Surface effects on the definition of type 1 and 2 superconductors

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In 1956 A.A. Abrikosov has shown that bulk superconductors fall into two categories, namely, type 1 and 2, and only the latter possesses vortex states. However, it has been known since long ago that an external surface can affect this view making the distinction between type 1 and 2 superconductors elusive. Superconductivity remains in a thin layer around the external boundary with thickness defined by the coherence length until the critical surface field, H_{c3}, is reached [1]. Superconductors of type 1 and 2 satisfy the inequalities $H_{c2}<H_c$ and $H_{c2}>H_c$, respectively, but since $H_{c3}>H_{c2}$ two type 1 superconductors are possible, namely, $H_{c2}<H_{c3}<H_c$ and $H_{c2}<H_c<H_{c3}$. Long ago M. Thinkham [2] has named the latter case as type 1.5 superconductors and pointed this as a questionable classification since its validity depends on the nature of the boundary condition at the sample surface and not on the intrinsic properties of the bulk of the material. Recent numerical studies of the Ginzburg-Landau theory [3,4] have also shown that mesoscopic type 1 superconductors have vortices due to their enhanced volume to area ratio. Here we show that type I and 2 superconductors must be redefined in presence of an external surface and this results is a straightforward consequence of the Ginzburg-Landau theory proven by the same method used by Abrikosov to obtain his seminal conclusions from this theory, but now extended to include an external boundary [5]. Basically, the critical coupling κ_c that splits the two categories of superconductors is affected by the presence of the external boundary and becomes much smaller than $1/\sqrt{2}$. We consider an infinitely long cylinder of radius R under an external applied field along the major axis which is then isothermally lowered and enters the superconducting state below the critical field. Superconductivity sets in a thin layer around the external boundary where paramagnetic currents are established and a giant vortex with vorticity defined by the trapped flux, HR^2 is then formed. We find that type 2 superconductors sustain this vortex state for $H<H_{c2}$, as expected, but surprisingly, type 1 superconductors unfold a new critical field, H_m, found to disappear in the limit of a very large cylinder. Therefore, type I superconductors are found to sustain giant vortices for finite R but in the regime $H_{c2}<H<H_m$. The present approach gives a new derivation of the surface field H_{c3}, based on the stability of the kinetic energy of the condensate.

References

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