Comment on "Pinning Strength Dependence of Mixed-State Hall Effect in $YBa_2Cu_3O_7$ Crystals with Columnar Defects"

In a recent Letter, Kang *et al.* [1] report their study of the pinning dependence of the Hall effect in $YBa_2Cu_3O_{7-\delta}$ (YBCO) crystals. They measure the Hall and longitudinal resistivity, ρ_{xy} and ρ_{xx}, respectively, both in crystals with relatively weak pinning and in those where pinning is enhanced through ion irradiation. They argue that differences between the two cases, in the Hall conductivity σ_{xy} $(\simeq \rho_{xy}/\rho_{xx}^2)$ and the exponent α (from the scaling relation $\rho_{xy} \propto \rho_{xx}^{\alpha}$), support Wang, Dong, and Ting (WDT) [2] who attribute the Hall effect sign change to pinning. We argue that the data of Kang *et al.* are quantitatively inconsistent with WDT and, in fact, support [3], which predicts σ_{xy} to be independent of pinning.

First, σ_{xy} is *unchanged* over a large range of temperature in spite of a substantial pinning enhancement from ion irradiation. This is illustrated by Fig. 1, taken from Figs. 1, 2, and 4 of Ref. [1], where ρ_{xy}, σ_{xy}, and $\rho_{xx}/\rho_{xx}(T = T_c)$ are plotted vs reduced temperature T/T_c. At temperatures above T_A, σ_{xy} is unaffected by ion irradiation, whereas both $\rho_{xx}/\rho_{xx}(T = T_c)$ and $|\rho_{xy}|$ are greatly reduced in the irradiated sample.

While WDT do allow ρ_{xx} and ρ_{xy} to be more strongly affected by pinning than σ_{xy}, the parameters in their model are inconsistent with this data. They predict [2]

$$\sigma_{xy} \propto \{\eta - \overline{\gamma}(\eta + 2\Gamma)\}/B\,, \tag{1}$$

where B is the magnetic field, H_{c_2} is the upper critical field, $\overline{\gamma} > 0$ sets the relative role of pinning, and both η and Γ are vortex drag terms; Γ is due to pinning effects and, in general, depends on the vortex velocity v_L in addition to T and B. To make the most favorable comparison with the data, we choose $\overline{\gamma}$ such that the relative change of σ_{xy} with respect to Γ is a minimum. This occurs in the limit $\overline{\gamma} \to \infty$ for *negative* σ_{xy} and in the limit $\overline{\gamma} \to 0$ for *positive* σ_{xy}. We consider the former case since $\sigma_{xy} < 0$ at the temperature T_A. We estimate the change in Γ due to ion irradiation from the expression [2] $\rho_{xx} \propto B/(\eta + \Gamma)$. At $T = T_A$ (see Fig. 1), ρ_{xx} is less in the ion irradiated sample by at least a factor of 7. This implies $(\eta + \Gamma') \geq 7(\eta + \Gamma)$, where the prime indicates the irradiated sample. Thus, considering Eq. (1) in the limit $\overline{\gamma} \to \infty$, where $\sigma_{xy} \propto \overline{\gamma}(\eta + 2\Gamma)$, σ_{xy} should be at least a factor of 6 more negative in the irradiated sample. However, this is contrary to Fig. 1, where σ_{xy} is *unchanged* by ion irradiation for $T \geq T_A$.

In addition, Kang *et al.* argue that their observation of a scaling exponent $\alpha = 1.5$ in irradiated samples supports the model of WDT. However, WDT only predict $\alpha = 1.5$ in the non-Ohmic regime since they assume $\Gamma \propto (1/v_L)^{1/2}$, whereas the data is in the Ohmic regime.

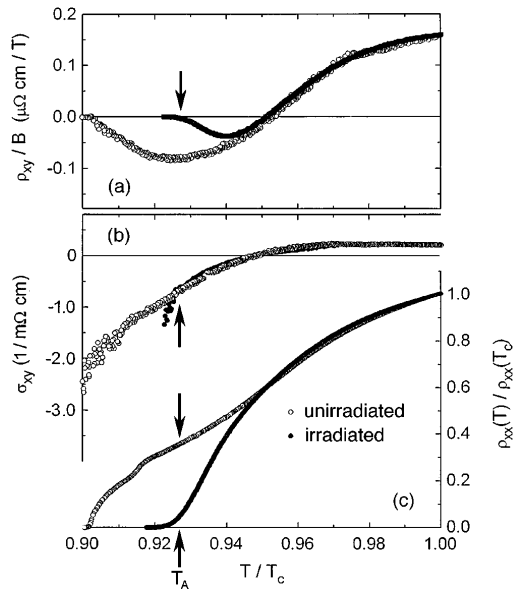

FIG. 1. ρ_{xy} (a), σ_{xy} (b), and ρ_{xx} (c) vs reduced temperature T/T_c of YBCO crystals at $\mu_0 H = 4$ T. Data shown as closed and open circles are from irradiated and unirradiated crystals, respectively. The arrows mark the temperature T_A.

Our studies [4] are also inconsistent with WDT. In fact, we show σ_{xy} in YBCO and Mo_3Si to be independent of current density (and therefore pinning) contrary to [2] but in agreement with [3].

We argue that sample inhomogeneities, an extrinsic effect, can easily explain the downturn of σ_{xy} in the irradiated samples. First, σ_{xy} is not measured directly, but is calculated by the expression [1] ρ_{xy}/ρ_{xx}^2. If the transport current is uniform, this expression is valid. However, variations in the current path do not affect ρ_{xy} and ρ_{xx}^2 in the same way, and any spatial variations in pinning strength, for example, will become amplified as vortex motion freezes out. Thus, it is not surprising that the downturn in σ_{xy} occurs only when ρ_{xx} is small. We find thin film samples of YBCO with relatively broad transition widths show features in σ_{xy} similar to that in Fig. 1, while higher quality samples do not

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