

Field dependence of critical current density in flat superconductor

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Abstract Surface field of a thin superconductor $\text{YBa}_2\text{Cu}_3\text{O}_{7-\delta}$ in the mixed state is measured by a Hall probe array. To reproduce the measured field profiles, shielding current distributions are determined by numerical iterative calculations without supposing any models for field dependence of critical current density $J_c(B)$. Though any model for $J_c(B)$ is not assumed for numerical calculations, the field variation roughly shows a dependence similar to Kim model.

Experiment

Sample : $\text{YBa}_2\text{Cu}_3\text{O}_{7-\delta}$

c-axis oriented epitaxial film

size $580 \times 3800 \times 0.8 \text{ } \mu\text{m}^3$

Micro Hall probe array:

GaAs doped with Si

10 elements

$10 \times 10 \text{ } \mu\text{m}^2$ active area

The sample is glued directly on the Hall probe array. Therefore a field component parallel to the c axis of the crystal is measured by the probe.

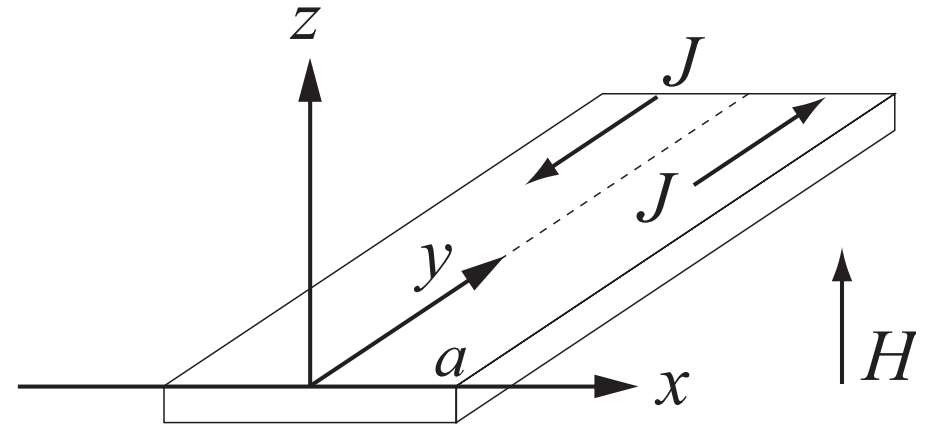
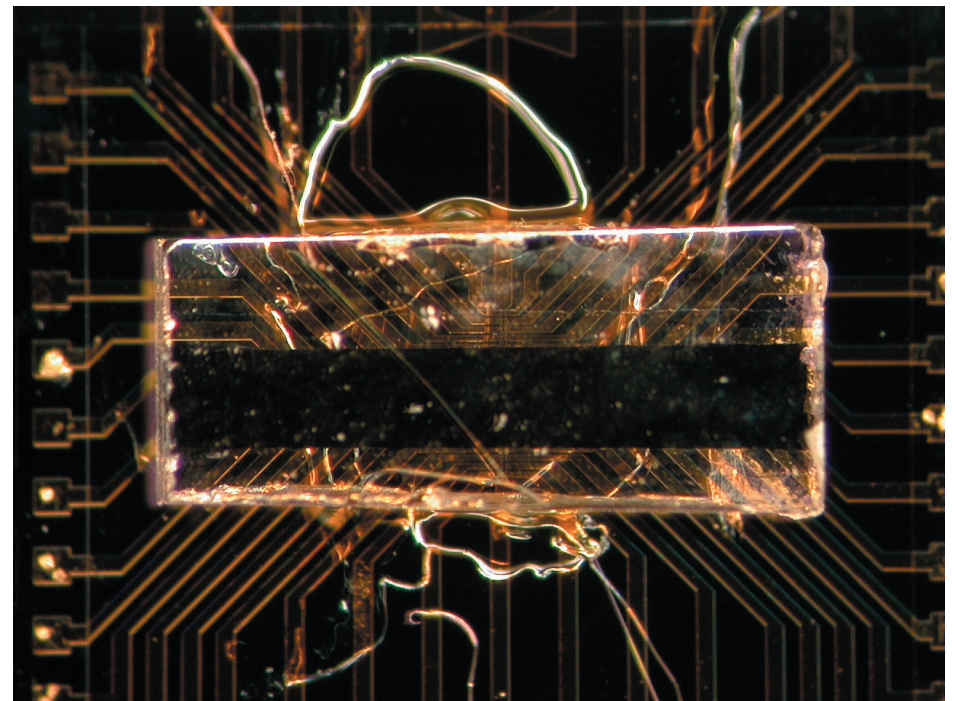


