3rd ICQMT 2025

3rd International Conference on Quantum Materials and Technologies

Type-III superconductivity

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Date and Time:

From 26 April to 3 May 2025, exact day&time will be announced later.

Lecture Room:

TBD

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Abstract

Superconductivity, a macroscopic-scale coherent quantum state, is one of the most fascinating quantum phenomena. It is usually described by the Ginzburg–Landau (GL) theory in terms of the order parameter, representing the macroscopic wave function of the superconducting condensate. The GL theory addresses one of the prime superconducting properties, screening of the applied electromagnetic field. The screening effect can be described as acquiring mass by electromagnetic field when it enters a superconductor and is known as the Anderson–Higgs mechanism. Here, we describe widely spread superconductors, granular superconductors with electronic granularity, where every granule carries a local order parameter shown by green arrows. We demonstrate that electronic granular materials possess a novel type of superconductivity whose electromagnetic response must be described by the Deser–Jackiw–Templeton topological mass generation. Accordingly, in these novel Type-III superconductors, the GL theory must be replaced by an effective topological gauge theory. We show that the corresponding superconducting transition is a three-dimensional generalization of the 2D Berezinskii–Kosterlitz–Thouless vortex binding–unbinding transition. The binding–unbinding of the vortices in 3D results in the Vogel-Fulcher-Tamman (VFT) scaling of the resistance near the superconducting transition, and experimental data fully confirm this VFT behavior. Type-III superconductors host a novel type of vortices that differ from the standard Abrikosov vortices, having a normal core and from Josephson vortices that are characterized by suppression of the order parameter in the vicinity of their centers. The novel vortices that define the unusual electromagnetic response of type-III superconductivity arise due to circular tunneling of the vortex phase between neighboring granules and the simultaneous change of the local superconducting phase over 2p when making a full circle (shown by red arrows) around the singular point in the vortex center. These novel vortices, which we call XY-vortices, do not carry the suppressed order parameter. This results in the new phase diagram for type-III superconductors: since the formation of an XY-vortex does not require energy, the magnetic penetration field at which XY-vortices start to form in the type-III superconductor is equal to zero.