TEMPERATURE DEPENDENCEFLUCTUATIONS OF SUPERCONDUCTING CORRECTIONS TO THE THERMAL CONDUCTIVITY IN METAL NANOGRAIN

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ABSTRACT

Superconducting fluctuations corrections on the thermal conductance in Nano grainmetals at different range of temperature are calculated. In these temperature regimes Coulomb interaction effects and weak localization effects (quantum interference) have an effective role and the Weidman-Franzlow is violated. We calculate and investigate these deviancesin the Weidman-Franz low and Lorenz number.

Keywords: *Superconducting, Nano grain, Thermal Conductivity*.

1. INTRODUCTION

The analysis of fluctuation corrections on the electrical conductivity, led to three corrections contributions with names the Maki-Thompson (MT), the Aslamazov-Larkin (AL), and density of states (DOS). In the MT correction, in the normal phase the Cooper pair leads to a parallel superconducting channel; in the AL correction the coherent scattering of impurities of the electronsinto account; and in the DOS correction the rearrangement of the electron states close to the Fermi energy are important. AL and MT corrections led to an enhancement of the conductivity [1]; in the other hand the DOS correction reduce conductivity.

Indeed, ingranular superconductors there is a temperature region in which a singular correction due to superconducting fluctuations for a quasi-zero-dimensional system dominates the behavior of the thermal conductivity; were negative or positive correction depending onthe ratiobarrier transparency and the critical temperature that it is a significant difference with the homogeneous systems is present, the constant correction at being either negative or positive depending on the above mentioned ratio. In temperatures that near, observed the behavior of homogeneous metals is recovered, and the divergence will be cut off to crossover to the regular behavior. Moreover, a significant difference with the homogeneous systems is present, the constant correction at $T = T_c$being either negative or positive depending on the above-mentioned ratio. For some choice of the parameter, a non-monotonic temperature dependent behavior of the correction is possible.

In this paper we investigated the existence corrections in the thermal conductivity in granular superconductors metallic grains, being in an insulating amorphous matrix and metal-superconductor phase transition dominant between each grain. The electrons in the granular materials can diffuse and tunneling between the grains.

2. PROBLEM FORMULATION

The calculated correction in the thermal conductivity in MT correction is given by [1, 2]:

$$\frac{\delta k^{(MT)}}{k_0} = \frac{3}{\pi^2}\frac{1}{g_T}\frac{g_T\delta}{T_c}\int (dK)\frac{1}{\epsilon + z\frac{g_T\delta}{T_c}(1-\gamma_K)} \quad (1)$$

The lattice Fourier transform is defined and$(dK) = [a^d/(2\pi)^2]d^dKandk_0 = \frac{8\pi}{3}g_T a^{2-d}T$is the Drude formula for classical conductivity, whichsize of a single grain, d is the dimensionality for an array and$\epsilon = {(T - T_c)}/{T_c}$the reduced temperature. We determined the dimensionless tunneling conductance$g_T = \left[({\pi}/{2})t\nu_f\right]^2$with the ν_f the electronic density of states at the Fermi level, and tthe hopping energy.

Using the same procedure to calculate the DOS correction, we get

$$\frac{\delta k^{(DOS)}}{k_0} = -\frac{3}{\pi^2}\frac{1}{g_T}\frac{g_T\delta}{T_c}\int (dK)\frac{\gamma_K}{\epsilon + z\frac{g_T\delta}{T_c}(1-\gamma_K)} \quad (2)$$

The AL correction term to thermal conductivity below [1]

$$\frac{\delta k^{(AL)}}{k_0} = \frac{9}{2\pi}\frac{1}{g_T}(\frac{g_T\delta}{T_c})^2 \int(dK)\frac{(1-\gamma_K)^2}{\epsilon+z\frac{g_T\delta}{T_c}(1-\gamma_K)} \quad (3)$$

Total superconducting fluctuations correction to the thermal conductivity close to critical temperature is

$$\frac{\delta k}{k_0} = \frac{\delta k^{(DOS)}}{k_0} + \frac{\delta k^{(MT)}}{k_0} + \frac{\delta k^{(AL)}}{k_0} = \frac{3}{\pi^2}\frac{\delta}{T_c}\int(dK)\frac{(1-\gamma_K)\left[\frac{3\pi g_T\delta}{2\ T_c}(1-\gamma_K)-1\right]}{\epsilon+z\frac{g_T\delta}{T_c}(1-\gamma_K)} \quad (4)$$

This correction has been obtained at all orders in the tunneling amplitude. Fig. 1 presents this manner as a function of the reduced temperature for the case of atwo dimensional sample, and for different values of the scales $\frac{g_T\delta}{T_c}$ [1].

