Quantum Monte Carlo Study of a Magnetic-Field-Driven 2D Superconductor-Insulator Transition

KWANGMOO KIM, DAVID STROUD, The Ohio State University — Using quantum Monte Carlo calculations of the \((2 + 1)D \, XY\) model, we study the superconductor-insulator phase transition of a disordered 2D superconducting film vs. the applied magnetic field. The \(XY\) coupling is assumed to be \(-J \cos(\theta_i - \theta_j - A_{ij})\), where \(A_{ij}\) has a standard deviation \(\Delta A_{ij}\). The critical coupling constant \(K_c = \sqrt{J/(2U)}\) and the universal conductivity \(\sigma^*\) are found to increase monotonically with \(\Delta A_{ij}\). Beyond a certain critical value of \(\Delta A_{ij}\), the superfluid density vanishes for all \(K\)'s, but a renormalized coupling constant \(g\) remains finite, suggesting a transition into a Bose glass phase. At a larger value of \(\Delta A_{ij}\), the system becomes a Mott insulator. The critical values are found to be \(K_c = 0.490 \pm 0.001\) and \(\sigma^*/\sigma_Q = 0.324 \pm 0.003\) when \(\Delta A_{ij} = 1/2\); \(K_c = 0.532 \pm 0.001\) and \(\sigma^*/\sigma_Q = 0.494 \pm 0.011\) when \(\Delta A_{ij} = 1/\sqrt{2}\); \(K_c = 0.585 \pm 0.004\) when \(\Delta A_{ij} = 0.854\); and \(K_c = 0.630 \pm 0.002\) when \(\Delta A_{ij} = \infty\). The last value, which represents a Bose glass to Mott insulator transition, is obtained from \(g\), whereas the others represent a superconductor-to-insulator transition and are obtained from the superfluid density. We conclude that, for certain couplings, a disordered film may undergo a transition from superconductor to Bose glass to insulator with increasing field.

\(^1\)Supported by NSF Grant DMR04-13395 and OSC.