COLLECTIVE PHENOMENA IN MULTI - BAND SUPERCONDUCTING SYSTEMS DOPED WITH NON MAGNETIC IMPURITY

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Abstract. *The overlapping of energy bands on the Fermi surface changes the properties of multi – band superconductors as qualitatively as well quantitatively.*

Here we investigate the appearance of collective oscillations caused by phase fluctuations of order parameters from different bands. Namely, how non- magnetic chaotic distributed impurity influences on the collective oscillations in two – band superconductors.

Two – particle Green function is considered and the system for vertex functions averaged on chaotic distributed impurity are obtained using the Hamiltonian of two – band superconductors. Necessary values to determine the frequency of collective oscillations ω are calculated in linear approximation after the impurity concentration. The equation for ω is obtained and its solutions are found. It is shown that in this doped system an exciton – like frequency of collective oscillations could arise. At low impurity concentration the damping of collective oscillations is absent.

Key words: *collective oscillations, many – band superconductors, non – magnetic impurity.*

I. Introduction

Band structure calculations of metal oxide ceramics show that on the Fermi surface of these compounds a few energy bands overlap [1-4]. We are to emphasise that due to the overlapping bands, the properties of multi-band superconductors differ thoroughly from those of one-band superconductors as qualitatively as well quantitatively – the occurrence of new phenomena is possible [5-11].

The present paper investigates one of these phenomena – the appearance of collective oscillations caused by phase fluctuations of order parameter from different bands. The pioneer in studying collective oscillations in usual superconductors is A. J. Leggett [12]. He showed that in ordinary superconductors along with Anderson acoustic mode ($\omega=0$ if $\boldsymbol{k}=0$) an exciton-like mode determined by electron interaction from different bands appears.

We investigate how non-magnetic chaotic distributed impurity influences on the collective oscillations in two-band superconductors. The usual two-band superconductors and the superconductors with reduced carrier concentration (in the cases of phonon and non-phonon mechanisms of superconductivity, respectively) will be researched.

II. The model of the researched system

In the present paper we proceed from the system for vertex functions which corresponds to the model of two – band dirty superconductors [13-15]. In this model the interband V_{nm} and intraband V_{nn} interaction, which correspond to the couples forming in the band and their transition from a band into another. The using of this model is permitted in the case of a high carrier concentration ($\mu>>\Delta$); this fact corresponds to the usual superconductors case. We apply this two – band model in the case of reduced concentration when along with above – mentioned restriction, also takes place the condition $\omega_{Dn}> \mu$, (ω_{Dn} is the cut – off phononical frequency of the integrals in

n^{th} band) or, generally, when the integration limits are non – symmetrical: $(D_{cn}-D_n)/D_n<<1$. We examine only low impurity concentrations and low frequencies: $1/\tau_{nm}\Delta_n<<1$; $\omega^2/4\Delta_n^2<<1$. The last inequality imposes certain restrictions on the values Δ_1 and Δ_2: the results are correct when Δ_1 and Δ_2 are the same order values.

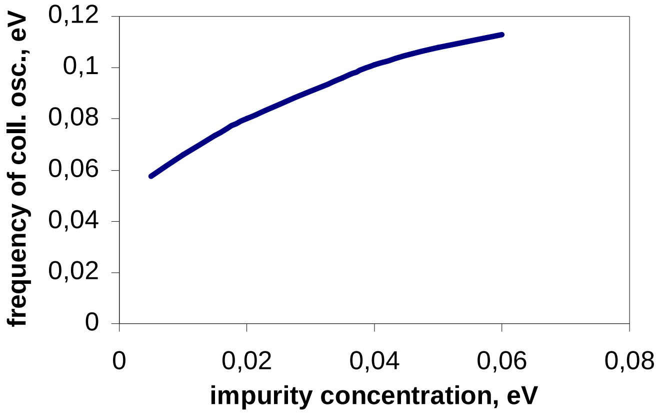

Fig. **1** The dependency of the frequency of collective oscillations ω from the concentration ***c*** of non-magnetic impurity.

From the poles appearance condition for the vertex function the equation for frequency of collective oscillations and its solution are obtained. The solution ω depends on impurity as well as on the superconductor type (usual or "exotic").

III. Conclusions

We can conclude:

a) in two – band superconducting system at a low impurity concentration in the case $\boldsymbol{k}\to 0$ the collective oscillations are not damping out;

b) the Bogolyubov – Anderson mode is absent, but appears an exciton – like mode;

c) the frequency ω of this mode is determined by electron – electron interband interaction (which corresponds to the case of native superconductors [12]) and by impurity presence;

d) the frequency ω increases with impurity concentration growing. This fact corresponds to the results obtained by Ginzburg [16] and Maki and Tsuneto [17] at the researching of appearance in the superconductors of excitons in the case of coupling with momentum different to zero.

The dependence of the frequency of collective oscillations ω from the impurity concentration ***c*** in the area of bands overlapping is shown on the Fig. 1. The following theory parameters are chosen: intraband interaction constants $\lambda_{11}=0{,}04$ *and* $\lambda_{22}=0{,}14$; for interband interaction $\lambda_{12}=\lambda_{21}=0{,}0125$; $\eta_{11}=\eta_{22}=0{,}5$; $\eta_{12}=\eta_{21}=0{,}05$ where $\eta_{nm}=1/2c\tau_{nm}$,; the beginning of first and second energy bands $\varepsilon_1=\varepsilon_2=0\ eV$; the end of first band – $\varepsilon_{c1}=0{,}6\ eV$; and respectively for second band – $\varepsilon_{c2}=0{,}7\ eV$. The graph relieves a quasi-linear character of the dependence of frequency ω from impurity concentration ***c***. The scattering on the non – magnetic impurity potential bring an essential contribution to the interband interaction and in the middle of bands overlapping area becomes more important. The calculations for the order parameter are performed in the same way as in the works [18, 19].

IV. References

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