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PROPERTIES OF NEW LOW DIMENSIONAL MATERIALS AND MECHANISMS OF HIGH T[SUB]C SUPERCONDUCTIVITY

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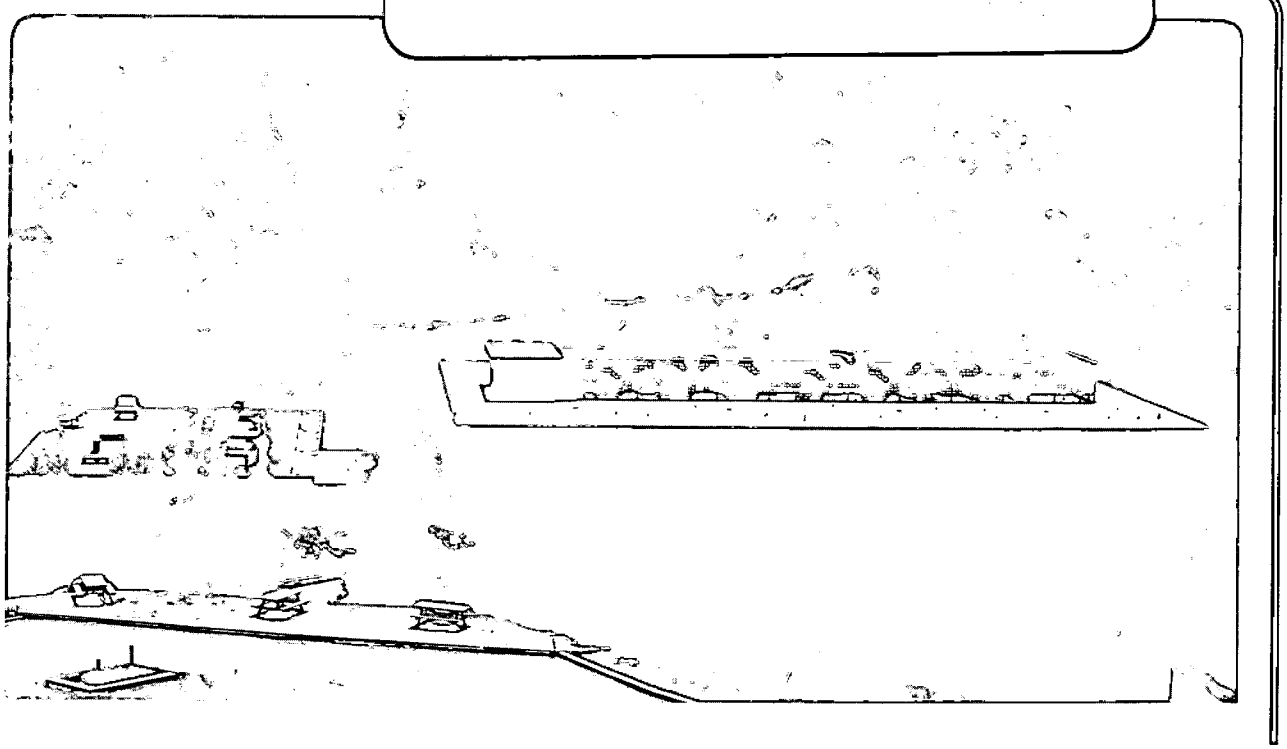

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Abstract

The new low dimensional high T_c superconductors are characterized by unusual values of normal and superconducting parameters, by peculiar behavior of the thermal conductivity. It is possible to observe a multigap structure. High T_c is due to the coexistence of the phonon and plasmon mechanisms. Proximity systems containing high T_c superconductors are promising from the point of view of building a three-terminal device and obtaining a high critical current.

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I. INTRODUCTION

This paper is concerned with properties of new super-superconducting oxides discovered in [1,2] and with mechanisms of high T_c superconductivity. At present, there are many experimental data which allow us to conclude that we are dealing with very unusual systems (Sec. II).

Speaking of the theory of high T_c superconductivity, one should distinguish two directions: 1) Analysis of normal and superconducting properties of the new material which do not depend on the precise mechanisms of high T_c superconductivity; 2) Origin of high T_c. The problem of two-gap superconductivity, proximity effect in the presence of high T_c oxide, etc., discussed in this paper are related to the first direction. We discussed also the contribution of the plasmon mechanism.

