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MAGNETIC AND ELECTRICAL MEASUREMENT OF CRITICAL CURRENTS IN SINTERED $YBa_2Cu_3O_{7-x}$ SUPERCONDUCTORS

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Magnetization measurements are used to separate the intra- and intergrain critical currents of dense YBaCuO ceramics. Transport (intergrain) critical currents agree well with those deduced from magnetization. An empirical relation between the a.c. susceptibility and intra- and intergrain critical currents is established.

In general either magnetization or U-I characteristic is used to determine the critical current of a superconductor. For the conventional superconductor both methods yield practically the same results. The same methods are also used for the new high temperature (HT_c) superconductors but so far no direct comparison between the results obtained with different methods has been reported. Here we report the main results of the detailed investigation of the magnetization, a.c. susceptibility and U-I characteristic for two dense ceramic YBaCuO samples. Reliable results both for intra- and intergrain critical currents are obtained. In addition an empirical relation enabling the determination of critical currents from the a.c. susceptibility measurements is obtained.

The sample preparation and characterization was reported earlier /1-3/. The rod shaped samples (typically 10x1x1 mm^3) S13-3 and S13-1 had the density 0.91 and 0.92 of the ideal density. The magnetization was measured in the temperature range 70-90 K with the a.c. susceptibility setup /4/ buth with 0.1 Hz a.c. current supplied to the primary coil. The transport critical current was measured at 77 K only with the pulse method (width 1s). The voltage sensitivity of these measurements (1 μV) corresponds to resistivity few times smaller than of copper at 77 K.

The magnetization hysteresis for sample S13-3 at temperatures 87 K and 78 K are shown in Figs 1a and 1b respectively. The corresponding critical currents calculated from the Bean's model /5/ for the cylindrical geometry are shown in the lower parts of the same figures. At higher magnetic field and temperatures the sample behaves as an assembly of individual grains. Thus Fig. 1a shows the intragrain critical current. Indeed the value $3x10^4$ A/cm^2 obtained by using the average grain size (5 μm) agrees well with the results obtained for YBaCuO monocrystals at the same temperature.

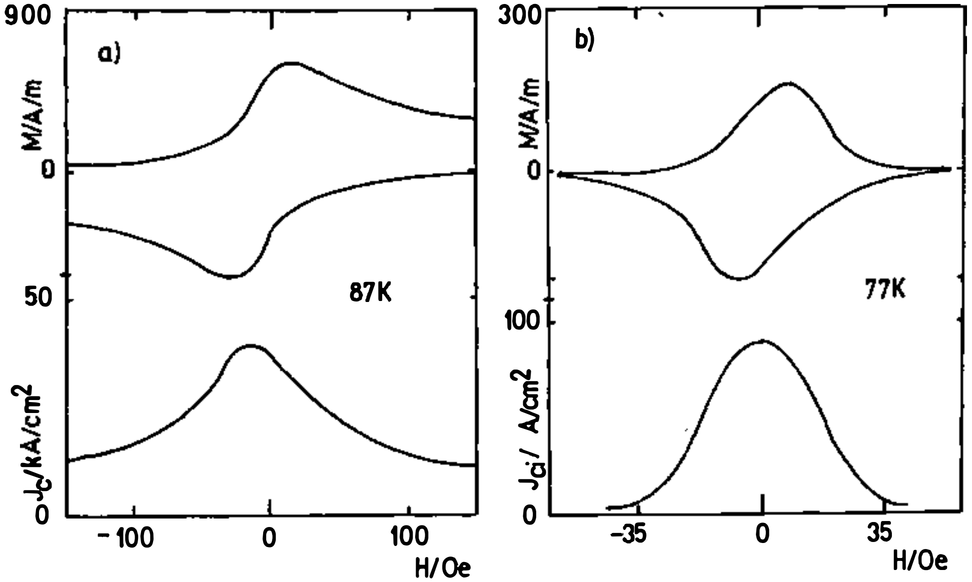

Fig.1 Magnetization and critical currents for S13-3.

At lower temperatures and for magnetic field lower than the lower critical field of a single grain the hysteresis (Fig. 1b) is due to intergrain currents and hence reflects the bulk critical current (J_{ci}). This current is several orders of magnitude lower than the intragrain eone. The source of this reduction shows up clearly in the magnetic field dependence of J_{ci} (Figs 1b and 3). Both the initial (sin aH)/aH dependence /6/ and the exp(-bH) variation at higher fields imply that the Josephson-like weak links limit the current flow through the sample. The origin(s) of these weak links is probably the anisotropy of the compound /7/ and/or the change in structure at the grain boundary /8/.

