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TEMPERATURE DEPENDENCE OF CRITICAL CURRENT AND I-V CHARACTERISTICS (IVC) IN THE $YBa_2Cu_3O_7$ (Y) AND $Bi_2Sr_2CaCu_2O_8$ (Bi) CERAMICS

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The temperature dependence of the transport critical current I_{cr} and the I-V characteristics (IVC) for Y and Bi ceramic samples has been measured. For $0.05 \leq T/T_{cr} < 1$, it was found that $I_{cr} \sim (T_{cr} - T)^{\alpha}$ for both the types of high -T_c superconductors, with $\alpha = 1.24$ and 1.48 (two samples) for Y and $\alpha = 2.58$ for Bi. For the low voltage region of the IVC ($V \leq 1$ mV), voltage and current could be naturally normalized so that for the nondimensional quantites $U = i^{\gamma(T)}$ both for Bi and Y. At the same time a great discrepancy in the temperature dependence of the characteristic parameters of the IVC fit point to a quite different process of transport current dissipation in Y and Bi.

The investigation has been performed at the Laboratory of High Energies, JINR.

Температурная зависимость критического тока и ВАХ керамик $YBa_2Cu_3O_7$(Y) и $Bi_2Sr_2CaCu_2O_8$(Bi)

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Измерена зависимость от температуры транспортного критического тока $I_{кр.}$ и ВАХ образцов из керамик Y и Bi. В диапазоне $0{,}005 \leq T/T_{кр.} < 1$ для обоих типов ВТСП $I_{кр.} \sim (T_{кр.} - T)^{\alpha}$, где для Y $\alpha = 1{,}24$ и 1,48 (2 образца), для Bi $\alpha = 2{,}58$. Для начальных участков ВАХ ($U \leq 1$ мВ) можно естественным образом ввести нормировку U и I так, что в безразмерных величинах $U = i^{\gamma(T)}$, как для Bi, так и для Y. В то же время большая разница в зависимости от T характерных параметров позволяет сделать вывод, что механизмы диссипации транспортного тока в этих керамиках весьма различны.

Работа выполнена в Лаборатории высоких энергий ОИЯИ.

The four-terminal measurement of I_{cr}(T), R(T) and the IVC were taken in the set-up which cryogenic part is shown in fig. 1. The ambient magnetic fields were not compensated. Two samples made of one Y pellet and one sample of Bi were used. The superconducting ceramics were prepared by a standard ceramic sintering process, but

