PHYSICS

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Resistance is Not Futile: Pinning Down Elusive Vortices in Superconductors

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Abstract

Though superconductors are revered for their ability to carry dissipation-free supercurrents below a material-dependent critical current (J_c), the seemingly inconspicuous action of vortices can introduce dissipation even for currents well below J_c. In type II superconductors (including high-T_c cuprates, iron-based superconductors, and MgB_2) immersed in high enough magnetic fields, vortices are formed by the penetration of magnetic flux and can be moved by current-induced forces and thermal energy. Vortex motion can be disruptive: it limits the current-carrying capacity in wires, can cause losses in microwave circuits, and, more generally, can induce phase transitions. Understanding vortex dynamics is a formidable challenge because of the complex interplay between moving vortices, material disorder (defining pinning sites) that can counteract vortex motion, and thermal energy that can cause vortices to escape from these pinning sites. In particular, we cannot precisely predict the rate of thermally activated vortex motion (creep) in a given sample, and tuning the creep rate by modifying the microstructure is typically achieved by means of trial and error. Furthermore, common techniques to enhance J_c by adjusting the disorder landscape (e.g., irradiation or incorporation of non-superconducting inclusions) are often accompanied by unfavorable increases in the creep rate.

In this talk, I will discuss the importance of minimizing creep and my efforts to better understand vortex creep. I will cover results from studies of a wide variety of materials. Additionally, I will present our proposal of the existence of a universal minimum realizable creep rate that depends on material parameters. This limitation is of both fundamental and technological significance: it provides new clues about the interplay between material parameters and vortex dynamics and about how to engineer materials with slow creep. This hard constraint, applicable at low temperatures and fields, has two important implications: first, the creep problem in high-T_c superconductors cannot be fully eliminated and there is a limit to how much it can be ameliorated; and second, we can predict that any yet-to-be-discovered high-T_c superconductors will have fast creep.

Biography:

Serena Eley is an Assistant Professor of Physics at the Colorado School of Mines (Mines) whose work focuses on understanding the effects of disorder on the electronic and magnetic properties of quantum materials and devices. Last August, she completed a postdoctoral research appointment in the Condensed Matter and Magnet Science department at Los Alamos National Laboratory (LANL). At LANL, her research on thermally activated vortex motion (creep) in disordered superconductors contributed to the discovery of a universal relationship for a lower bound on creep rates. She earned her B.S. in physics at the California Institute of Technology and her Ph.D. in physics at the University of Illinois Urbana-Champaign. Her dissertation work, for which she received the John Bardeen Award, focused on proximity effects and vortex dynamics in nanostructured superconductors, revealing behavior that deviated strongly from conventional proximity effect theories. Prior to graduate school and as a Henry Luce Scholar, she gained experience performing high-pressure synthesis of superconductors at the International Superconductivity Technology Center in Tokyo, Japan. She has also worked at Sandia National Laboratory on Si-based devices composed of quantum dot nanostructures and shallow donors for spin quantum bits. Her current research interests include skyrmion dynamics, superconducting device physics, and mitigating materials related issues that limit superconducting circuit operation.