DIMENSIONALITY OF VORTEX FLUCTUATIONS IN $Y_{1-X}Pr_XBa_2Cu_3O_{6.97}$ AND $YBa_2Cu_3O_{6.5}$

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Introduction

It has been inferred from scaling of the vortex-glass line, $H_g(T)$, that the dimensionality of vortex flux-line fluctuations undergoes a crossover from 3-D to 2-D at a reduced temperature, $T \approx 0.6\ T_c$ and that this crossover appears to be universal to the cuprate-based superconductors [1, 2]. By extending magneto-transport measurements to fields up to 45 tesla, we have been able to examine the vortex-glass melting line of $Y_{1-x}Pr_xBa_2Cu_3O_{6.97}$ thin film samples and that of an oxygen deficient $YBa_2Cu_3O_{6.5}$ single crystal over a large temperature range ($0.03 < T/T_c < 1$).

Experimental

Films of $Y_{1-x}Pr_xBa_2Cu_3O_{6.97}$ (x = 0 - 0.4) grown on $LaAlO_3$ substrates by pulsed laser ablation, as well as an ultra high purity oxygen deficient $YBa_2Cu_3O_{6.5}$ single crystal grown in a $BaZrO_3$ crucible, were investigated in magnetic fields up to 45 tesla in the hybrid magnet system. The vortex-glass melting line, $H_g(T)$, was determined from electrical transport measurements with H || c. The temperature was held fixed and the field was swept at 3 tesla/ min, while measuring ρ(H).

Results and Discussion

An expression (equation [1]) for the vortex-lattice melting line has been derived, and is shown to accurately describe the entire vortex-glass melting lines ($0.03 < T/T_c < 1$) of the $Y_{1-x}Pr_xBa_2Cu_3O_{7-\delta}$ films and the $YBa_2Cu_3O_{6.5}$ single crystal examined in this work (figure 1). A change in the dimensionality of the vortex flux-line fluctuations along the melting line transition is accounted for through a critical exponent, s, and is thus a direct means of detecting any such change. The vortex-glass melting line is given by,

$$H_m = \frac{4H_{c2}(0)\dfrac{(\pi c_L^2)}{G_i(H_g)}(1-t)^2}{\left(1+\sqrt{1+4(Q_0\Omega_0\tau_0)\dfrac{c_L^2}{\pi G_i(H_g)}t^{s/2}(1-t)^{2-s/2}}\right)^2} \qquad [1]$$

where H_{c2} is the upper critical field at T = 0 K, c_L is the Lindemann number, $G_i(H_g)$ is the field dependent Ginzburg number, Q_0 is the quantum of resistance, Ω_0 is a cutoff frequency, τ_0 is the vortex relaxation time, and $t \equiv T/T_c$.

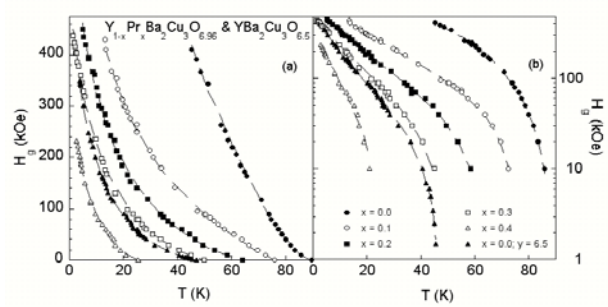

Fig.1. Vortex-glass melting lines, $H_g(T)$, of the $Y_{1-x}Pr_xBa_2Cu_3O_{7-\delta}$ and $YBa_2Cu_3O_{6.5}$ systems fitted by equation [1], shown in linear (a) and semi-log (b) plots.

Conclusions

The data for the above samples are well described by equation [1] over the *entire* range of field-temperatures examined. This points to the vortex flux-line fluctuations remaining 3D like along the entire melting line, in contrast to conclusions of previous studies.

Acknowledgements

We thank Dr. Alexei Souslov for assistance with the 45 tesla system. We also thank Prof. C. Kwon (CSU, Long Beach) for the films used in this work. This work was supported by the U.S. DOE under Grant No. DE-FG02-04ER46105.

References

[1] Almasan, C.C., *et al*., Physical Review Letters, **69**, 3812-3185 (1992).
[2] Maple, M.B., *et al*., Journal of Superconductivity, **7**, 97-106 (1994).