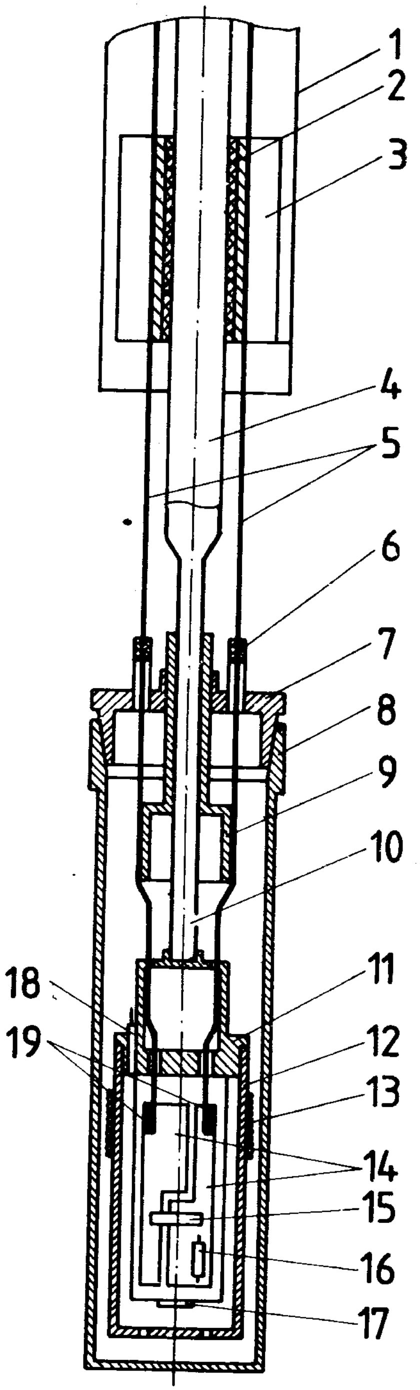

Fig. 1. The lower part of the set-up. 1 – external stainless tube, 2 – insulating gasket 3 – heat drain for terminals and current leads, 4 – constructive stainless tube, 5 – current leads, 6 – leak-tight inlets of current leads, 7, 8 – chamber, 9 – heat drain, 10 – pumping tube, 11 – sample holder, 12 – heat screen, 13 – heater, 14 – current electrodes, 15 – sample, 16 – TVO thermometer, 17 – Hall's sensor, 18 – capacitive thermometer, 19 – current lead soldering.

without pressure before the final sintering for Bi. The dimensions of sample were about 10x2x1 mm^3. The sample chamber (7, 8, fig. 1) is leakproof due to a very suitable cone-cone connection. All measuring wires and current leads pass through LHe or LN$_2$ and so keep the longitudinal heat conductivity of the insert away. The temperature of the sample holder (11) is stabilized by a capacitive thermometer (18) and the thermostabilizer CT-201 (Intermagnetics) better than about 0.1 K within the whole measuring range from 4.2 K up to T_{cr} . When the lower part of the insert is immersed in LHe, a power of 1.5 W is needed to warm the holder with the sample (15) up to 60 K. The temperature was measured by a TVO-thermoresistor (16) with an absolute accuracy better than 0.7 K at 77 K and 0.05 K at 4.2 K. Two current directions were used to measure the IVC with a voltage resolution of 0.1 μV. The contacts were made in the following way: a thin Ag film was formed initially at Y1 and then the leads were soldered by the Wood's alloy, for Y2 and Bi the contacts were prepared by rubbing in the Wood's alloy and the liquid alloy In-Ga-Sn (T_m = +10.3° C), respectively. The resistance of a single current contact is:

R, Ohm / T, K	Y1	Y2	Bi
293	1,3	≤ 2	2
10	≤ 0.1	5	≤ 0.15

The critical current was estimated graphically from the IVC at a voltage level of 1 μV and is denoted as $I_{cr.1}$. Over the range $0.05 \leq \leq T/T_{cr} < 1$ the results can be well expressed by the formula

$$I_{cr.1} = A(T_{cr} - T)^{a}, \tag{1}$$

where T_{cr} = 86.3 K for Y and T_{cr} = 78 K for Bi. In the $\ln I_{cr} - \ln(T_{cr} - T)$ plot the straight line corresponds to (1), as shown in fig. 2 (the current unit is mA). The points marked with arrows were obtained with the samples directly immersed in LHe. Two points in the circle demonstrate the overheating effect for Y2 with high resistivity contacts at low temperatures, where the thermal power dissipated in each contact was about 100 mW. As is seen in fig.3, the critical temperature estimated from fitting $I_{cr}(T)$ by (1) coincides for Bi with that one obtained graphically from R(T) and differs by 1.7 K for Y. In accordance with (1) and fig. 2, the critical current density can be expressed as:

$$\begin{aligned} &\text{Y1} \quad I_{cr.d.}(T) = 3.12 \cdot 10^{-3} (T_{cr} - T)^{1,48} \quad [\mathrm{A \cdot cm^{-2}}] \\ &\text{Y2} \quad I_{cr.d.}(T) = 2.98 \cdot 10^{-2} (T_{cr} - T)^{1,24} \quad [\mathrm{A \cdot cm^{-2}}] \\ &\text{Bi} \quad I_{cr.d.}(T) = 3.28 \cdot 10^{-4} (T_{cr} - T)^{2,58} \quad [\mathrm{A \cdot cm^{-2}}]. \end{aligned} \tag{2}$$

The difference in $I_{cr.d.}$ and in a for Y1 and Y2 may be caused by heating Y1 while forming the Ag-contacts (≃ 300° C, 5 sec). For the IVC—measurements a previously fixed current was supplied for a while of 1-3 sec and the voltage was measured by a digital voltmeter. For these data processing the IVC were expressed in a double logarithmic plot $\ln U - \ln(I - I_{cr})$, where the units of U and I were in μV and mA, respec-

