Pramāṇa – J. Phys., Vol. 31, No. 4, October 1988, pp. L343–L346. © Printed in India.

Magnetic field dependence of critical current density in $YBa_2Cu_3O_7$

P K MISHRA, G RAVI KUMAR, P CHADDAH, B A DASANNACHARYA and M K MALIK*

Nuclear Physics Division, *Atomic Fuels Division, Bhabha Atomic Research Centre, Bombay 400085, India

MS received 7 July 1988

Abstract. We have measured the transport critical current density J_c of sintered $YBa_2Cu_3O_7$, in various applied fields up to 185 Oe at 77 K. We find a sharp decay of J_c with magnetic field. We show that this sharp decay is consistent with the low field hysteresis results of Grover *et al.* We argue that the observed field dependence is not caused by intragranular weak links.

Keywords. Critical current density; magnetic field dependence; high temperature superconductivity.

PACS No. **74·60**

Superconductivity around 90 K in $RBa_2Cu_3O_7$ compounds has raised the possibility of applications at liquid nitrogen temperature. This requires critical current densities $J_c \geqslant 10^5$ A/cm^2, a value which is achieved at 77 K in single-crystal films but not in bulk-sintered samples. For large-scale applications, this J_c should not deteriorate in a magnetic field. We present results of our measurement of J_c in a sintered $YBa_2Cu_3O_7$ pellet, and find a sharp decay as the field is raised even in the region of 100 Oe. This is consistent with recent measurements of Jin *et al* (1987, 1988). Our results are also consistent with the low field hysteresis curves of Grover *et al* (1988a, b) on sintered and powdered specimens.

The samples were prepared by the normal procedure and were confirmed to be single-phase by X-ray diffraction. The resistive transition was exhibited at 90 K. The sample was cut into a rectangular bar shape of cross-section 0·73 mm^2 and length about 1 cm. The standard dc four-probe technique (Malik *et al* 1987, 1988) was used, with silver-paint contacts (contact resistance < 6 ohms) for the measurement of J_c. The sample was cooled in the earth's field to 77 K while it was inside the bore of a solenoid, and the desired field was then applied. The solenoid design ensured a field homogeneity of about 0·1% over the sample, and the sample-holder design ensured that it was held firmly in position. We show in figure 1 the V–I curves obtained. All the data shown were obtained uninterrupted, i.e. without remaking the contacts and without disturbing the sample position. We also made measurements at 26 Oe where the flux-flow transition could not be detected (the contacts gave way due to heating) but we could conclude that $J_c > 68$ A/cm^2 at this field. We have obtained similar results with other samples of $YBa_2Cu_3O_7$ but show here only the most exhaustive uninterrupted data we could obtain.

The magnetic field values for the various curves, and the J_c values obtained, are listed in table 1. The sharp drop of J_c with increasing magnetic field is evident from figure 2.

