influenced greatly on the magnetic flux trapping after the external magnetic field was switched off. In $H_{ext}\perp C$ and $H_{ext}=33$ mT the initial magnetic flux was not kept in the sample even at T=11K. In $H_{ext}\|C$ the trapped flux did not differ from the initial flux at $T\leqslant 35K$ but it decreased very quickly with the increase of the temperature. At $T>70K$ the trapped magnetic flux is practically absent. Such a temperature dependence of pinning was also observed in the ceramic sample $YBa_2Cu_3O_{6,9}$. But in the sample under investigation a time relaxation of the trapped flux takes place: the small changes of flux (>0.5%/hour) began at $T\geqslant 30K$ and they reached very big values (~50%/hour) at T=(40—50)K with a logarithmic time dependence.

The μSR-method permits to define not only the changes of the mean value of the magnetic field ($B^{Fr}$ in fig. 2) but also the change in the second moment $<\Delta B^2>$ of the magnetic field distribution (fig. 3) giving information about the process of departure of vortices from the superconductor. In the temperature range of (30—40) K the $<\Delta B^2>$ increases because the punning in different parts of the volume and the melting of the vortice lattice is not homogeneous. At higher temperatures the trapped magnetic flux seems to be very irregular at the first moment after $H_{ext}$ is switched off. But then both $B^{Fr}$ and $<\Delta B^2>$ decrease. This means that the trapped flux is not simply escaping the sample but will be more homogeneous over all the sample.

REFERENCES


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