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NON-EQUILIBRIUM EFFECTS IN LOCAL PAIRS SUPERCONDUCTORS INDUCED BY ACOUSTIC AND MAGNETIC FIELDS

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The simple arguments are given that acoustic and magnetic fields may initiate local pairs superconductivity in the materials with native –U centers, e.g. chalcogenide glasses.

1. Introduction

The local pairs superconductivity [1] is probably realized in some chalcogenide glasses and their melts under high pressure, cuprate oxides, and fullerides [2,3]. The superconductivity transition temperature Tc in these class of superconductors is

$$Tc \sim t^2 n^{2/3} \qquad (1)$$

where **n** is the local pairs (negative –U centers) concentration, and **t** is their transfer integral that related with local pair effective mass (compare [3a] and [3b]).
The non-equilibrium enhancement of transition has been widely studied for the BCS mechanism of superconductivity [4]. The possibilities of the enhancement of the local pairs superconductivity by charge carriers' injection, external electric fields and pressure [5] had been shown already. It seems interesting to find other conditions for the local pairs superconductivity enhancement.

2. Acoustic fields

High frequency acoustic fields (AF) can be localized in the region around a local pair where atomic structure is distorted due to the polaron effect [1] or by intrinsic disorder because of the Ioffe-Regel criteria. Powerful AF are capable to modulate local pair's potential well width R and total energy V and as result the local pair kinetic energy. Hence **t** changes as

$$\exp\,(dR*dV) \qquad (2)$$

Condensation AF waves may expel a local pair from its potential wells in the compressed microregions and dilatation AF waves may produce similar wells for the local pair transitions in the tension microregions. Then **t** may increase in the spread of the wave's direction in a material. As it follows from the equations (1) and (2) Tc (AF) can be lifted above the equilibrium transition temperature Tc(0) by an acoustic wave in the half-periods when **dR*dV > 0**. A standing AF can be suitable for materials with long-range order in local pairs (local pairs) positions. A soliton-like AF can be more convenient for disordered materials if soliton waves' and local pairs' velocities are close or equal. We assume here that acoustic fields' energy does not heat up the material strongly near Tc(0).
It is worth to mention that this enhancement mechanism may be used for creation the dynamically superlattice of Josephson junctions at

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$$Tc(AF) > T > Tc(0) \quad (3)$$

by standing (or soliton-like) AF in the local pairs superconductors with relatively long coherence length.

3. Magnetic fields

Let us show that small magnetic fields B can influence on probability of local pairs (negative –U centers) creation at T(U) >> Tc(0) [6.7]. Note, that in chalcogenide glasses T(U) is probably well above glass transition temperature, and that these glasses and their melts are diamagnetic, and that holes are major carriers in cuprate oxides and chalcogenide glasses.

Consider a pair of non-equilibrium holes h_j (j=1,2) with corresponding arbitrary spins $\mathbf{s_j}$ in the material there the singlet hole-like local pairs may be created at T(U). One of the holes (h1) creates a potential well due to polaron interaction with atomic subsystem, while another (h2) locates near the first and they form an exchange-bonding pair. The evolution of this pair may be develop either by its destruction with probability D or by the h2 self-trapping in the {h1}'s polaron well i.e. the local pairs creation with probability F:

$$h2 + \{h1\} \text{------>} \{h1,h2\} \text{------>} h2,\{h1\};\ \{h2\},h1;\ h1,h2;\ \{h1\},\{h2\} \quad (4)$$

We assume that the spin relaxation time S is longer than the singlet-triplet transition time. Thus weak B can shift the reactions (4). Hence B influence strongly on F if 1/D >> S >> 1/F > Q, where Q is the time of transition between singlet and triplet levels [6]. That is why the local pairs creation is a spin-dependent process [7] that is realized by Zeeman (Z) or hyperfine interaction (HI) mechanisms.

Z-mechanism is based on the difference between Lande splitting factors for $\mathbf{s_j}$. When **B=0** the local pairs creation is possible if $\mathbf{s_j}$ are in singlet S state according to the Pauli's exclusion principle which yields to **L(0) = L(S) = N.** If **B > 0** the singlet state is mixed with the triplet To state because Larmor's spins precession frequencies are different. Hence local pairs creation read as **L(B) = L(S)+L(To) = (1+a)*L(S), 0 < a < 1**.

HI-mechanism is based on $\mathbf{s_j}$ interaction with magnetic nuclei. When **B=0** the S state is mixed with the all triplet (To,T+,T-) states and the probabilities of local pairs creation from each state are equal:

$$L(0) = L(S) + L(To) + L(T-) + L(T+) = 4N.$$

The S-To and T+ T- levels are split out in finite B. The transition between S and To is realized, but the S-->T+ and S-->T- transitions are suppressed if level splitting energy greater than the energy of level's width. In the last case the probability of the singlet local pairs creation is

$$L(B) = L(S) + L(To) + b[L(T-) + L(T+)] = 2(1+b)*N, \quad 0 < b < 1.$$

The solutions of the kinetic equation systems are given by

$$n(B)/n(0) = [(1+a)(D+N)]/[D+N(1+a)] \quad \textit{for Z-mechanism} \ (5a),$$

$$n(B)/n(0) = [(1+b)(D+2(1+b)N)]/2(D+4N) \quad \textit{for HI-mechanism} \ (5b).$$

One can see from the eq.(1) and (4) that Tc may be increase in B for the Zeeman mechanism as

$$Tc(B)/Tc(0) = [(1+a)(D+N)]/[D+N(1+a)]^{2/3} \quad (6)$$

Perhaps it is explained the Tc increases under B influence on some cuprate oxides at the temperatures well above Tc [8]. According to this model **n** and hence [Tc(B) - Tc(0)] saturate in B ~ 5 kOe (for the Z-mechanism) or B ~ 100 Oe (for the HI-mechanism) [6,7].

Of course, any magnetic field destroys superconducting condensate although makes it differently in the cases of BCS and local pairs mechanisms [1]. It worth to note that Tc behaviour in strong magnetic fields for chalcogenide glasses under pressure corresponds to local pairs superconductivity [9].

4. Conclusion

Acoustic and magnetic fields can increase transfer integral of local pairs and their concentration and as the result lift up Tc. The simplest situations have been considered here. In reality the powerful AF create electric fields in chalcogenide glasses there **t** depends on electric field at T>Tc(AF)>Tc(0) and weak B influence on processes beyond spin dynamics in cuprate oxides hence the processes under consideration are more complex.

For experimental observation of these effects one need the substance in which local pairs superconductivity is realized. Currently some chalcogenide glassess, cuprate oxides and fullerides are candidates for such materials. Studies of non-equilibrium superconductivity can shed light on the nature of the collective phenomenon in these materials.

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