The aplicability of the Bean's model for a complicated array of Josephson junctions is not obvious. Therefore, a direct comparison between J_{ci} and the transport critical current (J_{ct}) is apparently desirable. The zero field critical current (U-I characteristic) for sample S-13-3 is shown in the inset to Fig.2. The comparison showed that at 77.3 K J_{ct} is about 50% higher than J_{ci}. Higher value of J_{ct} may indicate some normal conduction participating in this value. (Note that resistivities of our samples at 77.3 K are certainly lower than that of copper, but not necessarily zero). The comparison between J_{ct} and J_{ci} for sample S13-1 (inset to Fig. 2 and Fig. 3) yielded a similar result (J_{ct} about 1.5 times higher than J_{ci}). For that sample we also measured the field dependence of J_{ct} (Fig. 2). The variations of J_{ct} and J_{ci} with field for sample S13-1 are shown together in Fig. 3. Practically the same field dependence of J_{ct} and J_{ci} supports the aplicability of Bean's model for the evaluation of the bulk critical currents in YBaCuO ceramics.

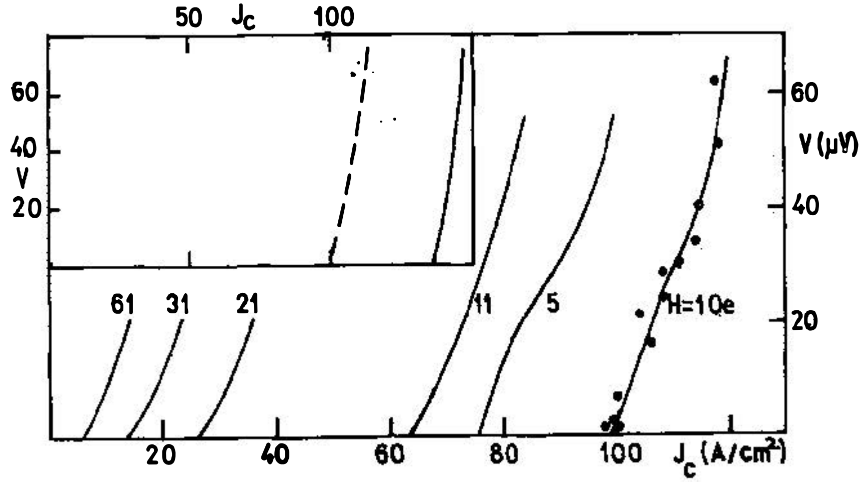

Fig. 2 U-J curves of S13-1 for different fields. Inset: U-J curves for S13-3 (full line) and S13-1 (dashed line).

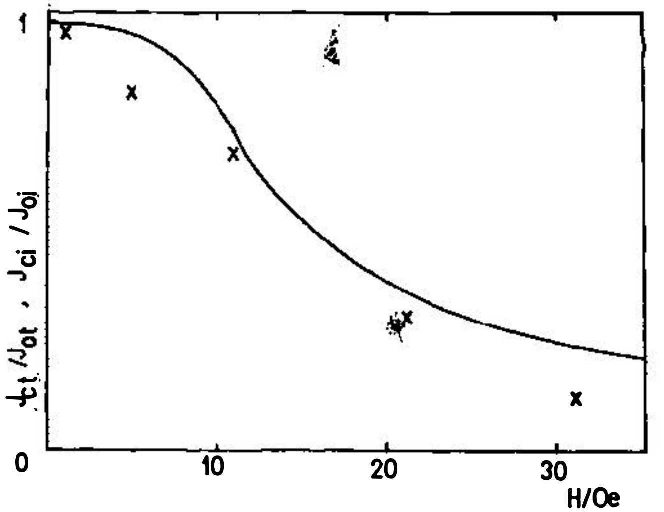

Fig. 3 Field dependence of normalized transport (+) and intergrain (-) critical current for S13-1.

We demonstrated earlier /2/ that the a.c. susceptibility can be used to separate the intra- and intergrain (bulk) diamagnetic shieldings and also to access the strength of the intergrain coupling (via its field dependence) in ceramic superconductors. Furthemore the effect of magnetic field on the intergrain features of the initial susceptibility (first step in its real part and the corresponding maximum in the imaginary part) is the same for all well sintered ceramics and their powders whereas its effects on the intergrain features (second step and maximum) depend sensitively on density and preparation conditions of a given compact. Since the imaginary part of a.c. susceptibility reflects the a.c. loss (magnetization hysteresis) it can be used to determine the penetration fields for grains and bulk and hence for the evaluation of corresponding critical currents through the use of the Bean's model. The comparison between the magnetization and a.c. susceptibility results showed that the insertion of magnetic field at which the relevant maximum in the imaginary susceptibility occurs at the given temperature in the Bean's formula /5/ instead of the full penetration field yields, within a factor close to unity, correct values of the intra- and intergrain critical currents. Therefore a.c. susceptibility alone can yield the accurate size and temperature dependence of the intra- and intergrain critical currents in YBaCuO superconductors. Detailed account of this work will be given elsewhere.

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