Thermal effects on current driven vortex dynamics in the Corbino disk

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A new class of artificial atoms, such as synthetic nanocrystals or magnetic vortices in type II superconductors, naturally self-assemble into ordered arrays. This property makes them applicable to the design of novel solids, and devices whose properties often depend on the response of such assemblies to the action of external forces.

In particular, much experimental and theoretical efforts have been devoted to charactering the phase diagram of magnetic vortices in the type II superconductors. Depending on the value of the magnetic field H, temperature T, and sample preparation, vortices can form a crystal (called the Abrikosov vortex lattice), liquid, and glassy phase. In clean systems the vortex solid melts into a liquid via a first order phase transition. If the barriers to vortex line crossing are high, a rapidly cooled vortex liquid can bypass the crystal phase and get trapped in a metastable polymerlike glass phase, such as the vortex glass, the Bose glass or the Bragg glass.

Of special importance is the non-equilibrium response of vortex matter to the flow of an external current, because the dissipative motion of the vortices induces an undersirable macroscopic resistance. The moving phase can be as simple as the collective motion of an elastically deforming vortex crystal, or can be more complex, such as in plastic or in channel vortex flow.

These transport experiments in type II superconductors are often performed in a strip geometry. Here we study the transport properties of a vortex lattice in a two-dimensional circular disk geometry (called the Corbino Disk) by molecular dynamics simulations for the vortices position. An external magnetic field is applied along the disk axis. The present model is based on the well-known point vortex picture. The thermal effect is also taken into account.

In the Corbino disk, the current is applied at the disk center and flows radically towards the boundary, whose density decays as r^{-1} with r the distance from the disk center. Thus, the radial driving current yields a spatially inhomogeneus Lorentz force, acting on the vortex, along the azimuthal direction that decrease as $\sim r^{-1}$. In the present model we include the effects of vortex-vortex repulsive interaction force, driving Lorentz force, the sample edge barrier force, and thermal noise effects.

From large scale simulations it is found that (1) at low currents, the local shear stress due to the Lorentz force is negligible, and all the vortices move as a rigid solid, giving rise to a liner velocity profile $v \sim r$, (2) at large current, the solid breaks up due to shear stress, and the vortices can move free as a liquid, leading to the fluid like velocity profile as $v \sim r^{-1}$, and (3) at moderate currents the vortex crystal cannot sustain the shear stress induced by the resulting inhomogeneous Lorentz force, and the response becomes plastic. Critical for the above regions are related to the shear modulus of the vortex lattice.

We also study the effect of thermal noise on the above behavior. Details will be discussed on the conference.