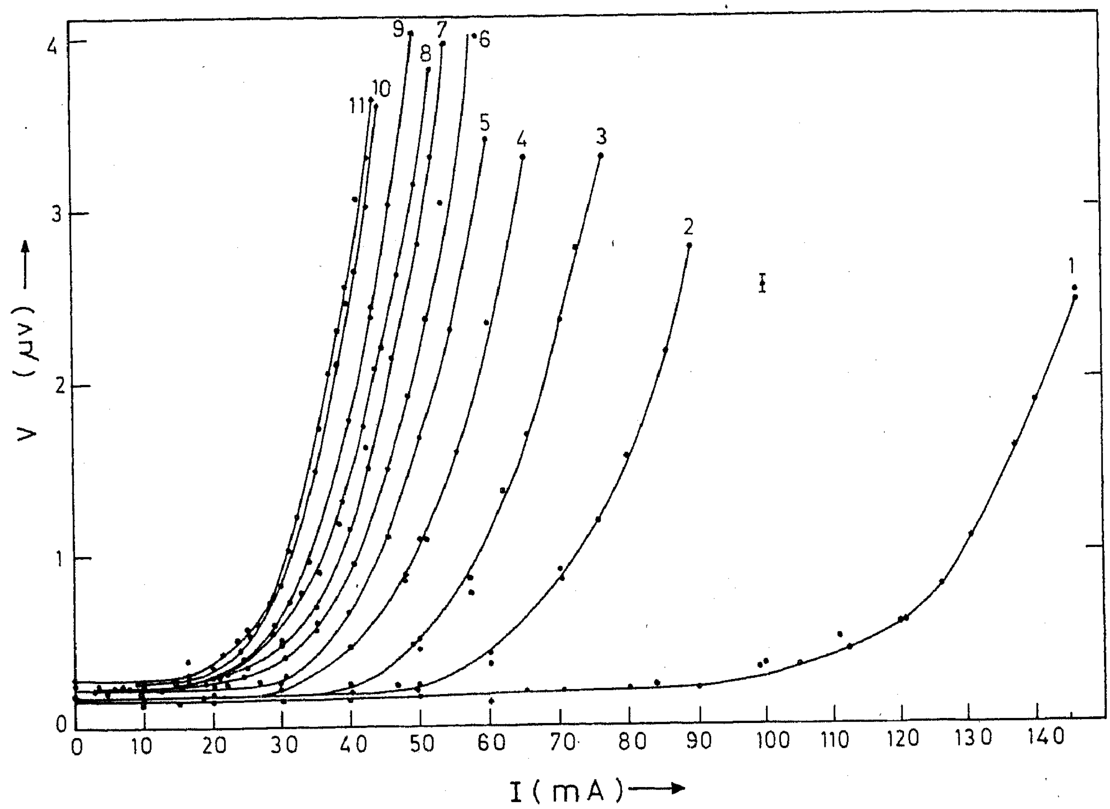

Figure 1. We show the V–I curves obtained, on the same specimen, in different magnetic fields. The fields corresponding to each curve are listed in table 1. The error is indicated.

Table 1. J_c values at various magnetic fields from figure 1.

Curve	H(Oe)	J_c(A/cm^2)
1	41·0	16·1
2	60·5	8·1
3	72·5	6·4
4	84·0	5·2
5	93·5	4·8
6	101·0	4·4
7	109·5	4·0
8	118·0	3·7
9	132·5	3·4
10	161·5	3·4
11	185·5	3·1
	26·0	>68

This type of behaviour has also been observed in sintered specimens of various $RBa_2Cu_3O_7$ superconductors by Jin *et al* (1987, 1988).

The sharp drop of J_c with increasing magnetic field has been attributed to intragrain weak links caused e.g. by twin boundaries (Deutscher and Muller 1987) and also to Josephson junctions caused by grain boundaries (Clem and Kogan 1987; Kwak *et al*

