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Effects of Varying Defect Geometry on the First Order Vortex Melting Transition in $YBa_2Cu_3O_{7-\delta}$ Single Crystals

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The first order vortex melting transition is very sensitive to the presence of disorder and can be supplanted by a second order phase transition in the presence of a sufficiently high density of defects. We present the results of systematic studies on the effects of defects on the first order vortex melting transition in $YBa_2Cu_3O_{7-\delta}$ single crystals, with a special focus on the upper and lower critical points. The experiments were performed with electrical transport and ac specific heat measurements. The geometry and strength of the defects varied from naturally occurring twin boundaries and detwinned single crystals irradiated with successive doses of electrons, protons, or heavy ions. Twin boundaries yield planar defects, electron irradiation yielded weak point defects, proton irradiation yielded strong point-like defects and heavy ion irradiation yielded strong columnar defects. Our results indicate that the origins of the upper and lower critical points of the first order melting transition arise from different mechanisms. The position of the lower critical point is determined by the pinning strength of the defect, whereas the upper critical point shifts in response to the geometrical correlation of the defects.