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Disorder-induced vortex phase transition in untwinned $YBa_2Cu_3O_{7-\delta}$ crystal

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Abstract

Local magnetic measurements in an untwinned $YBa_2Cu_3O_{7-\delta}$ crystal as a function of temperature, field and time reveal anomalies occurring along the same line $B_{ss}(T)$ in the field-temperature plane. We identify $B_{ss}(T)$ as a boundary line between two distinct solid phases of the vortex system.

Keywords: YBaCuO; Vortex phase transitions

Two distinct vortex–solid phases, characterized as a quasi-ordered and a highly disordered vortex solids, have been identified in $Bi_2Sr_2CaCu_2O_{8+d}$ (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 $YBa_2Cu_3O_{7-\delta}$ (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,

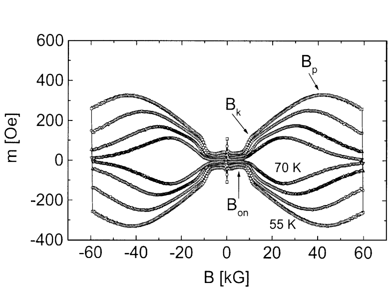

Fig. 1. Local magnetization curves for YBCO at $T = 55, 60, 65, 70$ K. B_{on}, B_k, and B_p for $T = 55$ K are indicated by arrows.

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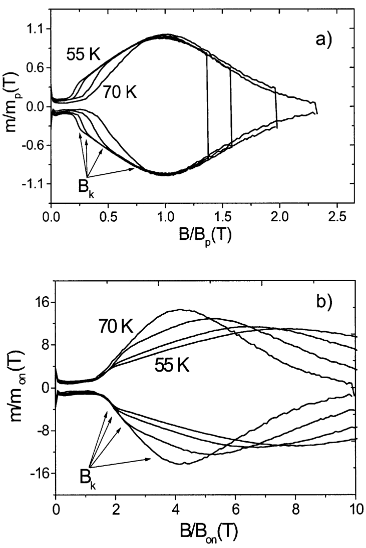

Fig. 2. Scaled magnetization curves for YBCO between 55 and 70 K. Attempts to scale the curves in the whole field range are unsuccessful. However, separate scaling can be obtained for fields (a) larger and (b) smaller than B_k.

showing the $B_{ss}(T)$ 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 $B_{irr}(T)$ (crosses – determined from the coincidence of the ascending and descending branches of

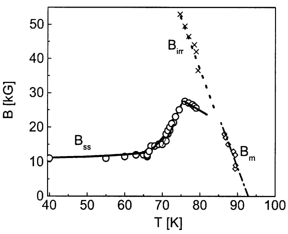

Fig. 3. Magnetic phase diagram for YBCO.

the magnetization curves). A quantitative analysis for the detailed behavior of $B_{ss}(T)$ is given in Ref. [3].

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