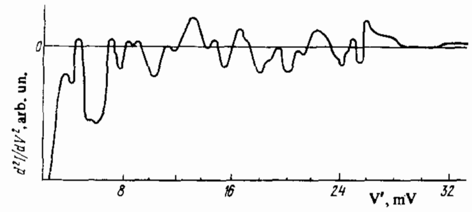

Dependence of d^2I/dV^2 on V' for the $Nb_3Sn-Al_2O_3-Nb_3Sn$ tunnel junction. Abscissas—$V' = V-2\Delta_{eff}$, where V is the voltage and $2\Delta_{eff} = 1.9$ meV is the effective energy gap of Nb_3Sn.

frequency. Each group of maxima of α^2F corresponds to an $F(\omega)$ maximum obtained from the results of neutron measurements[10].

4. The presence of low-frequency maxima in the phonon spectrum makes the Debye approximation unsuitable for practical use. In the calculation of the specific heat, the low-frequency maxima lead to the appearance of a term linear in the temperature and connected with the lattice. This circumstance is usually disregarded, and this greatly exaggerates the electronic density of states. It appears that this is the main cause of the aforementioned discrepancy between the optical data and the results of specific-heat measurements.

The electron and phonon spectra of Nb_3Sn turned out to be more complicated than for ordinary metals. This calls for a special check on the validity of McMillan's formula for T_c.

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V. M. Galitskiĭ, V. F. Elesin, D. A. Kirzhnits, Yu. V. Kopaev, and R. Kh. Timerov, Feasibility of Superconductivity in Nonequilibrium Systems with Repulsion. It is known that the size of the superconducting gap Δ in the simplest model[1], when the effective electron-phonon coupling constant g corresponds to attraction ($g < 0$) and is constant in the interval $\pm\omega_D$ near the Fermi level, is determined by the following expression:

$$1=-g\int_0^{\hbar\omega_D} d\varepsilon\,[1-2n(\varepsilon,\,T)]\,(\varepsilon^2+\Delta^2)^{-1/2}, \qquad (1)$$

where $\hbar\omega_D$ is the limiting phonon energy, $n(\epsilon, T)$ is the quasiparticle occupation function, and T is the temperature.

The critical superconducting transition temperature T_c is determined by condition (1) if we put in the latter $\Delta = 0$.

In the equilibrium state and in the absence of an external source at $T = 0$ we have $n = 0$ for all ϵ. An increase of n under the influence of the external source leads to a suppression of the superconductivity[2]. On the other hand, it is seen from (1) that for a system that is nonsuperconducting ($g > 0$) under normal conditions ($n < 1/2$) a superconducting state ($\Delta \neq 0$) is possible if $n > 1/2$ is produced under the influence of the external source. Since n characterizes the filling of the electronic states above the gap Δ and of the hole states below the gap, it follows that $n > 1/2$ corresponds to the condition of inverted population.

The last condition can be satisfied for the semiconductor model of Fig. 1, which is considered in[3], if the time τ_E of the intraband energy relaxation is much shorter than the time of interband recombination through the dielectric gap Eg. The superconducting state is possible in this case if $Eg < \Delta_0$, where

$$\Delta_0=\frac{2\mu^2}{\hbar\omega_p}\exp\left(-\sqrt{\frac{g_1^2}{g_0^2}-\frac{\pi}{4}}-\frac{1}{g_0}\right),$$

μ is the Fermi quasilevel of the electrons in the conduction band and of the holes in the valence band, ω_p is the plasma frequency; the quantities g_0 and g_1 characterize respectively the intraband and interband Coulomb interactions.

The superconducting gap is produced not at the Fermi quasilevels ($\pm\mu$), but near the band extrema. It is known that for a bound state to be produced it is necessary that the potential and kinetic energies have opposite signs. Under equilibrium superconductivity conditions, the pairing takes place with attraction between the electrons near the Fermi level, corresponding to a loss of kinetic energy. In a state with inverted

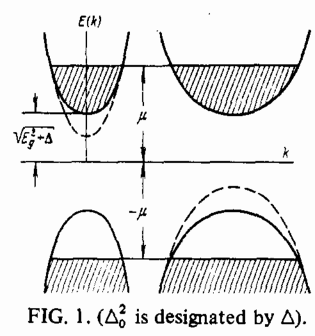

FIG. 1. (Δ_0^2 is designated by Δ).

population, superconducting pairing near the band extrema corresponds to a gain in the kinetic energy resulting from the virtual transition of an electron pair from the bottom of the "C" band to the lower-lying states of the "V" band. For superconducting pairing it is therefore necessary that the potential energy have a sign opposite to the customary one, meaning repulsion between the electrons.