The present author has proposed a concept of the co-existence of the phonon and non-phonon mechanisms of superconductivity [3-4] (see also ref. 5). Recent experimental data

show that this concept is getting an experimental support (Sec. III). We think that an exchange by two dimensional (2D) plasmons [3,4,6] is a most favorable non-phonon mechanism of high T_c superconductivity (Sec. IV).

The structure of the paper is as follows: Sec. II contains an analyis of the unusual normal properties of oxides, such as a small ϵ_F, behavior of the thermal conductivity; we discuss also the opportunity to observe a multigap structure. Sec. III addresses the problem of obtaining the main equations. Proximity system containing a high Tc superconductor is studied in Sec, IV.

II. EXOTIC PROPERTIES OF NEW MATERIALS

1. Parameters. The superconducting state in the new high Tc oxides has many similarities with the usual BCS-type superconductivity (the presence of the energy gap, pairing, etc.). This supported by a number of experimental data (infrared spectroscopy, tunneling, heat capacity. etc.). But despite these similarities, we are dealing with exotic systems with unusual sets of normal and superconducting parameters. An evaluation of these parameters based on heat capacity data has been carried out recently by S. Wolf and the present author [7]. Heat capacity, contrary to magnetic data, is not sensititive to the mutual orientation of crystals in polycrystal sample; that's why we think that the heat capacity data is

the most reliable source of information. The reduced dimensionality was taken into consideration in a consistent way. According to [7], the $La_{0.8}Sr_{0.2}CuO_4$ compound is characterized by the following set of parameters: $m^* \simeq 4m_e$, $\varepsilon_F \simeq 0.12$eV, $V_F = 9.25 \times 10^6$ cm/sec, $P_F = 3.7 \times 10^{-20}$ gm cm/sec; the coherence length is very small relative to conventional superconductors: $\xi_0 \cong 23.5$ Å. The coherence length in Y-Ba-Cu-O is even smaller than in La-Sr-Cu-O and is of the order of atomic distance; I am not quote an exact numerical value, because the definition $\xi = \hbar V_F/\pi\Delta$ assumes that $\Delta << \varepsilon_F$.

For a conventional superconductor, the ratio Δ/ε_F (Δ is the energy gap) is very small ($\sim 10^{-4}$).

The most striking feature of the new systems is that the quantitives Δ and ε_F are comparable, particularly in Y-Ba-Cu-O. This means that a large fraction of the carriers are paired.

2. Multigap structure. As was noted by the present author [9], the small value of the coherence length leads to a unique opportunity to observe a multi-gap structure. The two-gap model was first introduced by Suhl, Mattias and Walker [10] and then developed by Geilikman, Zaitsev and the present author [11] (see also [12]) and by the present author in [13]. The presence of several energy gaps is due to the energy bands overlap. Each band is characterized by its own energy gap. An analysis of the usual electron-phonon interaction shows [11,12]

that the presence of several bands is favorable for superconductivity. An additional non-phonon contribution could come from the acoustic plasmon branch (see below).

The difficulty of observing multigap effects as well as effects caused by gap anisotropy, are due to the Anderson theorem [14]. Namely, the inequality $\ell \ll \xi_0, \xi_0$ is the coherence length, ℓ is the mean free path) results in the gaps averaging out into a single one. Interband transitions are the main mechanism of this averaging.

New materials are characterized by a small value of coherence length. As a result, for relatively clean samples the criterion $\ell \gtrsim \xi_0$ can be met. Hence, we have a case of very small ξ_0 and the opportunity to observe several gaps in the presence of overlapping bands become apparent.

The analysis carried out above is applicable to the one-gap case when the system is characterized by a single coupling constant λ. If we study, for example, a system with two gaps (3 coupling constants) then even in the weak coupling approximation the ratios $\beta_i = \Delta_i/T_c$ $(i = 1,2)$ can differ drastically from $\beta_{BCS} = 1.76$. A situation when $\beta_1 \ll \beta_{BCS}$ while $\beta_2 \gg \beta_{BCS}$ is perfectly realistic. A similar statement is valid in the case of strong electron-phonon coupling. Strictly speaking, each subgroup of electrons is characterized by its own value of ξ_0^i.

