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Microscopic Insights into Superconducting Transition from Type I to Type II

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The interaction between magnetic fields and superconductors reveals a wide range of intricate phenomena. Superconductors, known for their magnetic properties, can be categorized into two primary types based on their response to an externally applied magnetic field. Type I superconductors completely expel the magnetic field, while type II superconductors allow it to penetrate, resulting in a mixed state. In this mixed state, the magnetic flux enters the superconductor as Abrikosov vortices, each carrying one flux quantum. These vortices exhibit repulsive interactions and tend to form a regular lattice pattern.The critical transition between these two types is precisely defined by the Ginzburg-Landau theory, which yields $\kappa = 1/\sqrt{2}$ as the critical value at which the transition occurs

Intriguingly, investigations on materials possessing a κ value close to one have uncovered a group of superconductors that do not easily fit into the traditional classifications. Empirical findings have demonstrated the presence of an *intermediate* mixed state (IMS) within these materials. The magnetic field permeates such superconductors, resulting in diverse spatial arrangements of vortices, including the co-existence of Meissner domains, vortex lattice islands, vortex clusters, and chains.

Within this investigation, a convenient microscopic approach based on self-consistent computation of the Bogoliubov-de Gennes and magnetic state equations is employed to reveal various phenomena, such as vortex clustering and the interactions between multiple vortices. In this study, we investigate the transition of the system from type I to type II superconductor, which involves passing through an IMS. Our research reveals that intricate many-body interactions among vortices lead to the emergence of unconventional vortex patterns during this transition. Our work provides insights into the IMS, revealing the rich physics of this class of superconductors.

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