THE INFLUENCE OF THE PARAMETERS OF THE STRUCTURAL PHASE TRANSITION ON THE SUPERCONDUCTING TRANSITION TEMPERATURE

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The most favorable conditions for the enhancement of T_c are achived if structural transition in superconductor does not occur before the appearance of superconductivity.

The experimental investigations of the lattice of high-T_c superconductors (T_c > 10 K) show that such materials are characterized by structural instability[1] and by the existence of two or more local configurations[2]. The excitations between these local states (local structural excitations - LSEs)[3], can explain the enhancement of T_c.

Let us consider a model for a superconductor with the hamiltonian

$$H = H_e + H_{ph} + H_{e-ph} + H_s + H_{s-e} \qquad (1)$$

where besides an interaction H_{e-ph} of electrons (H_e) with phonons (H_{ph}) an additional coupling (H_{e-s}) of electrons with quasilocal excitations (H_s) is introduced[2,3];

$$H_s = -\Omega \sum_i S_i^z - \frac{1}{2} \sum_{i \neq j} J_{ij} S_i^x S_j^x , \qquad (2)$$

where $\Omega = E_a - E_s > 0$ is the ground state energy splitting between the antisymmetric (ψ_a) and the symmetric (ψ_s) states, J_{ij} is an effective coupling

energy between different lattice sites i,j. The electron - LSE interaction, in Nambu representation, is given in the form[3]

$$H_{e-s} = \sum_{\vec{p}-\vec{p}'=\vec{q}} V_s(\vec{p},\vec{p}')\,(\psi^{+}_{\vec{p}}\,\tau_3\,\psi_{\vec{p}'})\,S^{x}_{\vec{q}} \qquad (3)$$

We now use the two-time Green's function method developed for general electron - lattice interaction[4]. According to such procedure a system of Eliashberg-type equations for the electron matrix Green's function can easily be obtained. We only quote the result for the effective coupling constant

$$\lambda_s = N(0)\langle J_s^2\rangle (2x_{sa})^2 \frac{\Omega\langle S_z\rangle}{\omega_s^2}, \qquad (4)$$

where $x_{sa} = \langle\psi_s|x|\psi_a\rangle$, $\langle J_s^2\rangle$ is the averaged matrix element of H_{e-s} interaction, ω_s - the averaged frequency of quasilocal excitations and N(0) - the electron density of states at Fermi level.

In the weak-coupling limit, for T_c one obtains

$$T_c = 1.14\,\omega_s e^{-1/\lambda},\quad \lambda = \lambda_s + \frac{\lambda_{ph} - \mu^*}{1-(\lambda_{ph}-\mu^*)\ln(\omega_D/\omega_s)}, \qquad (5)$$

where μ^* is the screened - Coulomb repulsion and ω_D - the Debye frequency. In the right - hand side of eg. (5), the mean values $\langle S^x\rangle$ and $\langle S^z\rangle$ are determined in the mean - field approximation. In this way the self-consistent system of equations for T_c is completed. The parameters of the model are: μ^*, λ_{ph}, $y = \omega_D/\Omega$ and $x = J_o/\Omega$. The parameter x determines the tehermodynamic state of the system described by H_s.

On the Fig. 1 the x - dependence of $\tau_c = T_c/T_c^o$ is presented (T_c^o being a temperature of the superconducting transition at $\lambda_s = 0$) for various y and $\mu^* = 0.11$, $\lambda_{ph} = 0.3$. The y - dependence of T_c/T_c^o for $\mu = 0.11$, $\lambda_{ph} = 0.3$ and $x = 0$ is given in Fig. 2. The analogous calculations for varios values of parameter λ_{ph} are also performed and it is obtained that the max (T_c/T_c^o) decreases when λ_{ph} increases.

The present results for the enhanced T_c are compared[6] with corresponding ones obtained by the approximate formula[5]. It turns out, that albeit the formula (5) has been deduced in the weak-coupling approximation, it can be used for the qualitative discussion in the range of middle couplings ($\lambda \lesssim 1$).

In the conclusion , we emphasize that the most favorable enhancement of T_c should be expected in those locally unstable superconductors in which the structural transition does not occur before the appearance of superconductivity. The obtained results can explain the experimentally observed enhancement of T_c in some structurally unstable materials such as binary and ternary compounds and alloys (see, e. g. refs. 1, 2 and those therein) particularly in the case of Nb_3Sn (see, e. g. ref. 7).

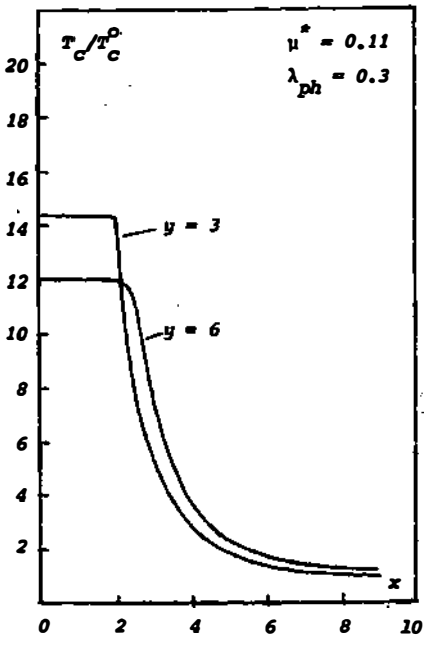

Fig. 1.

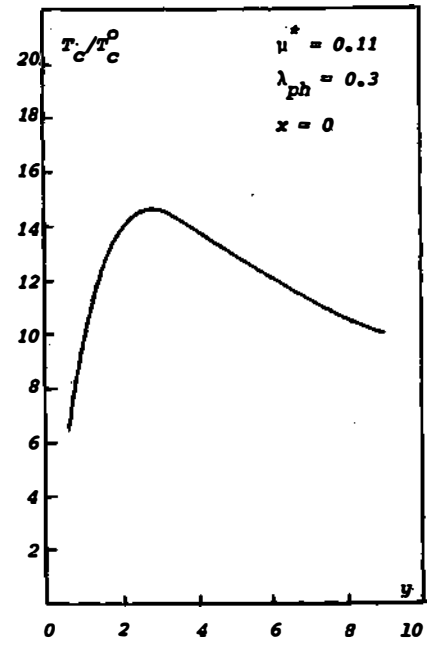

Fig. 2.

References:

1. *L. Testardi, Rev. Mod. Phys., 47 (1975) 637.*
2. *K.L. Ngai and T.L. Reinecke, Phys. Rev. B, 16, (1977) 1077.*
3. *G.M. Vujičić, V.L. Aksenov, N.M. Plakida and S. Stamenković, Phys. Letters, 73 A (1979) 439.*
4. *G.M. Vujičić, Z.K. Petru and N.M. Plakida, Preprint P17 - 12956 Dubna 1979, submitted to IMP.*
5. *A.E.Karakozov, E.G.Maksimov and S.A. Mashkov, Zh. Eksp. Teor. Fiz., 68 (1975) 1937.*
6. *G.M. Vujičić, V.L. Aksenov, N.M. Plakida and S. Stamenković, submitted to J. Phys. C.*
7. *A. I. Golovaškin, G.P. Motulevič, Pisma v ŠETF, 17 (1973) 114.*