Note that the Anderson criterion allows one to determine whether one is dealing with a multigap case. Indeed, additional doping of these materials will result in a decrease of ℓ and, subsequently, in ℓ becoming less than ξ_0, when a transition to the one-gap picture will take place. Such a transition can be observed experimentally, because the tunneling spectrum and the temperature dependences, e.g., of the kinetic coefficients, are different in the one gap and multigap cases.

The presence of a multigap structure affects the behavior of the thermodynamic and transport properties of superconductors. A study of thermal conductivity and sound attenuation can point out peculiar properties of a sample, and, in addition, can be used in order to determine the major parameters of the system (see Ref. (13)).

The quantity γ_s/γ_n (γ_s and γ_n describe ultrasonic attenuation in the superconducting and normal states, respectively) decreases with decreasing T. In the region $T << T_c$ this decrease is exponential and is given by the factor $\exp(-\Delta_{min}/T)$, where Δ_{min} is the smaller gap. Hence the ratio γ_s/γ_n may decrease much slower than in the BCS case. Adding impurities will result in a sharper dependence.

3. Thermal conductivity. Unusual properties of the new materials are manifested in the behavior of thermal

conductivity [15]. As is known, the total thermal flow is a sum of the electron and lattice contributions: $\kappa = \kappa_{el} + \kappa_{ph}$. Usually, in the normal state $\kappa_{el} >> \kappa_{ph}$. Even if we study alloys with small carrier mean free paths, κ_{ph} constitutes several percent of the total κ. Note that in the superconducting state the picture is entirely different (see, e.g., the monograph by Geilikman and the present author [12]); this fact is connected with the exponential decrease of κ^s_{el} with decreasing temperature below T_c and with the corresponding increase of κ^s_{ph}. In this section we are concerned with the behavior of the thermal conductivity above T_c, in the normal state. As noted above, usually $\kappa_{el} >> \kappa_{ph}$. However, the case is just the opposite in the new materials. Namely, the major contribution comes from the lattice part, and κ_{el} contributes only above 20 percent of the total thermal flow. This unusual behavior is due to the small value of ε_F. One can show (see, e.g., [12]), that $\kappa_{el} \sim \varepsilon_F$. The Fermi energy in the new oxides is about two orders of magnitude less than in usual metals, which leads to a small value of κ_{el}. Under such circumstances it is natural that below T_c the value of κ is determined by κ_{ph} and increases with decreasing temperature (because of the exponential increase of the phonon mean free path). At some temperature T_m one can observe a maximum of $\kappa(T)$ and then $\kappa \to 0$ due to impurity scattering.

Hence, the small value of ϵ_F leads to unusual behavior of the thermal conductivity of the oxides in the normal state.

III. ORIGIN OF HIGH T_c SUPERCONDUCTIVITY: COEXISTENCE OF PHONON AND NON-PHONON (PLASMON) MECHANISMS.

1. Coexistence of phonon and non-phonon mechanisms. The superconducting state in the new high T_c oxides is due to the coexistence of strong electron-phonon coupling and a non-phonon mechanism, namely, exchange of 2D plasmons. This theory was initially proposed by the present author in [3]. A strong electron-phonon interaction plays an important role, but, nevertheless, it is not sufficient for providing high T_c. Additional attraction is provided by exchange of low-dimensional plasmons.

I discussed the problem of coexistence of phonon and non-phonon mechanisms of superconductivity in conventional superconductors from the point of view of search for a non-phonon mechanism of superconductivity [5]. It has been stated that the superconducting state of usual superconductors, particularly those with complex band structure, could benefit greatly from an additional non-phonon contribution. A method was proposed for determining of the presence of a non-phonon mechanism (if the corresponding peak is located beyond the tunneling region), based on an analysis of tunneling and neutron spectroscopies and heat capacity data. Recently, it

was shown experimentally, with the use of the method [5], that a non-phonon interaction makes a noticeable contribution to the superconducting state of Nb_3Ge [16].

As mentioned above, the concept of coexistence of phonon and non-phonon mechanisms in the new high T_c materials was initially presented in [3]. An analysis of recent experimental data shows that this concept is receiving experimental support.

