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Vortex nanoliquid in high-temperature superconductors

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Vortex matter is commonly considered as a homogenous glassy medium. Correlated disorder in the form of columnar defects (CDs) is shown to result in formation of new heterogeneous phases of vortex matter. We have developed a magneto-optical method that allows visualization of the distribution of small transport currents applied to BSCCO crystals irradiated through patterned masks [1]. When vortices outnumber CDs we identify two distinct populations: vortices residing on CDs are strongly pinned and form a rigid 'porous' skeleton, whereas the excess vortices form weakly pinned ordered crystallites caged within the pores of the skeleton [2,3]. The melting process of this porous vortex matter is qualitatively different from melting of a homogenous system. The soft crystallites melt while the rigid skeleton remains in tact, forming a vortex nanoliquid in which intercalated liquid droplets of just few vortices are embedded in a porous solid matrix. The nanoliquid phase possesses unique properties and displays a high degree of correlation along the c-axis but no transverse critical current. The melting of heterogeneous vortex matter occurs in two steps resulting in a "Y" shaped phase diagram: first the soft crystallites undergo a melting transition forming a nanoliquid in which localized and delocalized vortices coexist, while a homogeneous liquid is formed at higher temperatures upon a delocalization transition of the skeleton from the CDs [1]. At lower fields the solid melts through a single first-order phase transition. [1] S. S. Banerjee, S. Goldberg, A. Soibel, Y. Myasoedov, M. Rappaport, E. Zeldov, F. de la Cruz, C. J. van der Beek, M. Konczykowski, T. Tamegai, and V. M. Vinokur, PRL 93, 097002 (2004). [2] S. S. Banerjee et al., PRL 90, 087004 (2003). [3] M. Menghini et al., PRL 90, 147001 (2003).