Local versus Nonlocal Conductivity in $YBa_2Cu_3O_{7-\delta}$

In a recent Letter Safar *et al.* [1] obtained results for the vortex liquid of $YBa_2Cu_3O_{7-\delta}$ which suggest that the conductivity close to T_c cannot be described by local electrodynamics. Our measurements in the same contact configuration are instead consistent with local conductivity. Two single crystals of $YBa_2Cu_3O_{7-\delta}$ were studied, of sizes $1.40 \times 0.35 \times 0.16$ and $0.70 \times 0.25 \times 0.06\ \mathrm{mm}^3$ with contacts as in Fig. 1. A magnetic field of 4 T was parallel to the c axis. A relatively large measuring current of 10 mA was chosen for good voltage resolution. In the top panels of Fig. 1 this is seen to be within the linear I-V regime.

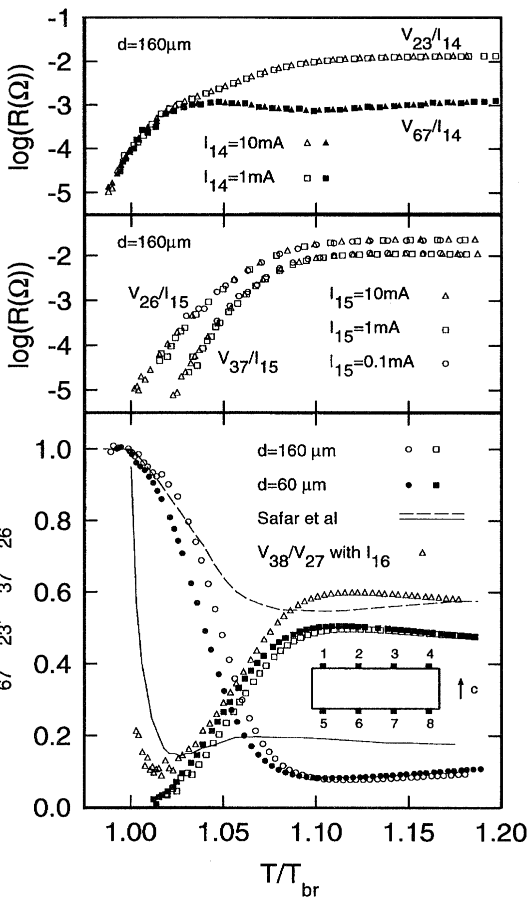

FIG. 1. Contact configuration and voltage ratios for $YBa_2Cu_3O_{7-\delta}$ samples. The magnetic field $\parallel c$ was 4 T. Two top panels show resistances between contacts 6–7 and 2–3 for current I_{1-4} and between contacts 3–7 and 2–6 for current I_{1-5} for a range of currents covering a factor of 100. Bottom panel: circles, $V_{67}/V_{23}(I_{1-4})$; squares, $V_{37}/V_{26}(I_{1-5})$; filled symbols, sample thickness 60 μm; and unfilled symbols, 160 μm. Results at 5 T are shown for a 35 μm thick sample from Ref. [1] with $T_c \approx 93$ K and T_{br} at about 84 K, similar to our T_{br} at 4 T. Dashed line, $V_{67}/V_{23}(I_{1-4})$; full line, $V_{37}/V_{26}(I_{1-5})$. The triangles are our results for a displaced contact arrangement: $V_{38}/V_{27}(I_{1-6})$.

$V_{67}/V_{23}(I_{1-4})$ for both samples is similar to the results of Ref. [1]. When $T \rightarrow T_{br}$, ρ_c goes to zero, a homogenous current distribution is approached with equal voltages on all a-b planes, and $V_{67}/V_{23} \rightarrow 1$. In contrast, the results for $V_{37}/V_{26}(I_{1-5})$ are strikingly different from those of Ref. [1]. Our observations are consistent with local electrodynamics; $\rho_c \rightarrow 0$ when $T \rightarrow T_{br}$, current will flow closer to the current contacts, and V_{37} decreases faster than V_{26}.

One possible explanation for these differences could be a planar current component. Below T_{br} (and above T_{irr}) vortices move uniformly with approximately straight vortex lines. Approaching T_{br} from above one could therefore expect an increasing rigidity in the vortex structure, and an ab-current component close to the current contacts exerting a force on nearby vortices could influence other parts of the vortex structure. Then, when $T \rightarrow T_{br}$ voltages along the c axis vanish, and voltages along planes could develop over the surface.

We tested this idea by injecting current through I_{16} and measuring V_{38}/V_{27}. The result somewhat resembles that of Ref. [1]. In a sense this is a nonlocal effect, since a voltage would be caused by vortex motion induced by a current in another part of the sample, but it is different from Ref. [1], where this nonlocal action is assumed to occur along the c axis.

Differences in sample thickness d are likely not significant. The effective depth in the c direction of current injected along the a-b planes is [2] $z_{\mathrm{eff}} \approx (L/\pi)\sqrt{\rho_{ab}/\rho_c}$. Hence $z_{\mathrm{eff}} \approx 0.1$ mm for $\rho_c/\rho_{ab} \approx 10$ at $T = 1.01T_{br}$ from Ref. [1] and $L \approx 1$ mm. z_{eff} increases when $T \rightarrow T_{br}$ and current distribution becomes homogenous.

Above T_{br}, when $\rho_c > 0$, current distribution begins to be nonuniform. In a local picture and for $R_c \ll R_{ab}$ one has $\Delta V = V_{23} - V_{67} \sim \rho_c(T)dI$, with current I. [At $T = 1.01T_{br}$, $R_c/R_{ab} \approx (\rho_c/\rho_{ab})(d/L)^2 \approx 0.1$ for $d = 0.1$ mm.] T_{br} determined with any voltage criterion, $\Delta V(T_{br}) = \mathrm{const}$, decreases for a thicker sample and/or larger current, and this fact may erroneously be taken as current induced vortex cutting or inverse thickness dependence of T_{br}.

Yu. Eltsev and Ö. Rapp
Solid State Physics
The Royal Institute of Technology
S-100 44 Stockholm, Sweden

Received 1 December 1994
PACS numbers: 74.60.Ge, 74.72.Bk

[1] H. Safar *et al.,* Phys. Rev. Lett. **72**, 1272 (1994).
[2] R. Busch *et al.,* Phys. Rev. Lett. **69**, 522 (1992).

 0031-9007/95/75(12)/2446(1)$06.00