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INFLUENCE OF THE ABRICOSOV'S VORTICES ON SUPERCONDUCTING TUNNEL JUNCTION PROPERTIES

A.A.Golubov and M.Yu.Kupriyanov
Institute of Solid State Physics, Academy of Sciences of the USSR, 142432 Chernogolovka, USSR

Josephson tunnel junctions are widely used in various crioelectronic devices. One of the problems encountered in the development of tunnel junctions based circuits is variation in its parameters caused by the magnetic flux trapping in the superconducting electrodes in the form of Abricosov's vortices [1-3]. So an influence of the trapped magnetic flux on junction properties is of interest now. Nevertheless no rigorous teoretical study of this question had been previously reported.

We have studied this problem on the basis of microscopic approach in the following assumptions: 1) dimensions of junction are small compared to the Josephson penetration depth; 2) electrodes are identical dirty superconducting films with GL parameter $\varkappa \gg 1$; 3) external magnetic field penetrates into electrodes as regular static vortex lattice oriented perpendicular to the junction; 4) vortices in both electrodes are exactly aligned with each other on the scale of superconducting coherence length and no spatial variation in the phase difference between two superconductors results; 5) transparency of tunnel junction is small, so that the results of tunnel teory[4] are valid, but with modified normal and anomalous Green's functions F and G in electrodes due to the presence of the trapped flux quanta. In the problem under consideration F, G are energy and space dependent and its calculation on the basis of Usadel's equations is the two stage problem[5]. On the first stage the spatial dependence of order parameter $\Delta(r)$ within vortex unit cell is obtained. The latter is taken according to the well known circular cell approximation for the vortex lattice. Here r denotes the coordinate relative to the cell center. On the second stage with known function $\Delta(r)$ Usadel's equations are analitically continued by replacing the discrete Matsubara frequence w with continuous energy variable $-i\varepsilon$, and functions F (ε, r), G (ε, r) are calculated. Then with known functions F (ε, r) and G (ε, r) tunnel current components are numerically found for various magnetic fields H/Hc2 and temperatures T/Tc by energy intergation and spatial averaging on the circular unit cell. Here Tc and Hc2 denote critical temperature and upper critical field of superconducting film electrodes, respectively. The results of this procedure are shown on fig. 1,2.

Fig. 1a shows increase of the quasiparticle current I_{q} with increase of the magnetic field at the low voltage $V < 2\Delta_0/e$ (Δ_0 is an equilibrium value of order parameter) for the temperature T=0.6 Tc. This "leakage current" is caused by excess density of low energy exitations, localized in the kern regions of the vortices. There is a "knee" structure on differential conductance curves at voltage nearly equal to Δ_0/e, which is shown on fig. 1b for the low temperature T=0.1 Tc. Its amplitude is significantly reduced with the temperature rise. It is necessary to note that this structure is due to the trapped vortices only and is unrelated to the well known anomalies at $V=\Delta_0/e$ caused by the multiparticle tunneling[6]. Supercurrent and interference current amplitudes, I_p and I_{pq}, respectively, are suppressed by magnetic field (for fig. 2a temperature T=0.1 Tc; for fig. 2b T=0.6 Tc). In particular, critical current of junction is reduced with magnetic field increase. All curves, presented on the fig. 1a and 2a,b, show the smearing of jumps and singularities, predicted by tunnel teory[4]. In the weak field limit (isolated vortices) tunnel current is a linear function of the field. All mentioned fenomena are in good agreement with the experiment[1-3].

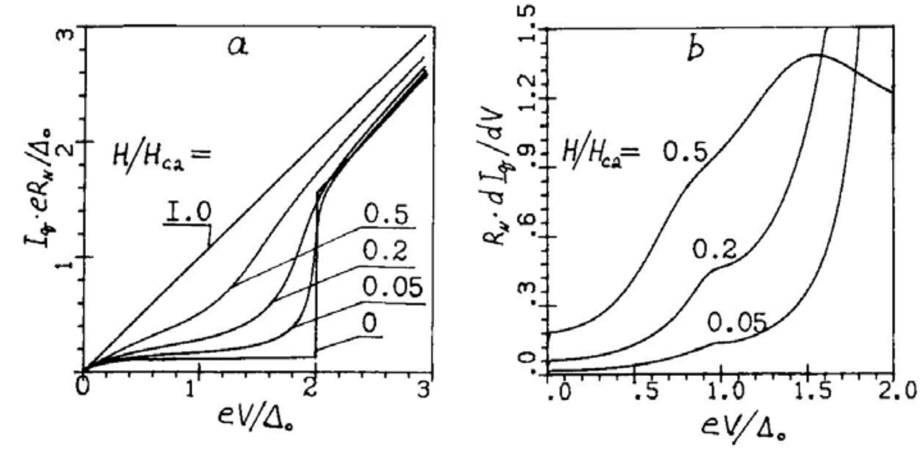

Fig. 1. Quasiparticle current (a) and its first derivative (b).

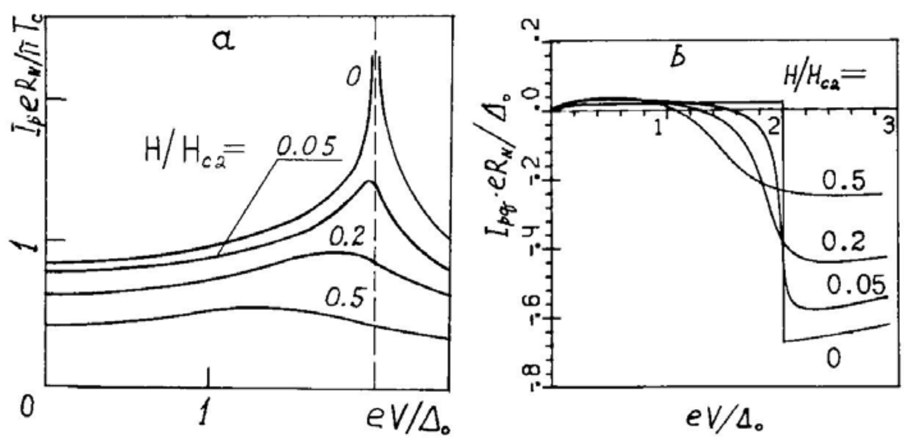

Fig. 2. Supercurrent (a) and interference current (b) amplitudes.

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