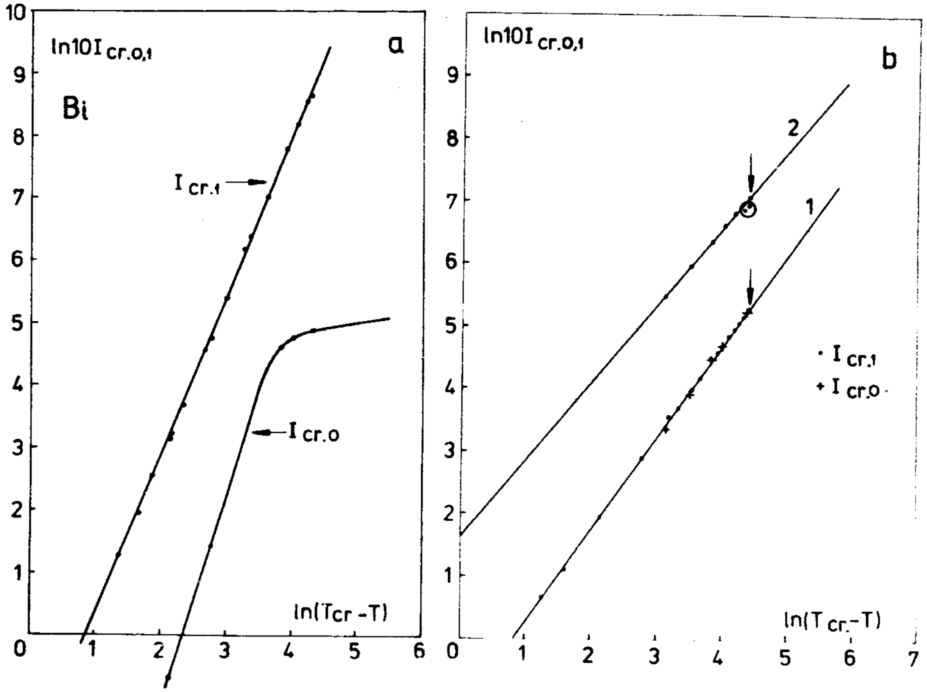

Fig. 2. $I_{cr.1}$ and $I_{cr.0}$ VS temperature: a) Bi, b) 1 – Y1, 2 – Y2.

tively. The value of $I_{cr.1}$ was used as a first approximation for I_{cr}. A certain value of I_{cr} was found to exist for each $T < T_{cr}$, when the corresponding IVC can be expressed in such a plot by a straight line.This current is denoted as $I_{cr.o}$. It is obvious that $I_{cr.o}$ will be the critical current for $U \to 0$, if the U(I)— dependence can be extrapolated to $U < 1\mu V$. Thus, a number of straight lines can be obtained

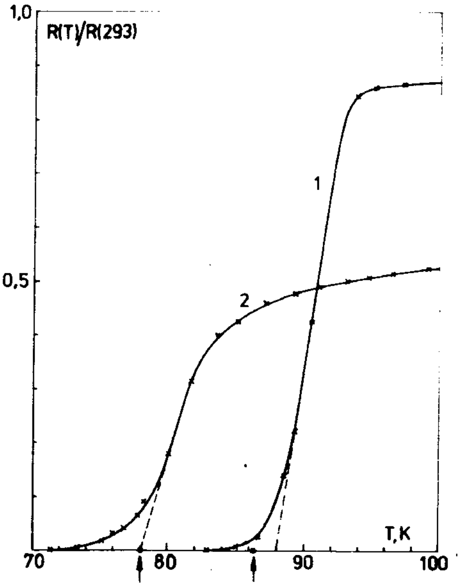

Fig. 3. SN – transition of the samples. 1 – Y1, 2 – Bi. The arrows show critical temperatures obtaind from fitting $I_{cr.}(T)$.

