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NONEQUILIBRIUM PHENOMENA IN VARIABLE THICKNESS BRIDGES OF SUBMICRON DIMENSIONS

V.N. Gubankow, V.P. Koshelets and G.A. Ovsyannikov

Institute of Radio Engineering and Electronics of the Academy of Sciences of the USSR, Marx Avenue 18, Moscow GSP-3, USSR

Abstract. Peculiarities of the behaviour of submicron variable thickness bridges caused by the influence of nonequilibrium electrons in the weak link region have been investigated in the presence of dc and microwaves.

Thin-film variable thickness bridge (VTB) is one of the most suitable types of weak link of superconductors for the investigation of different nonequilibrium and relaxation phenomena because of the possibility of correct estimation of bridge dimensions and electrical parameters.

In the paper/1/ we have investigated conditions of the transition from coherent motion of vortex to resistively shunted junction (RSJ) model/2/. It has been experimentally shown that the description of the coherent phenomena in VTB using the vortex model evidently cannot be applied if the length $L$ or the width $W$ of VTB is less than $(2+3)\xi(T)$ where $\xi(T)$ is the coherence length. However we have observed essential differences from the conclusions of the RSJ model even in VTB with $L, W < (2+3)\xi$, where narrow-band Josephson generation was registered earlier/3/.

These differences can be easily observed in the shape of I-V curve (IVC)/4/. Figure 1 shows temperature dependences of IVC and the dependence of $\frac{dV}{dT}(V)$ for $T = 3.641$ K. It is seen from figure 1 that when the temperature is lowered the IVC shape changes: according to /2/ at $T = T_c$ the IVC shape is similar to the "hyperbolic" shape. But at $T$ slightly less than $T_c$ there are the linear part of IVC with differential resistance $R_d < R_N$ at the beginning of the resistive range and the part with $R_d > R_N$ of abrupt increasing of $V(R_N)$ is the resistance of VTB in the normal state. This shape of IVC of VTB can be explained by the influence of nonequilibrium electrons in the weak link region caused by the stimulation of superconductivity in the presence of dc and by the increase of superconducting current to the value $I_s^0 > I_c$ where $I_c$ is the critical current.

Fig. 1: The family of the bridge CS-81 IVC at different temperatures. For $T = 3.641$ K IVC and differential resistance dependance on voltage $\frac{dV}{dT}(V)$ are given for $P_c = 0$ and $P_o$ when $I_c = \frac{I_{max}}{2}$. (see the insertion to figure 1). According to the theory/5/ when VTB dimensions are larger than the characteristic length $\eta = \xi(T)\frac{d\xi}{dT}$, on which nonequilibrium electrons may diffuse from the bridge, the stimulation of superconductivity for the three-dimensional bridge structure occurs. As can be seen on figure 1 the IVC part with $R_d < R_N$ becomes visible at $T = 3.7$ K when $\eta = 0.3\mu$ is less than $L = 0.5\mu$. Furthermore in the region $T \sim T_c$ the fact that the critical temperature of the bank films is usually higher than that of the bridge exerts essential influence on stimulation of superconductivity because in the range $\frac{T_c^b}{T_c} > T_c$ our bridges are SNS structures.

With microwave affection we observed Joseph-
son effect together with the well-known Dayem effect /4-5/ (increase of the VTB critical current). This effect (figure 1) was observed on all investigated bridges for frequency range \( f = (\approx 10+150) \) GHz. Figure 2 shows values of \( \frac{(I_{\text{emax}} - I_c)}{I_c} \) for different frequencies of the external signal and values of \( \frac{(I^0 - I_c)}{I_c} \) as functions of \( I_c(T) \). It is seen that unlike the results of /6/, Dayem-effect in our bridges has always temperature threshold \((<T_c)\) and reaches its maximum \( (\approx I^0_c) \). When \( T \) is close to \( T_c \), this temperature threshold is bounded by the same condition as dc stimulation. When \( T \) is not very close to \( T_c \) temperature threshold of the Dayem effect in our bridges is determined by equality \( h\omega = 2A \) where \( 2A \) is energy gap, \( \Delta(T) = 3.06 K \sqrt{\frac{T_c - T}{T_c}} \) and is caused by dominated process of super pair destruction and decrease of the energy gap.

Usually stimulation of the superconductivity by microwaves was explained by the theoretical model developed by Eliashberg et al. /7/ in which appearance of the nonequilibrium distribution function of the electrons in superconductors in the presence of microwave signal with the frequency \( \omega > \tau^{-1} \) (\( \tau \) is electron-phonon energy scattering time) can result in the increase of the energy gap. In fact at \( \frac{\omega}{2\pi} < 1 \) GHz when \( \omega \tau < 1 \) we did not observe Dayem effect in all the investigated bridges.

Besides, in our experiments, we have obtained correlation between the increase of the critical current and the increase of the value \( V_{\text{e}} \frac{\Delta(T)}{\Delta_c} \) at which energy gap peculiarity occurs at IVC. However unlike the theory /7/ and experiments /6/, we have not observed the increase of the critical temperature in our bridges in the whole investigated frequency range \((\approx 1+150)\) GHz.

In the recent theoretical papers /5/ Aslamazov and Larkin have shown that the stimulation of superconductivity by microwaves in weak links is due to the energy electron diffusion upwards owing to "vibration" of the bottom of the weak-link potential wall with the frequency \( f_e \) and the formation of the nonequilibrium electron distribution function. In weak links of small dimensions \( (<\xi) \) this phenomenon is stronger than the direct influence of microwaves /7/. In accordance with the theory /5/ maximum increase of the critical current \( (\approx I^0_c) \) has to be observed when \( L = \xi(T) \); these results agree well with our experimental data. Besides, temperature dependencies of the frequency-optimized value \( \frac{(I_{\text{emax}} - I_c)}{I_c} \) (figure 2) obtained by us and temperature thres-

Fig. 2: The dependency of the value of the microwave stimulation \( \frac{(I_{\text{emax}} - I_c)}{I_c} \) for different frequency of external radiation and the value of the dc stimulation \( \frac{(I^0 - I_c)}{I_c} \) on critical current \( I_c(T) \).

Besides, in our experiments, we have obtained correlation between the increase of the critical current and the increase of the value \( V_{\text{e}} \frac{\Delta(T)}{\Delta_c} \) at which energy gap peculiarity occurs at IVC. However unlike the theory /7/ and experiments /6/, we have not observed the increase of the critical temperature in our bridges in the whole investigated frequency range \((\approx 1+150)\) GHz.

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