TRANSFORMATION OF A THREE DIMENSIONAL FIRST ORDER VORTEX MATTER TRANSITION WITH INDUCED DISORDER

Abstract

by

Ruobing Xie

The understanding of vortex matter in high temperature superconductors is important since vortex behavior determines the entire electromagnetic response of high T_c superconductors and hence holds the key to a variety of technical applications. On the other hand, vortex matter can be considered as a new form of matter with solid, liquid and gas phases analogous to solid state materials, except that the building blocks in this case are vortices or magnetic flux quanta rather than atoms. In clean high T_c superconductors, in the presence of a finite magnetic field, a triangular Abrikosov lattice is formed from a collection of vortices. This Abrikosov lattice can melt at higher temperatures, giving way to a vortex liquid state where long range translational and orientational order of the vortices are lost, similar in the way ice transitions to a liquid at the melting temperature. Remarkably, unlike in solid materials, the main parameters which control the vortex lattice melting

transition such as thermal energy, vortex interaction energy and defect density are surprisingly easily controlled in vortex matter. For example, the number of vortices can be precisely tuned with a magnetic field, the temperature can be controlled in a cryostat and in particular, the number of defects can be carefully controlled by introducing them via particle irradiation. Hence the vortex matter system is ideally suited for the study of phase transitions in general.

In this thesis, I present a systematic thermodynamic study of the effect of columnar defects induced by heavy ion irradiation on the first order melting transition in an optimally doped YBCO high temperature superconducting vortex system. The thermodynamic properties are characterized with a home-built ac-micro-calorimeter capable of measuring very small crystals (< 200 nanograms). I explore the entropy change at the first order vortex melting transition as a function of defect dose and also the effect of anisotropy pinning by columnar defects. The main gist of the thesis is to empirically explore how a first order transition transforms into higher order in a three dimensional melting system. We find that a threshold of defects can trigger an abrupt loss of a first order transition, contrary to conventional wisdom which suggests a gradual transformation from first to higher order melting with increasing defects as proposed by Imry and Wortis. Since there is currently no microscopic theory of 3D melting, our results provide an empirical starting point using vortex matter as a new paradigm for the development of such a theory.