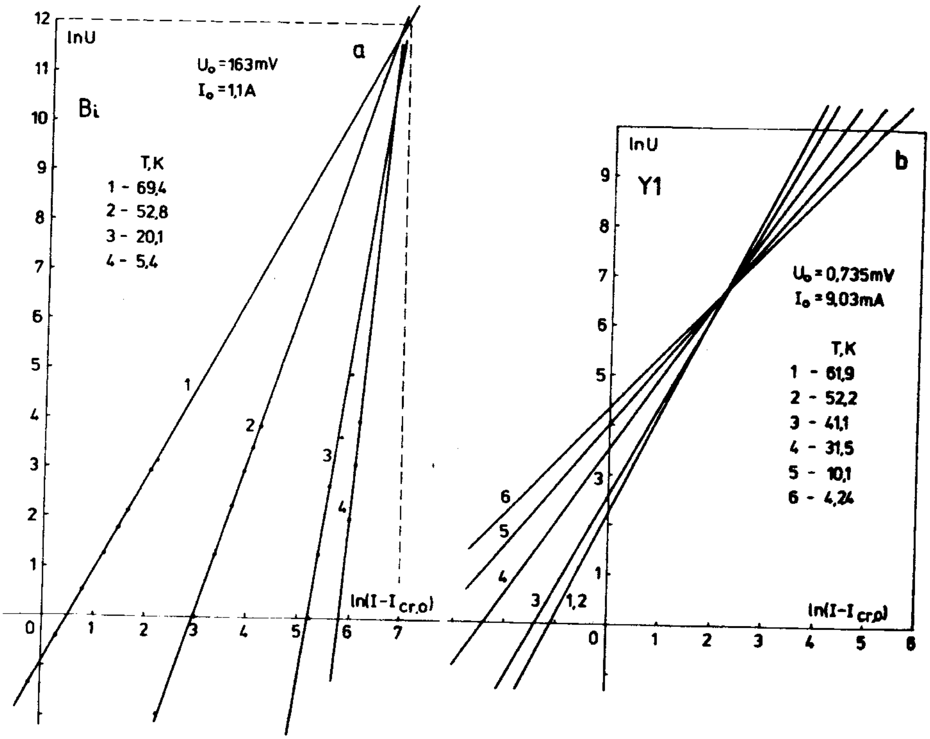

Fig. 4. The low voltage (U < 1 mV) parts of the IVC: a) Bi, b) Y1.

for different temperatures (fig. 4). As is seen, these lines pass through nearly one point and so the normalized quantities can be used: $u = U/U_0$ and $i = (I - I_{cr,0})/I_0$, where $U_0 = 163 \cdot 10^3\ \mu V$, $I_0 = 1{,}1 \times 10^3$ mA for Bi and $U_0 = 735\ \mu V$, $I_0 = 9.03$ mA for Y1. In the new ln u — ln i coordinates all the IVC pass through the origin and the expression for the IVC is extremely simple:

$$u = i^{\gamma(T)} \qquad (3)$$

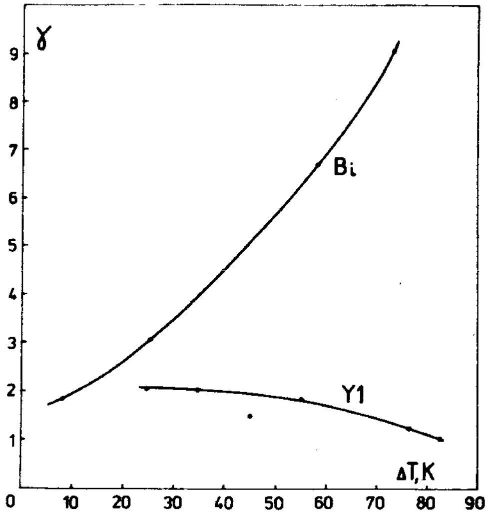

Fig. 5. γ VS temperature.

The temperature dependences of $I_{cr.o}$ and γ are shown in fig. 2 and 5, respectively. A great difference in these curves for Bi and Y is quite obvious.

Conclusions

For both the types of high-T_c superconductors $I_{cr.1} = A(T_{cr} - T)^{a}$ over the range $0.05 \leq T/T_{cr} < 1$, but for Y $a < 2$ while for Bi $a > 2$. It is known that $a = 2$ corresponds to a SNS-type weak link and so the transport critical current is probably limited by different reasons in these ceramics. Although the IVC for Y and Bi can be expressed by the same formula (3), the temperature dependences of $I_{cr.o}$ and γ for these ceramics are not similar. This points to different processes of current dissipation in accordance with the previous conclusion.

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