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Materials Engineering of Superconductors: Challenges and transformative opportunities in superconductor vortex physics

ABSTRACT

In superconductors, the motion of vortices introduces unwanted dissipation that is disruptive to applications, for example, limiting the current-carrying capacity in wires and causing energy losses in microwave circuits. Fortunately, material defects can immobilize vortices, acting as vortex pinning centers, which engenders dramatic improvements in superconductor material properties and device operation. This has motivated decades of research into developing methods of tailoring the disorder landscape in superconductors to increase the strength of vortex pinning. Yet efficacious materials engineering still eludes us. The electromagnetic properties of real (disordered) superconducting materials cannot yet be reliably predicted, such that designing superconductors for applications remains a largely inefficient process of trial and error. In this talk, I will discuss major open questions in vortex physics and our efforts to understand the complex interplay between vortex elasticity, vortex-vortex interactions, and material disorder. I will cover results from studies of a wide variety of materials, specifically discussing the effects of incorporating artificial pinning centers and anisotropy on the critical current, thermally-activated vortex motion (creep), and vortex phases. Lastly, I will present our work towards answering two of the major open questions in vortex physics — determining the ceiling for the critical current density and the minimum achievable rate of thermally activated vortex motion. Understanding these limitations provides new clues about the interplay between material parameters and vortex dynamics as well as how to engineer materials with slow creep.

BIO

Dr. Serena Eley is an Assistant Professor of Electrical and Computer Engineering at the University of Washington in Seattle, WA. She has won a National Science Foundation Career Award, a Cottrell Scholars Award, and the American Institute of Physics Joseph A. Johnson Award. After earning her B.S. in physics at the California Institute of Technology, she conducted research at the International Superconductivity Technology Center in Tokyo, Japan as a Henry Luce Scholar before earning her Ph.D. in physics at the University of Illinois Urbana-Champaign. Her dissertation work, for which she received the John Bardeen Award, explored proximity effects and vortex dynamics in nanostructured superconductor–normal-metal arrays, revealing behavior that deviates from conventional proximity effect theories. After graduate school, Eley performed research at Sandia National Laboratories on Si-based devices designed for use as spin quantum bits, at Los Alamos National Laboratory on vortex dynamics in superconductors, and as an Assistant Professor of Physics at the Colorado School of Mines. Currently, Professor Eley's research group studies the complex interplay between material disorder, thermal energy, spin and charge in quantum materials and devices. More specifically, they focus on superconductivity and magnetism, with a particular interest in vortex dynamics, skyrmion dynamics, energy loss mechanisms, in superconducting circuits, and next-generation spintronics

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