Let us begin with La-Sr-Cu-O system ($T_c \simeq 40K$). According to [17], this system exhibits the isotope effect. This means the electron-phonon interaction contributes to superconductivity. As a result, we face the following question: is the electron-phonon interaction in La-Sr-Cu-O sufficient to provide the high $T_c \simeq 40K$, or is there a need for an additional mechanism? This is a very serious question, because the usual BCS mechanism, based on the electron-phonon interaction, is not restricted to low T_c values [18]. The Eliashberg equation which is a more general equation describing the BCS phonon mechanism, is valid if $\tilde{\Omega} << E_F$ ($\tilde{\Omega}$ is the characteristic phonon frequency, $\tilde{\Omega} \sim \Omega_D$), and T_c can, in principle, exceed the value of $\tilde{\Omega}$ in the limit of very strong coupling ($\lambda_{ph} >> 1$). Hence, theoretically high T_c can be caused by very strong electron-phonon coupling, and each real system has to be examined separately.

Consider the question: how large should be the value of λ_{ph} in La-Sr-Cu-O in order to provide Tc ≃ 40K? In order to answer this it is convenient to use the expression for T_c obtained by the present author in [19].

$$T_c = \frac{0.25\,\tilde{\Omega}}{\left[e^{2/\lambda_{eff}} - 1\right]^{1/2}} \qquad (1)$$

Here $\tilde{\Omega} = \langle\Omega^2\rangle^{1/2}$, $\langle\Omega^2\rangle = \int d\Omega\, \alpha^2(\Omega)\, F(\Omega)\, \Omega$, $F(\Omega)$ is the phonon density of states, $\alpha^2(\Omega)$ describes the electron-phonon interaction; $\lambda_{eff} = (\lambda-\mu^*)\,(1+2\mu^* + \mu^* + \mu^*\lambda t(\lambda))^{-1}$ the function $t(\lambda)$ is defined in [19]. Eq. (1) was obtained directly from the Eliashberg equation and is valid for any value of λ_{ph} (for more detailed analysis and limiting cases, see [19]).

Let us apply Eq. (1) to the La-Sr-Cu-O system in order to estimate the value of λ_{ph}. According to neutron inelastic spectroscopy data [20], the phonon density of states $F(\Omega)$ in the $La_{1.8}\,Sr_{0.2}\,Cu\,O_4$ system exhibits two sharp peaks at $\Omega_1 \simeq 100K$ and $\Omega_2 \simeq 200K$. The function $\alpha^2(\Omega)$ can be determined by the tunneling spectroscopy technique (these measurements have not yet been carried out) but usually $\alpha^2(\Omega)$ is a relatively smooth function. As a result, it is reasonable to put $\tilde{\Omega} \simeq 150K$. Assuming that $\mu^* \simeq 0.1$ (larger values of μ^* lead to an increase of λ_{ph}, see below), we obtain from Eq. (1): $\lambda_{ph} \simeq 5$.

This means that the electron-phonon interaction can provide the high $T_c \simeq 40K$ in La-Sr-Cu-O compound, but this requires very strong coupling.

The value of λ_{ph} for different materials can be measured with the use of tunneling spectroscopy (see, e.g., the review [21]), but the data are unavailable at present. However, the necessary information can be obtained from another set of data, namely from measurements of the energy gap. Indeed, the quantity $\beta = 2\Delta(0)/T_c$ depends on the value of λ_{ph}. For example, $\beta_{BCS} = 3.52$ (weak coupling) $\beta_{Pb} \simeq 4.3$ ($\lambda \simeq 1.5$), $\beta_{Hg} \simeq 4.5$ ($\lambda \simeq 1.6$), $\beta_{Pb-Bi} \simeq 5$ ($\lambda \simeq 2$).

The magnitude of the energy gap has been determined by infrared spectroscopy and various types of tunneling. Although there is some variation in the data that have been reported, the majority corresponds to $\beta \lesssim 5$. Note that our analysis corresponds to the one-gap picture (see above), or to the situation when $\ell < \xi_o$. According to [22] and the experimental data for Hg, Pb -Bi, etc. (see above), this means that λ_{ph} for the La-Sr-Cu-O system does not exceed the value $\lambda_{ph} = 2$. However, this is not sufficient to provide the experimentally observed $T_c \simeq 40K$. This temperature requires $\lambda_{ph} = 5$ (see above).

