Vortex Glass-Liquid Transition in Pinned Superconductor

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Abstract

It has been clarified that the flux pinning strongly affects the so-called vortex glass-liquid transition. This transition is investigated using the statistical theory in which the elastic energy of flux lines and the pinning energy are taken into account. From the condition of equilibrium the well-known balance between the Lorentz force and the pinning force is obtained. There exists formally a threshold value, $f_{\rm pt}$, for the elementary pinning force, $f_{\rm p}$, and the flux pinning is not effective for $f_{\rm p} < f_{\rm pt}$. According to the theory by Yamafuji *et al.*[Physica C **212**, 424 (1993)], the effect of thermally activated flux motion can be approximately taken into account by reducing the depth of pinning potential. This means that the elementary pinning force varies with temperature as $f_{\rm p} - f_{\rm pt} \propto T_{\rm g} - T$ in the vicinity of the transition temperature, $T_{\rm g}$. Using the statistical average the free energy of the flux lines is calculated. The first derivative of the total energy with respect to T at $T_{\rm g}$ is continuous, while the second derivative is discontinuous. Thus, the depinning is a kind of phase transition of the second order. It is also found that the parameter representing the disorder in the flux line lattice becomes small above $T_{\rm g}$. This explains the observation by Tonomura *et al.* using Lorentz microscopy that the flux line lattice becomes more perfect in this temperature region.