Nanoengineered Pb islands: critical fields and vortex configurations from Ginzburg–Landau modelling

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We theoretically investigate the superconducting response of nanosized Pb-island structures containing a central hole whose radius and depth are systematically varied to elucidate the evolution of the superconducting condensate under a strong applied magnetic field. Using numerical simulations based on the Ginzburg–Landau framework [1,2], we analyze how nanoengineered geometry controls vortex nucleation and penetration, as well as the stability of the condensate. For each designed Pb island, we determine the critical magnetic fields for vortex entry, compute the free-energy landscape, and identify the resulting vortex configurations as functions of the hole radius and depth. The results reveal pronounced geometry-driven changes in vortex patterns and energetic stability, demonstrating that both parameters act as effective control parameters for tailoring superconducting properties at the nanoscale. These findings provide insight into emergent superconducting behavior in confined Pb structures and suggest a route to tune superconducting circuits through precise nanoengineering of island geometry.

References

[1] B.J. Baelus, F.M. Peeters, Phys. Rev. B, 65, (2002),104515.
[2] W.A. Little, R.D. Parks, Phys. Rev. Lett. 9, (1962), 9.
[3] J.D. González, M.R. Joya, J. Barba-Ortega Phys. Lett. A, 382, (2018), 3103.
[4] J.D. González, O.J. Gaona, J. Barba-Ortega, J. Low Temp. Phys. ,198, (2020), 123.

Figures

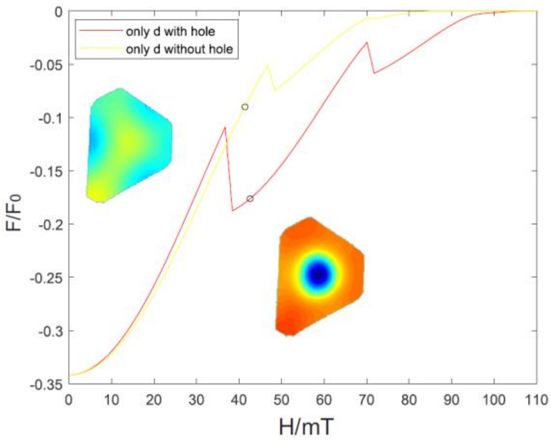

Figure 1: Free energy curves and corresponding snapshot of vortex states on a Pb island without a hole (up) and with a central hole (down) at the same magnetic field.

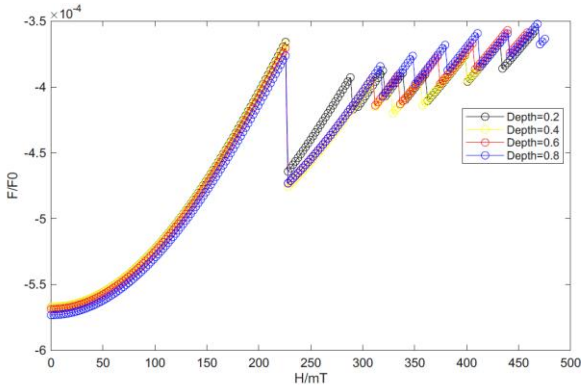

Figure 2: Free energy curves for a Pb island with a central hole (down) and different depth