Hence, we come to the conclusion that the electron-phonon interaction plays an important role in La-Sr-Cu-O, as manifested

by the presence of a noticeable isotope effect, but, nevertheless, there is need for a additional mechanism of attraction between the carriers.

At first sight, the situation with Y-Ba-Cu-O compound looks less certain. However, this system and La-Sr-Cu-O have a lot of similarities (they contain Cu-O, are low dimensional, and have small carrier concentrations); their superconducting behavior is similar (see, e.g. [23]). It is natural to think that superconductivity in these materials is caused by identical mechanisms, although their relative contributions may be different in the two cases.

Morever there are other experimental data indicating strong electron-phonon interaction in Y-Ba-Cu-O, namely the thermal conductivity data [15]. It has been observed that the thermal conductivity increases sharply with decreasing temperature below T_c. Such a behavior means (see, e.g., the review [12] by Geilikman and the present author) that the major contribution to the thermal flow comes from the lattice, and the scattering of phonons by electrons is the main relaxation mechanism. This scattering is described by the same electron-phonon coupling constant λ_{ph}. Hence the electron-phonon interaction plays an important role in the Y-Ba-Cu-O system.

An analysis similar to that for La-Sr-Cu-O above also leads to the conclusion about the necessity of additional non-phonon mechanisms.

Hence, an analysis of the recent experimental data allows to conclude that the concept of a coexistence of the phonon and non-phonon mechanisms is receiving experimental support.

I think that exchange of 2D plasmons provides the additional mechanism.

2. Plasmon mechanism. The plasmon mechanism of high T_c has been proposed in [3] and then developed in [4,6]. Later different aspects of this mechanism has been studied in [24]. Here I would like to stress several important features of this mechanism studied in [3,4,6]:

1. Low dimensionality and a small carrier concentration makes the contribution of 2D plasmons very favorable. Reduced dimensionality along with presence of the overlapping energy bands leads to an appearance of two plasmon branches: 1) the branch $\Omega(q) \sim q^{1/2}$ $(q \to 0)$, which is specified for 2D system (this branch was introduced in [25], see also the review [26]). 2) acoustic branch $\Omega \sim q$, which is due to the presence of the several bands. This branch was introduced (in 3D case) in [27]; its contribution to superconductivity is studied in [28].

2. The main contribution to pairing comes from the short-wave length region; interlayer interaction is not important for this region.

3. The presence of 2D plasmons is not an assumption. They exist, and in the presence of electron-phonon interaction they can provide an additional pairing contribution to the pairing.

Note that 2D plasmons in layered systems similar to La-Sr-Cu-O have been observed experimentally in [29].

4. Hybridization of plasmons and phonons leads to an opportunity to observe a reflectance peak (see ref. 6).

5. Electron-plasmon coupling $\lambda_{p\ell}$ increases with decreasing carrier concentration n: $\lambda_{p\ell} \sim n^{-1/2}$

It is important to stress that we consider the plasmon channel as an addition to the usual electron-phonon interaction. The Coulomb repulsion is overcome by λ_{ph} and the attractive part of the electron-plasmon interaction provides an additional contribution to pairing.

The very important question arises of how to detect the non-phonon plasmon mechanism. Such a separation can be carried out experimentally because plasmons are excitations of the carrier system whereas phonons involve ionic motion. It would be important to carry out a tunneling and neutron scattering experiment. Tunneling spectroscopy based on inversion of

the Eliashberg equation will display all modes, including plasmons. As for neutron scattering, it will show the function $F_{ph}(\Omega)$ only, because neutron scattering is not affected by the electron subsystem. Usually $F_{ph}(\Omega)$ and $g_{ph}(\Omega)$ have a similar structure (position and number of peaks, the value of Ω_{max}). If the plasmons play an important role (this is the case of the high T_c superconductors), then a comparison of the neutron and tunneling data would allow to detect the presence of the additional (plasmon) mode. It would be particularly important to compare the frequency ranges.

