Reversible magnetization of irradiated layered superconductor.

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Theory of reversible magnetization of a layered superconductor with columnar defects is proposed. Magnetic properties of layered superconductors are conditioned by the its system of magnetic vortices. In high magnetic field (>0.05 T) it consists of 2D magnetic vortices (pancakes). The vortices form a gas with nonzero topological charge connected with external magnetic field. Thermodynamic potentials of such a system contain a large entropy term. Reversible magnetization of the system is due to instability of 2D vortex dipoles and Abrikosov vortices against dissociation into 2D vortex gas analogous to that takes place at Kosterlitz–Thouless transition. Columnar defects are nonsuperconducting cylindrical region formed by means of irradiating a sample by high–energy heavy ion beams. They influence the vortex system equilibrium in two ways. Defects are more advantageous places due to zero core energy and both free and occupied defects contribute add portion in the entropy of the system.

The partition function of the vortex system in external magnetic field was constructed. The thermodynamic potential of the system averaged over defect configuration was calculated in the mean field approximation. The equilibrium magnetization of the system vs the external magnetic field H_e is calculated at different temperatures. It is shown that the magnetization depends on the matching field B_ϕ, which is connected with the defect concentration n_d by the expression $B_\phi = 2H_{c2} n_d \pi \xi^2$. At low external field $H_e << B_\phi$ magnetic flux is mainly realized by the trapped vortices, but in the opposite case $H_e >> B_\phi$ all defects are occupied and the main contribution to the magnetization processes is provided by free vortices. At low temperatures $T < 0.8 T_{KT}$ both low and high field branches of the magnetization curves are proportional to $\ln H_e$. Their difference depends on the defect concentration (matching field) and the energy U_{pin} of pinning of the vortex on a defect

$$\Delta M = \frac{1}{\phi_0 s}\left[U_{pin} + T \ln \frac{B_\phi}{2H_{c2}}\right],$$

where ϕ_0 is the flux quantum and s is layered structure period.