Phases of disordered films near a superconductor-insulator transition

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We investigate the possibility of a zero-temperature magnetic field-tuned superconductor-to-insulator transition in disordered thin films. This is an example of a quantum phase transition where an external parameter (i.e. the magnetic field) induces a transition from one quantum ground state to another, fundamentally different one. In our studies we were particularly interested in the possibility of a boson-dominated transition in which in the presence of a finite amount of quenched disorder, the ground state at low magnetic field is a vortex glass consisting of localized vortices and mobile Cooper pairs. As the magnetic field is raised, the phase fluctuations of the order parameter increase and ultimately drive the transition to a Bose-insulating phase, above a critical field Hc.

The different phases can be studied by measuring the resistivity and the Hall resistance as a function of temperature and magnetic field for a series of films of varying disorder. Isotherms of the resistivity cross at the temperature- independent transition, Hc, then peak at a higher field and decay slowly toward the normal state at the very highest fields. The peak in the resistivity appears to be activated and characterizes the strength of the insulating phase. We suggest that at the resistivity peak the film crosses over from a boson-dominated insulating phase at lower fields to a fermion-dominated insulating phase at higher fields, a result of an increased depairing rate, which suppresses the order-parameter amplitude and destroys the Bose-insulator. Despite the increased depairing rate, pairing susceptibility persists to the highest accessible fields, as the normal state does not appear to be fully recovered and a vestige of superconductivity remains. This interpretation is reinforced by measurements of the Hall resistance, which show zero resistance in the expected superconducting regime, finite resistance in the Bose-insulating regime, diverging resistance in the Fermi-insulating regime, followed by a peak at high fields that portends a return toward the normal state.

The phase transition itself can also be studied by carefully measuring the linear and dynamic resistance near the crossing point. As with all critical phenomena, the

resistance is expected to scale with a reduced parameter and collapse onto a universal curve. The exponents describing the data collapse can thus be extracted, revealing insights into the universality class of the underlying transition.