Figure 1 : Thin superconductor. The half width a is $290 \text{ } \mu\text{m}$.



Surface field measurements

The sample is cooled at zero field. External field H is once set to -5000 Oe and the field profiles are measured by increasing H .

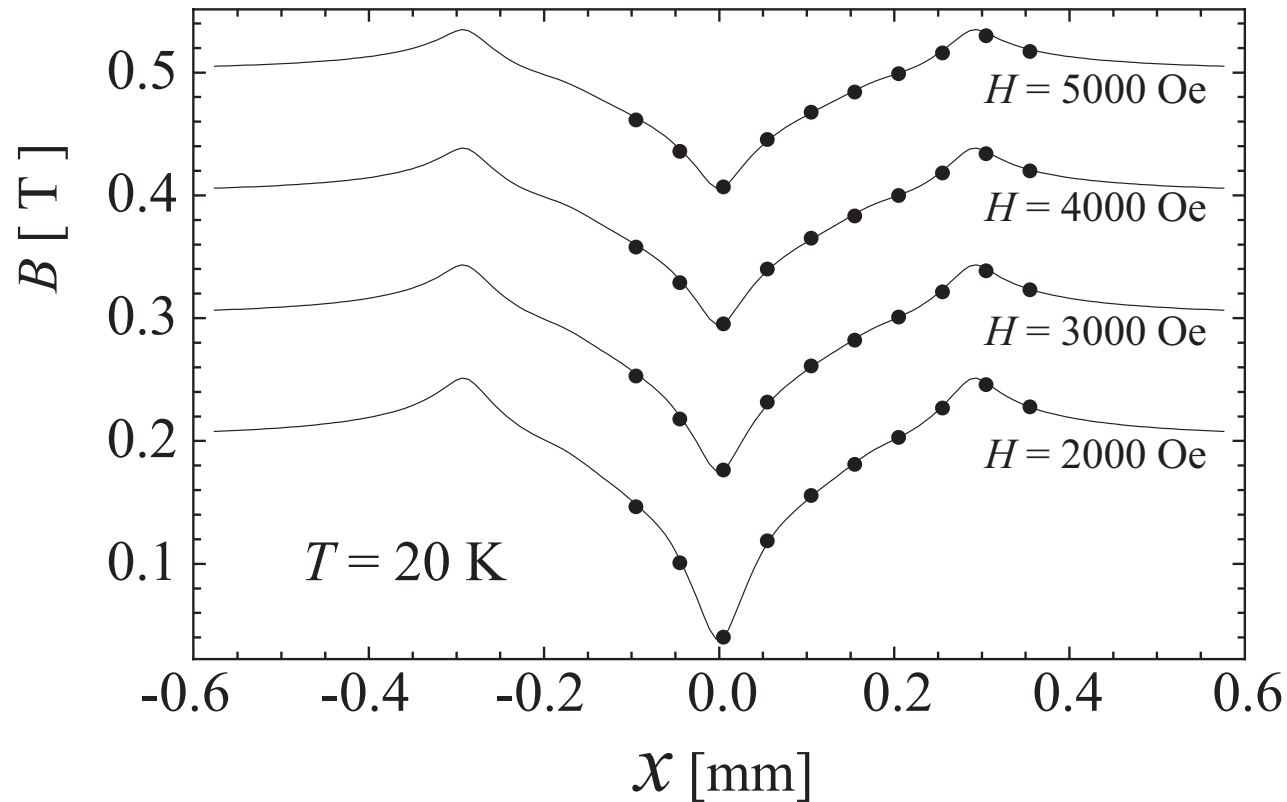


Figure 2 : Profiles of local field B at $T=20$ K. The solid curves show calculated local field B at $20\text{ }\mu\text{m}$ above the specimen surface.