It is important to stress two points. First of all, the smallness of the Fermi energy (e.g., for $Las_{1.8}Sr_{0.2}CuO_4$, $\epsilon_F \simeq 0.12$ eV) leads to the plasmon edge within the region suitable for tunneling spectroscopy.

If the energy of additional virtual excitations providing the pairing (e.g., excitons) lies beyond the tunneling region then one should use the method developed in [5,16].

In addition, the electron-plasmon coupling constant $\lambda_{p\ell}$ depends on the carrier concentration and increases with decreasing n. This is important because the new high T_c materials are characterized by small values of n. This fact makes the plasmon contribution crucial for explaining the high T_c in these materials.

The Eliashberg equation in the presence of both the phonon and plasmon mechanisms can be written in the form:

$$\Delta(\omega_n) = \frac{T}{(2\pi)^2 Z} \sum_{\omega_{n'}} \int d\Omega \left[K_1(\omega_n - \omega_{n'}; \Omega) + K_2(\omega_n - \omega_{n'}, \Omega)\right] \times \Delta(\omega_{n'}) |\omega_{n'}|^{-1} |_{Tc} \quad (2)$$

where $K_1 = g_{ph} D_{ph} - 2\mu^*$ and $K_2 = g_{p\ell} D_{p\ell}$. If $K_2 = 0$ we obtain the usual Eliashberg equation describing the phonon mechanism. One sees that the 2D plasmon exchange leads to the appearance of the additional attractive term K_2.

T_c in the presence of both phonon and plasmon mechanisms is described by the expression [3,4]:

$$T_c = T_c^{ph} (\tilde{\omega}_{p\ell} / T_c^{ph})^r \quad (3)$$

where $r = \lambda_{p\ell} (\lambda_{ph} + \lambda_{p\ell})^{-1}$ and T_c^{ph} is described by Eq. (1). I would like to emphasize that the large value of $\tilde{\omega}_{p\ell}/T_c$, that is a large scale of the plasmon mechanism, leads to a noticeable shift of T_c with respect to T_c^{ph} even for relatively small $\lambda_{p\ell}$. Indeed if $\lambda_{ph} \simeq 2, \tilde{\Omega} = 150K$, we obtain $T_c^{ph} = 21K$ (see Eq. (1) and the following discussion). Putting then $\tilde{\omega}_{p\ell}/T_c^{ph} \simeq 20$ and assuming $\lambda_{p\ell} \simeq 0.5$, we obtain $T_c \simeq 1.8\ T_c^{ph} \simeq 38K$. Hence, a coexistence of the phonon and plasmon contributions may provide the observed high T_c of La-Sr-Cu-O system.

IV. PROXIMITY EFFECT AND HIGH T_c

In this section we are concerned with the use of the proximity effect in the light of the discovery of the new high T_c superconductors.

As is known, the proximity effect allows to induce the superconducting state in materials which are not superconductors by themselves. If, for example, this material is a semiconductor, then, as a result, one can take advantage of both superconducting and semiconducting properties [30].

Another interesting proximity system is $S_\alpha - S_\beta$, consisting of two superconductors (assume that $T_c^\alpha > T_c^\beta$). Such a system characterized by a single T_c with $T_c^\alpha > T_c > T_c^\beta$ (see, e.g. Ref. [31]). As a result of the proximity effect, one can effectively increase the T_c of the S_β superconductor. This opportunity is particularly interesting in the light of the recent discovery of the high T_c materials.

Consider the important case when S_β is an A-15, or B1 compound with high values of such parameters as the critical current and the critical field. If $S_\alpha \equiv S_h$ is a high T_c superconductor, one can use the proximity effect in order to increase T_c of the β film and to take advantage of its high values of the critical parameters.

1. <u>High T_c and the Field Effect</u>. The paper [32] in which

the field effect has been used in order to change the amplitude of the Josephson current has attracted a lot of interest. The system Nb-InAs-Nb was studied. InAs contains an inversion layer which provides coupling between the two superconductors.

The detailed theoretical analysis carried out by the present author in [33] shows that the low dimensionality of the barrier plays a key role. It has been shown that the use of a one-dimensional channel will lead to an even stronger field effect.