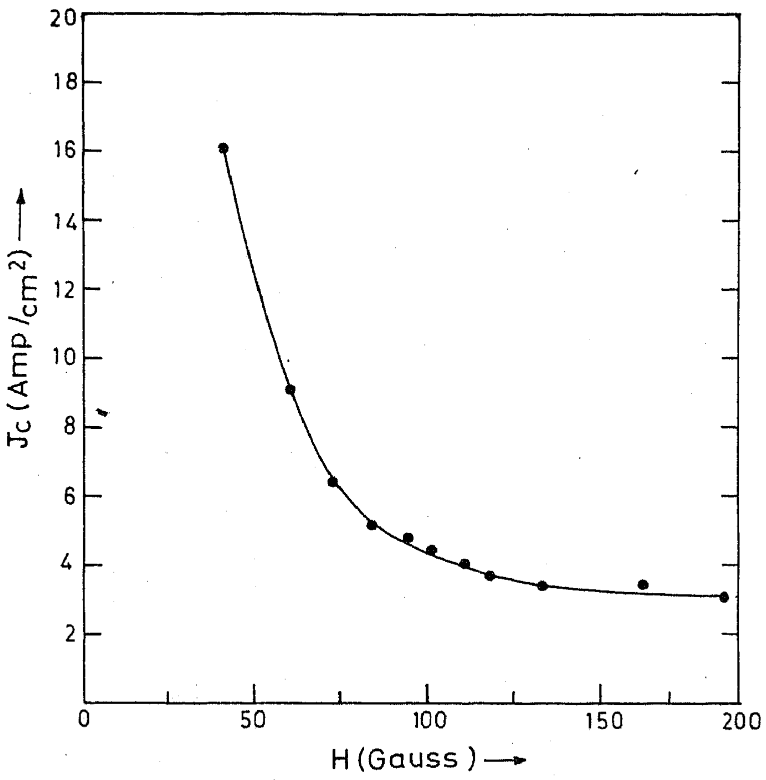

Figure 2. We show the measured J_c as a function of field.

1988). We shall argue that a comparison of our data with the low field hysteresis data (Grover *et al* 1988a, b) rules out the possibility of an intragrain origin.

Grover *et al* found that the low-field hysteresis consisted of a bubble region, which terminated at about 60 Oe, and a reversible magnetization at higher fields. The low field bubble was attributed to intergrain/interparticle currents as are measured in our transport measurement. The reversible region was attributed to intragrain contributions. Implicit was the assumption that intergrain J_c decreased by a large factor ($\geqslant 4$) as the field is raised from 0 to 60 Oe. This is borne out by the present measurements. The low field bubble of Grover *et al* is just a manifestation of our field-dependent transport J_c.

The low field bubble was found (Grover *et al* 1988b) to disappear on powdering. The powdering procedure reduces the sample to particles of size of a few microns, which is also of the same order as the size of the grains in these materials (Farrell *et al* 1987). It is thus reasonable to assume that powdering destroys intergrain links. Thus the low field bubble, and the field-dependent transport J_c we measure, can both be attributed to intergranular/interparticulate links.

To conclude, we have confirmed a sharp field dependence in the transport J_c of sintered pellets, and have argued that this dependence cannot be due to intragranular weak links.

We are grateful to Shri K L Patel and Shri G Mohanty for assistance. We thank Dr A K Grover for discussions.

References

Clem J R and Kogan V G 1987 *Jpn. J. Appl. Phys. Suppl.* **26–3** 1161

Deutscher G and Muller K A 1987 *Phys. Rev. Lett.* **59** 1745

Farrell D E, Chandrasekhar B S, DeGuire M R, Fang M M, Kogan V G, Clem J R and Finnemore D K 1987 *Phys. Rev.* **B36** 4025

Grover A K, Radhakrishnamurty C, Chaddah P, Ravi Kumar G and Subba Rao G V 1988a *Pramana – J. Phys.* **30** L167

Grover A K, Radhakrishnamurty C, Chaddah P, Ravi Kumar G and Subba Rao G V 1988b *Pramana – J. Phys.* **30** 659

Jin S, Sherwood R C, Tiefel T H, Van Dover R B, Johnson Jr. J W and Grader G S 1987 *Appl. Phys. Lett.* **51** 855

Jin S, Fastnacht R A, Tiefel T H and Sherwood R C 1988 *Phys. Rev.* **B37** 5828

Kwak J F, Venturini E L, Nigrey P J and Ginley D S 1988 *Phys. Rev.* **B37** 9749

Malik M K, V D Nair, Raghavan R V, Chaddah P, Mishra P K, Ravi Kumar G and Dasannacharya B A 1987 *Pramana – J. Phys.* **29** L321

Malik M K, Nair V D, Biswas A R, Raghavan R V, Chaddah P, Mishra P K, Ravi Kumar G and Dasannacharya B A 1988 *Appl. Phys. Lett.* **52** 1525