Screening-current profiles

Figure 3 shows the screening-current profiles used for calculating B plotted in Figure 2. Each current profile is determined iteratively to reproduce the measured field profile without assuming any models for B dependence of critical current.

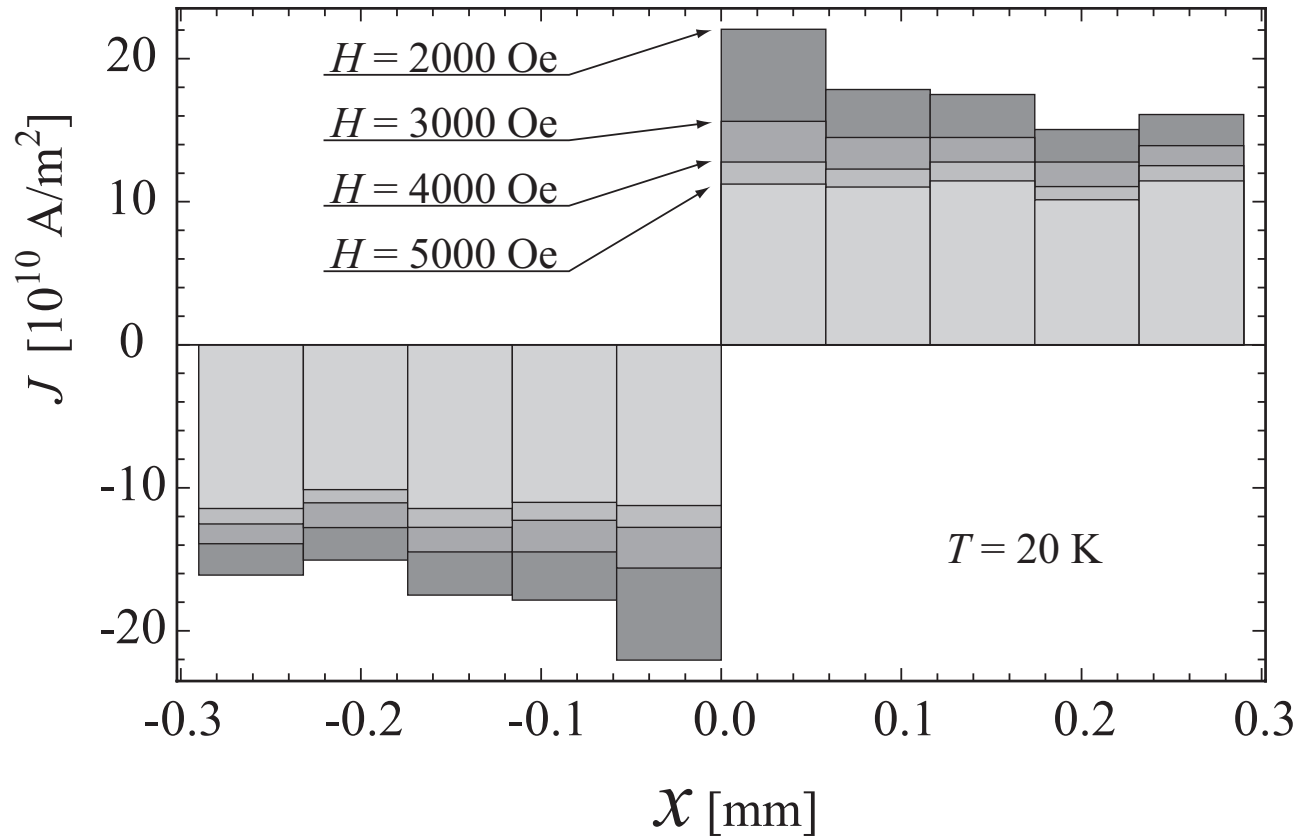
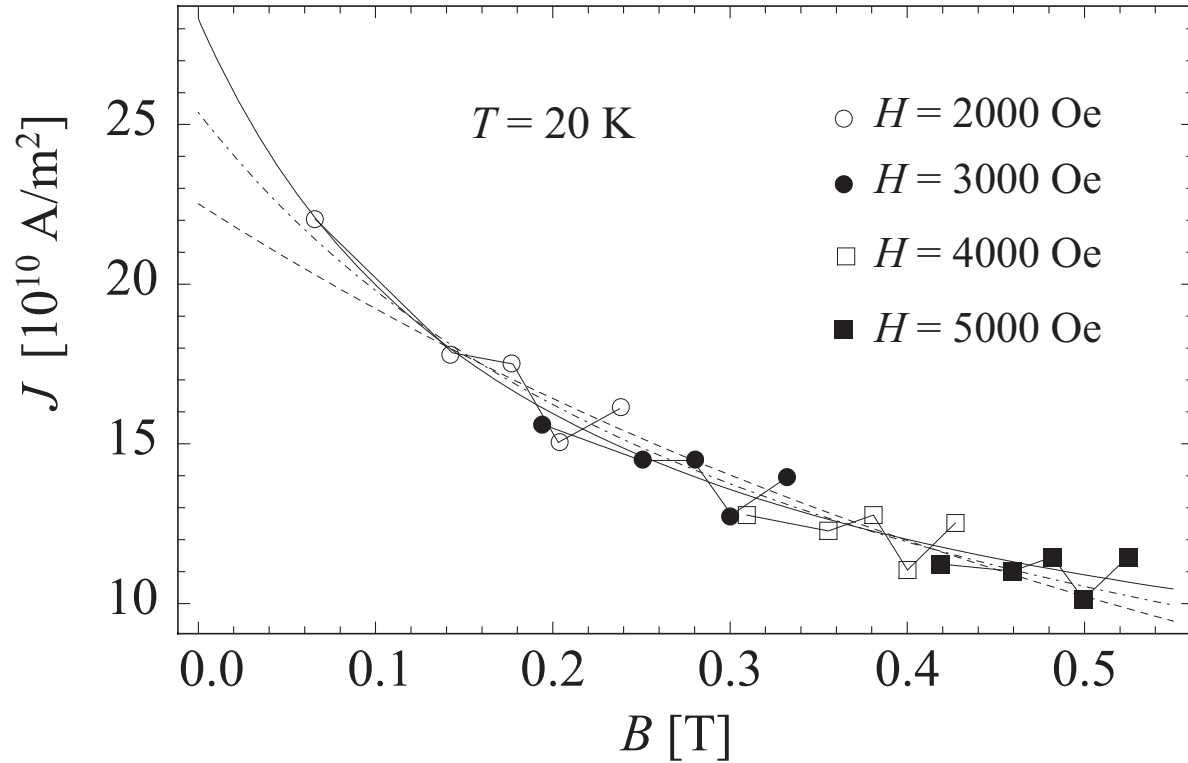


