T.027 THE $J_s(\varphi)$ RELATIONSHIP, ABRIKOSOV VORTICES AND JOSEPHSON VORTICES IN VARIABLE THICKNESS BRIDGES

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A Variable Thickness Bridge (VTB) is a specific type [1] of superconducting weak link in which the bridge film is significantly thinner than the two thin film electrodes ("banks") to which it is connected. As a result of the relative thinness of the bridge, nonlinear effects are localized entirely in the bridge. This report deals with the transition from weak superconductivity ( Josephson effect ) to type II superconductivity as the length of the bridge ( and thus also the spacing between the banks ) L is increased.

We consider first a VTB of a very small width W, in which the current is distributed uniformly over its cross section. We have calculated the $J_s(\varphi)$ relation in such a bridge for different values of T, $T_c$, the bridge film transition temperature, and $T_{cb}$, the bank transition temperature. The calculations may be done using the Ginzburg-Landau equations for $T \approx T_c \lessapprox T_{cb}$, or the Eilenberger equations in the Uzadel form [2] for arbitrary Ts. The value of the modulus of the orderparameter ( or the Gor'kov functions ) on the bridge-bank boundary can be taken to be equal to its equilibrium value in the banks [3].

When L is small ( $L \ll \xi(T)$), $J_s(\varphi)$ is always single valued. In S-N-S bridges, increasing L results in an exponential decrease of critical current, while $J_n(\varphi)$ stays single valued. In S-S'-S bridges, increasing L results in $J_s(\varphi)$ becoming multiple valued, while continuing to have period $2\pi$ and to be odd, as shown in Fig.1.



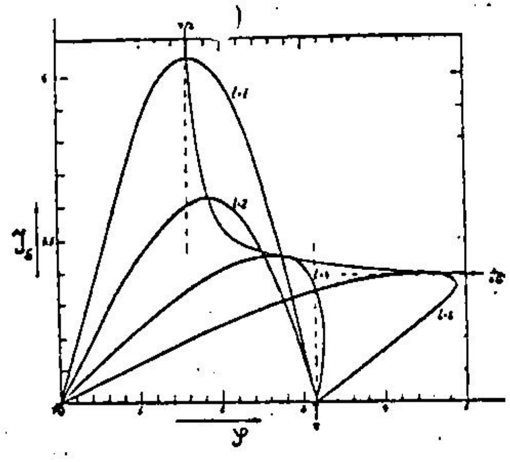


Fig.1
$J_s(\varphi)$ relation for $T \ll T_c = T_{cb}$.
($\lambda = 1$)

Fig. 2 shows the critical length $L_c$ for which $J_s(\varphi)$ becomes multiple valued, versus the value of $\lambda = \Delta_b/\Delta_\infty =$ $((T_{cb}-T)/(T_c-T))^{1/2}$ at $T \ll T_c \lessapprox T_{cb}$.

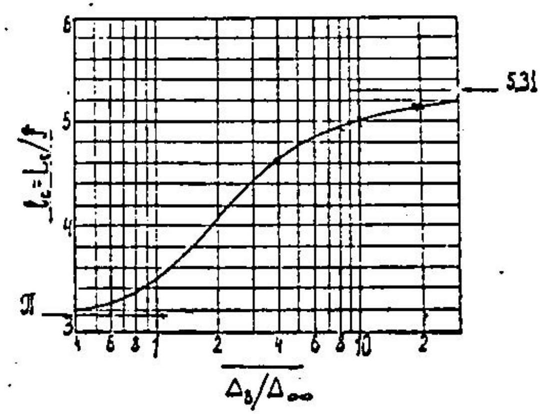


Fig.2

Next we considered the two-dimensional problem of the form of vortex with the center of the vortex at the center of the bridge. When L is large, there is the usual Abrikosov vortex in the bridge, with core radius $\sim\xi \ll L$ and magnetic field dimension along the bridge width $\delta_J \gg L, \xi$. When L is decreased, the vortex core deforms: its width goes to infinity as $L \to L_c$, and the core disappears at $L=L_c$. The remaining vortex has a structure typical for a Josephson vortex with only one characteristic dimension $\delta_J$ along the width of the bridge. $\delta_J$ is equal to $\delta_I L/4t_e = c\Phi_0/16\pi^2 t_e J_c$ for the VTB over a superconducting ground plane, and $\sim(\delta_I L)^{1/2}$ for a VTB without the plane. $J_c$ is a critical current linear density, $\delta_I = 2\delta^2/d$, $\delta$ is the penetration depth, d is the thickness of the film[5].

So, an Abrikosov vortex may exist only in systems with a multiple valued $J_s(\varphi)$ relationship and in particular can never be induced in S-N-S bridges. Although a system with a moving Abrikosov vortex structure has some of the features of the Josephson effect [1,6], it is reasonable to take $L=L_c$ as the boundary: type II superconductors - "pure" Josephson effect.

If the width of a VTB is decreased ($W \approx \xi$), the vortex transition length increases (Fig.3), and goes to infinity when $W \to 4.41\xi$. This width is the minimum width of a superconducting strip which can support vortices with axis normal to the plane of the strip in weak magnetic fields ($H \ll H_{c2}$).

References:


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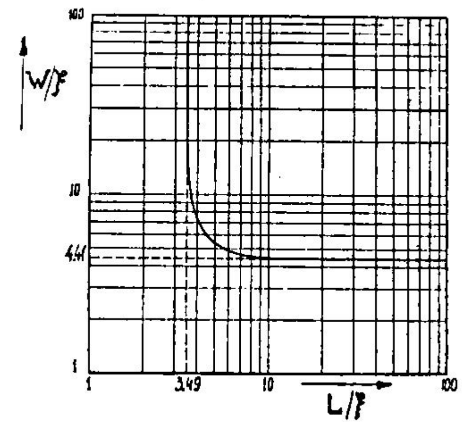


Fig.3

The Abrikosov vortex can exist only if L and W are more then the boundary value.

$T \lessapprox T_c = T_{cb}$ (A=1).