Angular Dependence of the Melting Line of $YBa_2Cu_3O_7$+$BaZrO_3$ Thin Films

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Introduction

In presence of a magnetic field (H), for 3-D anisotropic superconductors containing random point-like defects, the angular dependence of the vortex liquid-solid transition is governed by the electronic-mass anisotropy (γ), and scales with $\varepsilon(\theta)H = H[\cos^2(\theta)+\gamma^{-2}\sin^2(\theta)]^{1/2}$, where θ is the angle between H and the crystallographic c-axis. In contrast, pinning by correlated defects leads to a solid phase known as Bose-glass that can be distinguished from random point-like defects by the presence of a peak in the angular dependence of the melting line when H is aligned with the defects [1]. The addition of $BaZrO_3$ (BZO) into $YBa_2Cu_3O_7$ (YBCO) films can be source of both random and correlated defects, depending on growth conditions [2].

Experimental

Electrical ac-transport was used to measure the vortex dissipation in the liquid phase as well as to determine the melting line (where dissipation goes to zero), as a function of angle for YBCO+BZO films in the 50 T short-pulse magnet using the newly rebuilt rotator probe. Three films were studied, one with mostly columnar defects, one with mostly randomly distributed nanoparticles, and one with significant amounts of both.

Results and Discussion

In Fig. 1a the angular dependence of the H_m is shown. Although columnar defects are preferentially oriented along the c-axis, no clear peak is observed in $H_m(\theta)$ in any film. Also, H_m cannot be scaled (over any angular range) with anisotropy parameters consistent with the electronic mass anisotropy of the normal state. Well into the liquid ($H>H_m$), the dissipation scales with the γ=5.5, indicating that the particular shape of $H_m(\theta)$ is due to the influence of the pinning centers. Once the anisotropic contribution of the H is taken into account (Fig. 1b) a maximum that extends close to the ab-planes is observed. This could be due the splay present in these defects, or that the melting line is governed by random particles, as predicted by Hwa *et al.*[3] The latter is supported by the fact that very similar behavior is seen for $|\theta|>35^o$ for all three samples.

Both types of pinning centers induced by BZO additions remain effective in the high field regime. Moreover, a crossover in H_m is observed between the sample with a mixture of pinning centers and the one with mostly columnar defects, with the latter more effective at higher temperatures and the former below 75 K (see Fig 1). Material aspects in the films are yet to be ruled out as the reason for this change.

By means of these studies it has been possible to explore the role of extended random particles on the solid-liquid vortex phase transition, as well as on the Bose-glass phase.

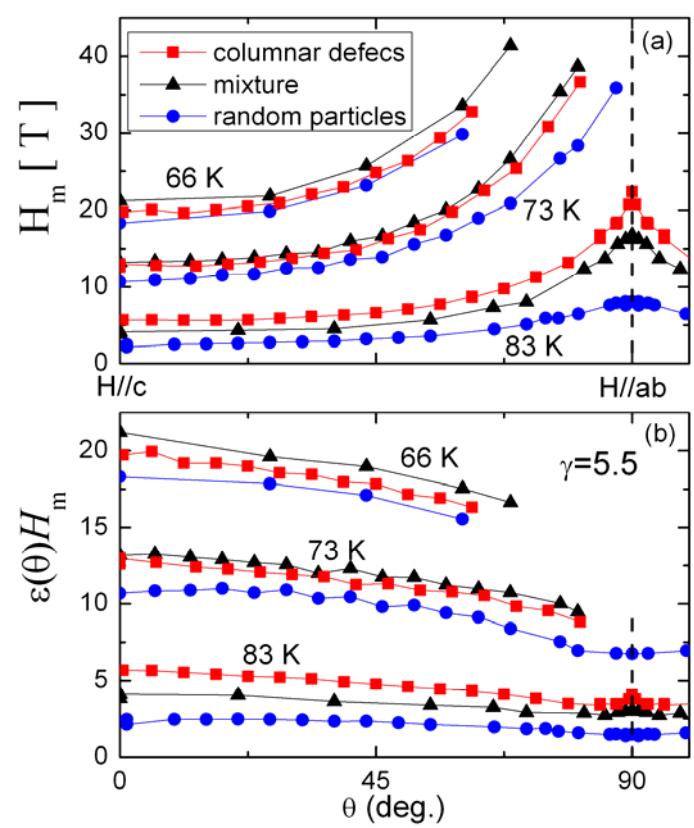

Fig. 1. a) Melting field (H_m) vs. angle (θ) at three temperatures for samples with extended random particle defects (circle), columnar defects (square), or a mixture of both (triangle). b) ε(θ)H vs. θ for the same data as 1a.

Acknowledgements

This work was supported by the NSF through the NHMFL and NHMFL IHRP, the State of Florida and the DOE.

References

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