According to [33], the sharpness of the field effect depends strongly on several parameters: T, L_N, m^*_N, N_S (m^*_N is the effective mass in the semiconductor film, N_S is the surface carrier concentration). For example, in the region $T \sim T_c$, the Josephson current is described by the dependence $j_{max} \sim \exp\{-F_{d(c)}\}$, where F_d and F_c correspond to the "dirty" ($\ell << \xi_{Ni}$, ℓ is the mean free path) and the "clean" limits, respectively . One can show that $F_d \sim (T/N_s \mu)^{1/2} L_N$, where μ is the mobility, and $F_c \sim T_s N_s^{-1/2} L_N$.

We would like to stress the strong dependence of the current on temperature. An increase in T leads to a decrease in the absolute value of the Josephson current but at the same time it leads to an increase of the field

effect, that is, the dependence $j_m(N_S)$ is getting sharper (the applied electric field affects the carrier concentration N_S and this influence is the main mechanism of the field effect). That's why the use of the system NbN-InAs-NBN has been suggested in [33]. From this point of view, the use of a high T_c superconductor instead of Nb, or the use of the system S_h-Nb-InAs-Nb-S_h is promising for applications of the field effect. (S_h is a high T_c superconductor; the proximity sytem S_h-Nb has a higher T_c than the T_c of Nb). Note that ξ_o is small in high Tc oxides, but, on the other hand, the density of states is large (see [7], and it results in a noticeable manifestation of the proximity effect.

Such a dependence of the field effect on temperature makes the use of the high T_c oxides very promising. In principle, there are two possibilities. One of them is giving the replacement Nb $\rightarrow$ S_h, the system S_h- InAs-S_h. This will allow to increase the temperature of the contact. If preparation of such a contact is difficult (undesirable effect of the interface on the oxide, etc.), then one can use another structure: S_h-Nb-InAs-Nb-S_h. The proximity systems S_h-Nb will permit an observation of the field effect at higher temperatures.

2. Proximity effect and critical current. Let us consider the behavior of the system S_h-S_β-S_h; S_β is a conventional superconductor in an external magnetic field. If the field is perpendicular to the system, then in a field $H < H_{c2}$ one can observe vertex penetration (see, e.g., [34]). It is important that the new high T_c materials are characterized by large values of Hc2. As a result, the case of when $H_{c2} > H_{c2}^{\beta}$ (H_{c2}^{β} is the critical field for the isolated β film) is perfectly realistic.

Consider now the flow of the transport current. The critical current (the transport current in this film is assumed to be perpendicular to the magnetic field) is determined by the pinning force F_p, and can be evaluated with the use of the expression

$$j_c B = F_p$$

The pinning force can be written in the form (see, e.g., the review [35]) $F_p = \alpha H_{c2} f(h)$, where $h = H/Hc2$, α = const; The values of α as well as a value of n (usually n = 2) and the dependence f(h) are determined by the properties of the sample. It is important that an increase in H_{c2} leads to an increase in the value of j_c. Since $H_{c2} > H_{c2}^{\beta}$ (see above), the pinning force can be increased by the proximity contact with a high T_c materials. As a result,

one can obtain an effective increase in j_c in the β film. But most importantly that, because of the proximity effect, the β film is able to carry a high critical current at a higher temperature than a conventional superconductor.

It would be interesting to study the properties of the proximity system S_h-S_β -S_h, where S_β is a Nb, NbN, A-15 or other conventional superconducting film.

SUMMARY

The main results can be summarized as follows:

1. The new materials are characterized by unusual values of normal and superconducting parameters, such as ϵ_F, ξ_o, etc. A large fraction of the carriers are paired. As a result, one can observe unusual behavior of the normal thermal conductivity. In addition there is unique opportunity to observe a multigap structure.

2. The origin of high T_c is due to the coexistence of the phonon and plasmon mechanisms.

3. The proximity system S_h-S_m-S_h and S_h-Nb-InAs-Nb-S_h are promising from the point of view of making a three-terminal device (S_h and S_m are high T_c and semiconductor films). The proximity system S_h-S_β-S_h (S_β is A-15 or B 1 compound) is able to carry a high critical current at $T>T_c^\beta$.

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