Thus, the inverted-population state and superconductivity with interelectron repulsion are realized here because of the semiconducting character of the band structure.

Is such a state possible for the metallic model?

From a simultaneous solution of Eq. (1) and of the kinetic equation for the quasiparticle distribution function $n(\epsilon)$, under conditions of continuous action of an external source, we get an affirmative answer to this question[4]. Namely, in addition to the trivial solution $\Delta = 0$ and $n < 1/2$, there exists a nontrivial self-consistent solution $\Delta \neq 0$ and $n > 1/2$ (Fig. 2) at

$$\Delta_0 = (2\mu^2/\hbar\omega_p) \exp(-1/g) > \hbar\omega_D/2. \tag{3}$$

It was assumed here that the energy relaxation is due mainly to electron-phonon collisions. This is true if $\mu/\epsilon_F \ll 1$, i.e., the electron-electron collisions are suppressed, owing to the Pauli principle, by a factor $(\mu/\epsilon_F)^2$. Condition (3) means then that the processes of recombination via the gap $2\Delta_0$ cannot occur as a result of single-phonon processes that determine the quasiparticle energy relaxation. Consequently, the recombination time is much larger than the relaxation time.

One of the methods of taking the system from the state with $\Delta = 0$, $n < 1/2$, by application of an external source, to the superconducting state is the formation of a dielectric gap λ on the Fermi level as a result of interband transitions induced by a strong electromagnetic field[5]. If $\Delta > \lambda > \omega_D/2$, the superconducting state is possible: the superconducting gap is then $\Delta = \sqrt{\Delta_0^2 - \lambda^2}$.[6] Once this state is established, the strong field can be adiabatically turned off, $\lambda \to 0$, $\Delta \to 0$, but a stationary superconducting state will nevertheless continue to exist in the presence of the external source.

The superconducting transition temperature T_c is of the order of μ rather than Δ, since an energy on the order of μ is required for thermal breaking of the superconducting pair.

To satisfy the condition (3), the intensity I of the external source should be

$$I > \frac{1}{\varkappa\tau_R}\left[\frac{m^{*2}\omega_\lambda\omega_p}{2}\exp\left(\frac{1}{g}\right)\right]^{3/4}, \tag{4}$$

where κ is the absorption coefficient at the frequency $\hbar\omega \gg 2\mu$.

At reasonable values of the parameters that enter in (4) ($\kappa = 10^3 - 10^4\ \text{cm}^{-1}$, $\tau_R = 10^{-8}$ sec, $\hbar\omega_p = 1$ eV, $m^* = (10^{-1} - 1)m$, $g = 0.5$, the intensity I should be of the order of $10^3 - 10^5\ \text{W/cm}^2$, and T_c then turns out to be of the order of $10^{3\circ}$K.

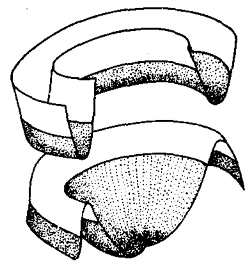

FIG. 2

Since the gap is produced not at the Fermi quasi-levels, the minimum energy of quasiparticle excitation is equal to zero as in a normal metal. This raises the question: does an undamped current flow in such a system in the presence of scattering? An investigation shows[4] that as $\omega \to 0$, the current in an alternating electric field $E = E_0 e^{i\omega t}$, with allowance for elastic scattering by impurities, is equal to

$$j = F\,(2\sigma_N + i\,(\pi\Delta_0/\hbar\omega)\,\sigma_N), \tag{5}$$

where σ_N is the conductivity in the normal state.

It is seen from (5) that such a system can be described by a two-fluid model, the normal non-superfluid component corresponding to the first term, while the conductivity of the superfluid component (the second term) becomes infinite as $\omega \to 0$.

We note that the sign of the second term in (5) is the opposite of the sign of the equilibrium-superconductor current. The current in a constant magnetic field is likewise of opposite sign[4]:

$$\dot{j}_q = \frac{e^2 n_0}{mc} A_q, \quad n_0 = \frac{p_F^3}{3\pi^2\hbar^3}; \tag{6}$$

$\dot{J}_q$ and A_q are the Fourier components of the current and of the vector potential, respectively.

This means that the system in question has anomalous paramagnetism that leads to the penetration of the magnetic field into the sample, and this field executes oscillations with a period $(4\pi m_0 e^2/mc)^{1/2}$.

For the semiconductor model, the expression for the current in the magnetic field differs from (6) by a factor $(\Delta/\mu)^2$.

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