Disorder-induced vortex phase transition in untwinned YBa$_2$Cu$_3$O$_{7-\delta}$ crystal

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Abstract

Local magnetic measurements in an untwinned YBa$_2$Cu$_3$O$_{7-\delta}$ crystal as a function of temperature, field and time reveal anomalies occurring along the same line $B_{on}(T)$ in the field-temperature plane. We identify $B_{on}(T)$ as a boundary line between two distinct solid phases of the vortex system. © 2000 Elsevier Science B.V. All rights reserved.

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Two distinct vortex-solid phases, characterized as a quasi-ordered and a highly disordered vortex solids, have been identified in Bi$_2$Sr$_2$CaCu$_2$O$_{8+d}$ (BSCCO) [1] and Nd$_{1.85}$Ce$_{0.15}$CuO$_{4-d}$ (NCCO) [2] crystals. The vortex phase transition in these crystals manifests itself in magnetization measurements as a sharp onset of a second magnetization peak.

Recently, we have reported [3] on local magnetic measurements in untwinned YBa$_2$Cu$_3$O$_{7-\delta}$ (YBCO) crystals revealing a well-resolved peak, characterized by three fields indicated in Fig. 1. The onset-field $B_{on}$, the “kink”-field $B_{k}$, and the peak-field $B_{p}$. Clearly, the peak-field cannot signify a transition field because it depends on time; Measurements of the time evolution of the second peak in the range 10–3000 s show that $B_{p}$ drifts with time to lower fields by several kG. It is natural to identify the transition field with the onset-field $B_{on}$. However, two experimental evidences indicate that the kink-field $B_{k}$ marks the transition field. First, local magnetization measurements versus temperature exhibit an abrupt increase in the magnetization, $m(T)$, on crossing the $B_{k}(T)$ line [3,4]. In contrast, the $m(T)$ curves are smooth, and do not show any anomaly around the field $B_{on}$.

A second evidence is illustrated in Figs. 2a and b. Scaling of the magnetization curves at different temperatures in a field range which includes $B_{k}$ is unsuccessful. However, as demonstrated in the figures, the magnetization curves can be perfectly scaled above and below $B_{k}$ separately. Above $B_{k}$ (Fig. 2a) the magnetization curves are scaled by the peak field $B_{p}$ and the magnetization peak value $m_{p}$. Below $B_{k}$ (Fig. 2b) the scaling parameters are the onset field $B_{on}$ and the magnetization $m_{on}$ at that field. The perfect scalings above and below $B_{k}$ suggest different nature of the vortex matter states above and below this field. This result, together with the accumulated results mentioned above, indicates that the kink field marks the vortex solid–solid-phase transition.

In Fig. 3 we summarize our results in a field-temperature phase diagram for the untwinned YBCO crystal,
Fig. 2. Scaled magnetization curves for YBCO between 55 and 70 K. Attempts to scale the curves in the whole field range are unsuccessful. However, separate scaling can be obtained for fields (a) larger and (b) smaller than $B_c$.

Fig. 3. Magnetic phase diagram for YBCO. showing the $B_{\text{m}}(T)$ line (circles), together with the melting line $B_{m}(T)$ (diamonds – determined by a discontinuity in $m(T)$ in the reversible regime) and high-field part of the irreversibility line $B_{\text{irr}}(T)$ (crosses – determined from the coincidence of the ascending and descending branches of the magnetization curves). A quantitative analysis for the detailed behavior of $B_{\text{m}}(T)$ is given in Ref. [3].

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References