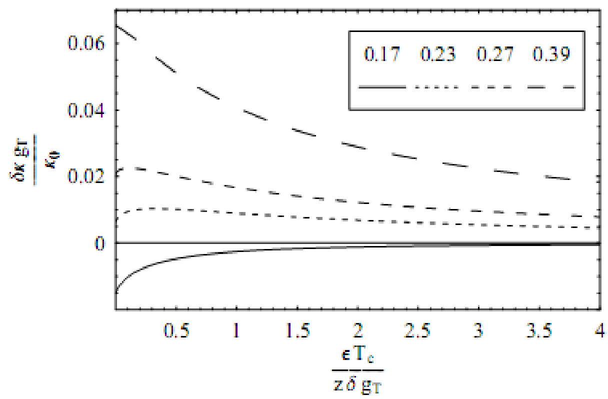

FIG.1.Fluctuation correction to the thermal conductivity for a two-dimensional granular array.

We can recognize two different regimes of temperatures: of temperatures: "high temperatures", and "low temperatures" that this temperature is far from and close to critical temperature.

High temperature regime or far from T_ci.e.$T - T_c \gg g_T\delta$;in which electron tunnelling between grains is ineffective, and the system behaviour is as a zero-dimensional system. This sentences means that only the DOS and AL corrections are significant to thecorrections of superconducting fluctuations;in this regime the coulomb correlations and the quantum coherent effects are important and by the decreasein temperature, the coulombinteractions play themajor role, and by the increase in temperature, the thermal conductivity increases in two and three dimensional samples[2]. In these regionas$\int(dK)\gamma_K = 0$, the MT correction equals zero and is not going to have any role. The correction to heat conductivity reads

$$\frac{\delta k}{k_0} = \frac{\delta k^{(DOS)}}{k_0} + \frac{\delta k^{(AL)}}{k_0} = \frac{3}{\pi^2}\frac{\delta}{T_c}\frac{1}{\epsilon}\left[\frac{3\pi}{2}\frac{g_T\delta}{T_c}\left(1+\frac{1}{z}\right)-1\right] \quad (5)$$

As we have seen, byincreasing the barrier transparency$g_T\delta$, the AL term becomes more important. With comparison the behaviour of the electrical conductivity and thermal conductivity, there is a deviation of the Weidman -Franz law and

$$\frac{\delta L}{L_0} = \frac{\delta k}{k_0} - \frac{\delta\sigma}{\sigma_0} \approx \left[-\frac{3}{\pi^2} + \frac{9}{2\pi}\frac{g_T\delta}{T_c}\frac{z+1}{z} + \frac{7\zeta(3)}{\pi^2}\right]\frac{\delta}{T_c}\frac{1}{\epsilon} \quad (6)$$

Low temperature regime or far from T_c i.e. $T - T_c \gg g_T\delta$;in which electron tunneling between grains is effective (in other words, coherence length is comparable to distance between the nearest neighbors, by which the electron tunneling gets important).In this regime the coulomb correlations and the quantum coherent effects are weakand electrical conductivity whit respect of cooper pair fluctuations increased.[3]By the decrease in temperature, the coulombinteractions play the major role, and by the decrease in temperature, the thermal conductivity increases and behaves as a coulomb barrier. In critical temperatures $T \to T_c$, the AL term is neutralized andjust the DOS term is going to be useful in corrections. So by the change in electrical conductivity the Drude classical conductivity$\sigma_0 =$

$2e^2 g_T a^{2-d}$[4], followed by Weidman-Franz low $\kappa/_{\sigma} L_0 T$ in whichL_0 is the Lorenz number, gets some changes and these changes are more tangible and more effective. The thermal conductivity correction is defined as below:

$$\frac{\delta k(\epsilon=0)}{k_0} = \frac{3}{z\pi^2}\frac{1}{g_T}(\frac{3\pi}{2}\frac{g_T\delta}{T_c} - 1) \qquad (7)$$

Following this we get to the Lorenz number variations and the deviance of Weidman-Franz low, according to the below equation:

$$\frac{\delta L}{L_0} = \frac{\delta k}{k_0} - \frac{\delta\sigma}{\sigma_0} \approx \frac{1}{\pi^2}\frac{\delta}{T_c}(\frac{9\pi}{2}\frac{1}{z} + \frac{7\zeta(3)}{\epsilon}) - \frac{3}{z\pi^2 g_T} \qquad (8)$$

As can be seen, this deviance is more apparent than the deviance of Lorenz number in high temperatures regime.

3. CONCLUSIONS

In high temperatures regime, the thermal conductivity correction is due to AL and DOS effects. Also weak localization effectcause that the systems behave as a zero dimensional system. In temperatures close to the critical temperatures, the DOS correction is neutralized due to MT correction; and AL term is a limit measure. As seen before in temperature; like homogenous superconductors, a convergence behavior in the equation about conductivity is obtained.

5. REFERENCES

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