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THE PENETRATION LENGTH λ, THE BULK CRITICAL FIELD H_{c1}, AND THE GEOMETRICAL BARRIER IN $Tl_2Ba_2CaCu_2O_8$ SINGLE CRYSTALS

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Magnetization curves of $Tl_2Ba_2CaCu_2O_8$ crystal were measured in applied fields up to 8 Tesla At temperatures above 25 K we observe reversible magnetization at high magnetic fields Equilibrium magnetization value was derived from these data. The penetration length λ and the bulk critical field H_{c1} were determined by fitting the theoretical curves to the reversible magnetization data The magnetization corresponding to the first maximum is much higher than the calculated value based on the measured equilibrium magnetization at high fields. We conclude that geometrical barrier effects change the magnetization curves drastically

The first critical field H_{c1} and penetration length λ are important characteristics of high temperature superconductors (HTSC) Due to the high anisotropy only single crystals and epitaxial films may be used for accurate determination of these properties

The usual critical state model derived for infinite cylinders or slabs [1] is inapplicable to plate-like single crystals or epitaxial films in perpendicular field and a more detailed analysis is required [2-4] It was noted in Ref [5] that the first critical field value cannot be obtained by estimating the magnetization curve deviation from the linearity and should be extracted rather as an intrinsic parameter of the whole curve especially in fields far from H_{c1}

The investigations were carried out on TlBaCaCuO single crystals with T_c in the vicinity of 110 K, which were grown from the melt in oxygen flow In this study a crystal dimensions of 1 1x0 7x0 07 mm^3 was used X-ray study of the crystals showed that they have a tetragonal symmetry with a=b=3.858 A, c=29 318 A All the measurements of the magnetization (M), as a function of field H or temperature T were carried out using the "Oxford" vibrating sample magnetometer (V)

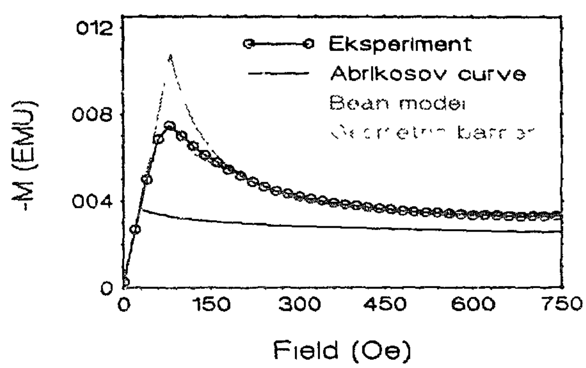

Fig 1 a) experimental magnetization curve M(H) at T=65K b) Calculated curve for the ellipsoid with the same dimensions (Abrikosov case, J_c =0) c) Calculated curve for bulk critical current (Bean model). d) Geometrical barrier

In Fig 1 we compare the experimental magnetization curve M(H) at T=65K with the different models Abrikosov case (Jc =0) Bean model, and geometrical barrier with bulk pinning

In perpendicular applied magnetic field the vortex penetration is delayed significantly due to the presence of potential barrier of geometrical origin [6] In order to extract penetration length and the thermodynamical first critical field we should analyze the reversible part of magnetization loops

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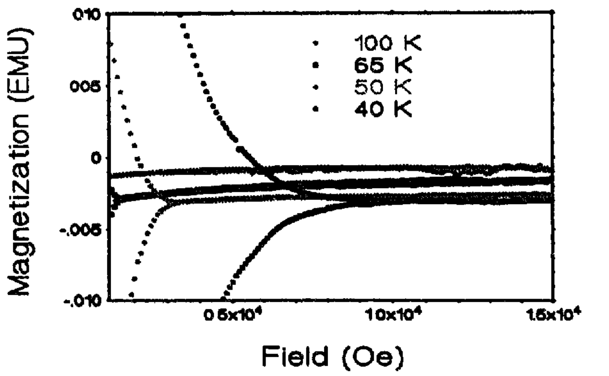

Fig.2 Magnetization curves of a high quality Tl-based crystal at various temperatures. Solid lines present calculated curves.

From the London theory, in the region $H_{c1}<H<H_{c2}$ the reversible magnetization is approximated by

$$-4\pi M=V\Phi_0 \ln(\eta H_{c2}/H)/8\pi\lambda^2$$

were $\eta=1$ and V is the volume of the sample. V is calculated from the slope of the magnetization curve for $H \| ab < H_{c1(ab)}$ through the relation $-4\pi M=HV$. This value is in a good agreement with the dimensions of the sample. Using $H_{c1}=\Phi_0 \ln(\kappa)/4\pi\lambda^2$ and the parameters $\kappa=70$, $\ln(\kappa)=4.25$, and $H_{c2} \sim 10^4(T_c-T)$ one obtains

$$M=1.2\ 10^{-6} H_{c1}[\ln(10^4(T_c-T))-\ln(H)]$$

The bulk critical field H_{c1} was determined by fitting the theoretical curves to the reversible magnetization data as shown in Fig. 2. The resulting $H_{c1}(T)$ and $\lambda(T)$ are shown in Figs. 3 and 4.

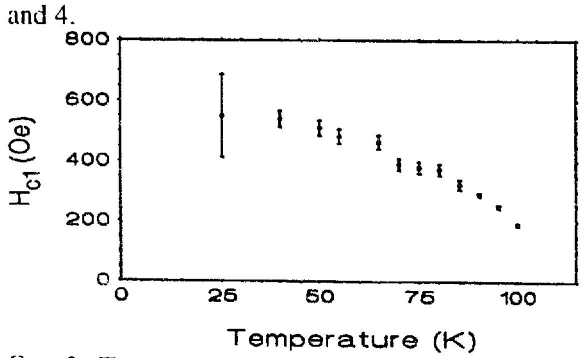

Fig. 3 Temperature dependence of the first critical field calculated using the measured equilibrium magnetization at high fields.

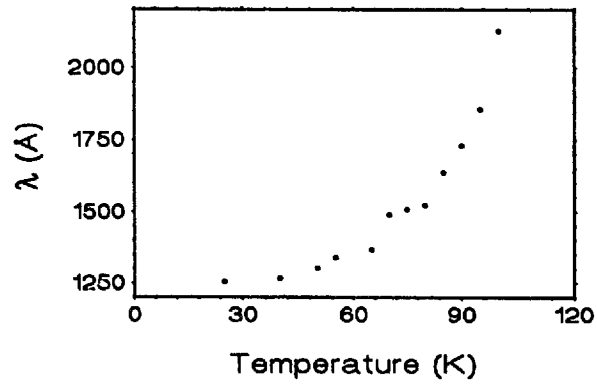

Fig. 4. Temperature dependence of the penetration length λ (T) calculated from $H_{c1}(T)$.

Thermodynamic values of the bulk first critical field of $Tl_2Ba_2CaCu_2O_8$ single crystals were obtained. The measured first penetration field is significantly higher than H_{c1} values obtained from fitting of the entire reversible part of hysteresis curve. Also the magnetization at the first maximum is substationly higher than the calculated value based on the measured equilibrium magnetization at high fields. These two effects are consistent with the presence of geometrical barriers. These geometrical barriers have a significant effect on the magnetization curves. We found that the vortices penetrate into a rectangular sample at significantly higher magnetic fields as compared to an ellipsoid of same dimensions. Vortices move to the center of the sample and accumulate there if the field near the edge of the sample exceeds H_{c1}. These conclusions are in agreement with our preliminary data of local field profiles measured using Hall-sensor arrays.

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