Understanding the Magnetic Field Penetration in Mesoscopic Superconductors Via COMSOL Multiphysics® Software

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Abstract

Introduction: One of the main characteristic of the superconductors is its diamagnetic response of applied magnetic fields. The superconductors refuse the penetration of magnetic field into its interior, it is the well know Meissner effect, B=0 into the superconductor sample. However when the applied field reach a determined value, the magnetic field can enter. There are two different ways of these penetrations, and it is characteristic of two types of superconductors. Superconductors type I permits the penetration of B continually. While in superconductors type II, the penetration of the magnetic field is quantified with a magnetic flux hc/2e. One powerful theory to understanding the superconductivity is the Ginzburg-Landau (GL) theory. In this context we must solve a couple of no-linear partial differential equations along of the sample. The GL equations are given by

∂Ψ/∂t=-(i/k ∇+A)^2 Ψ+(1-T)Ψ(1- |Ψ| ^2)
1/σ ∂A/∂t=1/2iκ (Ψ^* ∇Ψ-Ψ∇Ψ^*)-|Ψ|^2 A-∇×∇×A,
and must satisfy the boundary conditions,
∇Ψ·n=0
∇×A=B_a
A·n=0.

COMSOL Multiphysics® software: In order to solve this couple of partial differential equations along of a determined geometry, the finite element method (FEM) is a good technical tool. The COMSOL software uses this method and allows even not experts in FEM work in high level problems. In this work I have used the PDE, Coefficient Form interface.

Results: In this section I show the magnetic field penetration for type I and type II mesoscopic superconductors. In Figure 1, we can see a mesoscopic superconductor type I. In Figure 2, we see a type II superconductor. In both cases the simulation conditions are the same, the applied magnetic field is B = 2 Hc2, and the temperature is T = 0. The dark region represents the magnetic field, while the clear region represents the superconducting region. For type I the magnetic field enter initially by the corners. The behaviors of the magnetic field penetration are in quite agreement of results found in literature. New aspects of magnetic field penetration in mesoscopic type II superconductors, using the same method, have been investigating and it will

be published. Using this same method we could study penetration of magnetic field in mesoscopic sample with defects [1].

Conclusion: Using COMSOL was possible solve the Ginzburg-Landau theory, and thus investigate a very important effect of superconductors, the magnetic field penetration. Our numerical results are in quite agreement with experimental and theoretical results for type I and type II superconductors.

Reference

1. Isaias G. de Oliveira, Magnetic Flux Penetration in a Mesoscopic Superconductor with a Slit, J. Supercond. Nov. Magn., 27, 1143-1152 (2014).

Figures used in the abstract

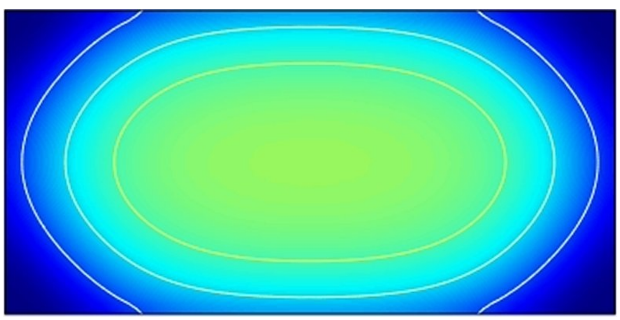

Figure 1: Plot of $|\Psi|^2$ along the sample. Type I superconductor with Lx=100, Ly=50 and k=0.5. T =0, and B= 2 Hc2. The dark blue region is the magnetic region, where Ψ is suppressed.

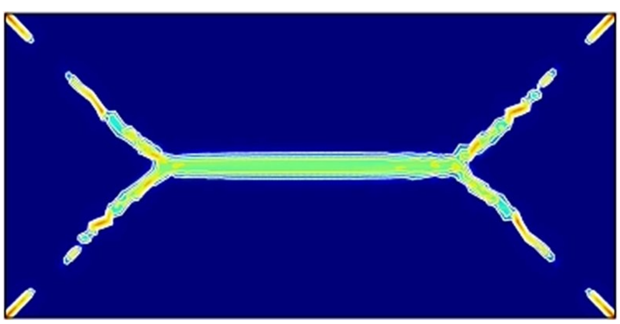

Figure 2: Plot of $|\Psi|^2$ along the sample. Type II superconductor with Lx=100, Ly=50 and k=0.5. T =0, and B= 2 Hc2. The dark blue region is the vortices region, where Ψ is suppressed.