Experimental studies of metastability and history dependence in the vortex phase diagram in low-Tc superconductors*.

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Abstract

We have studied transport, magnetic response via both ac and dc magnetization and muon spin rotation measurements of single crystal samples of the low-T_c superconductor 2H-$NbSe_2$ with varying amount of doping by substitutional impurities for the transition metal of both isoelectronic and pair-breaking kinds. These crystals have Ginzburg number ranging between 10^{-4} and 10^{-3} and pinning parameter j_c/j_o ranging between 10^{-6} and 10^{-3}, making it an ideal system to study the interplay between quenched disorder and thermal fluctuations. Special emphasis was placed on the evolution of the peak effect in these systems and the concomitant destabilization of the ordered lattice. Muon data show direct evidence of a structural disordering of the lattice at the onset of the peak effect, through a jump in the asymmetry parameter of the field distribution, similar to what has been observed in BSCCO crystals at the melting transition as well as at the second magnetization peak. Magnetization data show clear evidence of a novel disorder-induced first order transition between a elastically deformed and a plastically deformed lattice. This transition shows its unique character in its irreversible nature in thermal cycling in contrast with magnetic field cycling. Magnetic response data also show remarkable similarity with spin glasses in the occurrence of a robust metastability. Pronounced history dependence is shown to be a consequence

of enhanced pinning which can be obtained either by studying samples with greater disorder or by going to low temperatures and high magnetic fields in a single sample. The zero-field cooled state shows a greater degree of order than the field cooled state in much of the (H,T) space, consistent with direct transport study. The origin of this difference is shown to be the stability of an amorphous pinned phase in samples of stronger pinning. The analog of the spin glass freezing temperature is an amorphization temperature, coincident with the peak effect, above which the system shows no history dependence. The locus of this amorphization line in the (H,T) space yields information on the relative roles of thermal fluctuations and quenched disorder in destabilizing the ordered lattice. We also obtain information of the mysterious double peak effect and show this to be a direct effect of disorder, which generically occurs at the transition between a stiffer and a softer vortex phases. Finally, we find that the experimentally obtained vortex phase boundaries separating elastically deformed, plastically deformed and amorphous phases show remarkable correlation with the moving phases in the analogous part of the (H,T) phase space exhibiting elastic flow, plastic flow and fluid flow respectively, obtained through detailed transport measurements of the same system. Many of the features seen in this system are remarkably similar to what is observed in both the cuprates and other low-Tc systems with significantly different microscopic physics.

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