Figure 3 : Profile of calculated current density J at $T = 20 \text{ K}$.

Field variations of current densities

Local current densities J shown in Figure 3 are plotted in Figure 4 as a function of calculated B shown in Figure 2. Taking all plotted points into consideration, they are roughly fitted by the following modified Kim model.



$$J(B) = \frac{J_0}{1 + \frac{B}{B_0}} + J_1. \quad (1)$$

Figure 4 : Field variations of current densities at $T = 20 \text{ K}$. A solid line is modified Kim model, a dotdashed line is normal Kim model and a dashed line is exponential model.

Field variation of J at several temperature

Figure 5 shows field variation of J at several temperature T . The three parameters used in the fitting, B_0 , J_0 and J_1 , are summarized in Table 1.

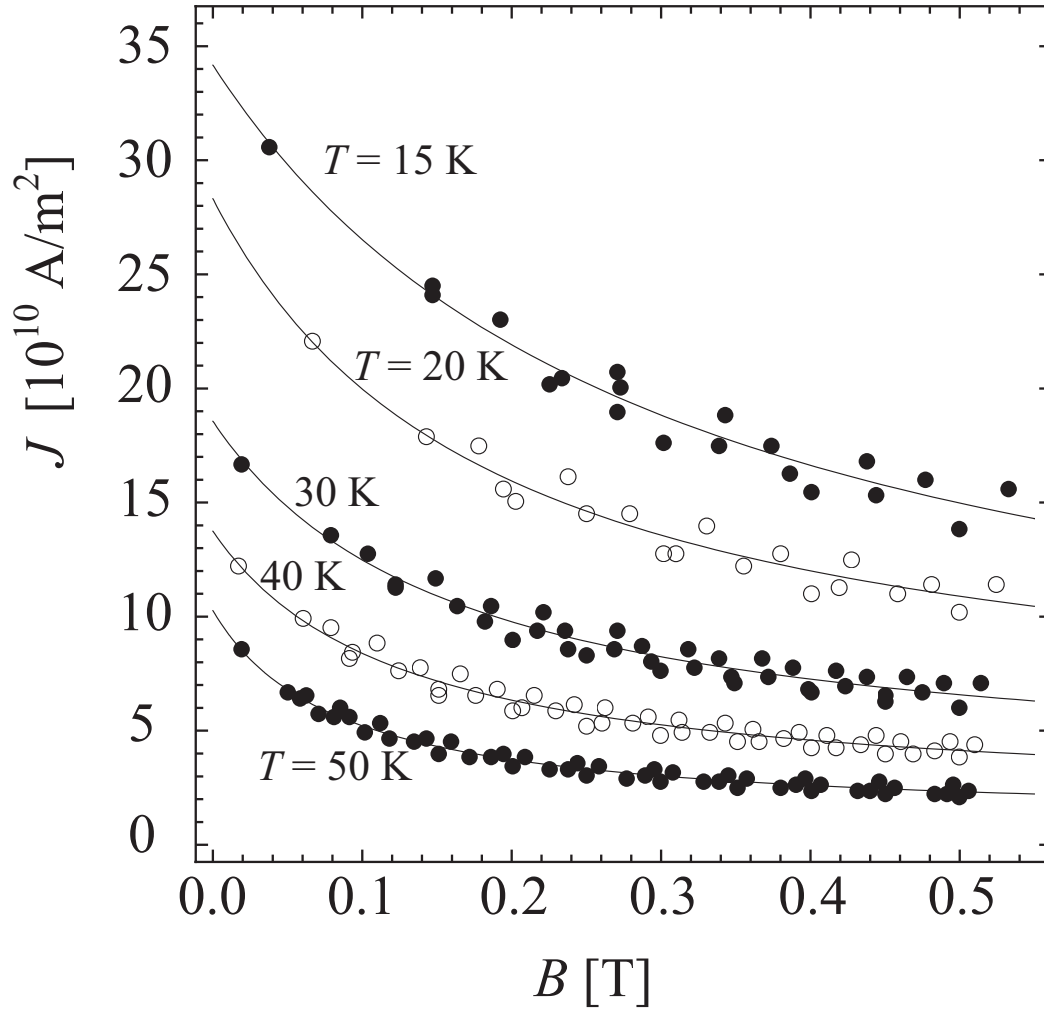


Figure 5 : Field variations of J at several temperature. Solid lines are fits using modified Kim model.

Table 1. Parameters used for fitting in Figure 5.

Temperature [K]	B_0 [T]	J_0 [10^{10} A/m ²]	J_1 [10^{10} A/m ²]
15	0.302	30.9	3.35
20	0.187	23.9	4.38
30	0.160	15.8	2.73
40	0.124	11.9	1.74
50	0.083	9.3	1.01

Conclusion

We have measured the surface field profile of a YBa₂Cu₃O_{7- δ} film in perpendicular field. Although any models for field dependence of critical current are not assumed, the field variations of current density is described by the modified Kim model. However calculated current profiles also show influence from uncertain origins other than the local field.