AZƏRBAYCAN MİLLİ ELMLƏR AKADEMİYASININ XƏBƏRLƏRİ
Fizika-riyaziyyat və texnika elmləri seriyası, 2003 №2

УДК 621.312.592

# THE INFLUENCE OF THE MAGNETIC FIELDS ON THE THERMAL CONDUCTIVITY OF HIGH-$T_c$ SUPERCONDUCTING $Bi_2Sr_2CaCu_2O_{8+x}$

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It was investigated the temperature and magnetic field dependence of thermal conductivity of Bi-2212 superconducting polycrystal near $T_c$. It was observed that the thermal conductivity is increased with magnetic field in superconducting state. The electronic part of thermal conductivity ($k_e$), the superconductivity fluctuation contribution ($k_{fl}$) to the thermal conductivity was estimated.

## INTRODUCTION

The thermal conductivity (k) of high-$T_c$ superconductors (HTS) remains an interesting and controversial transport property. In contrary to resistivity (ρ) and thermal power (S) k have a limit value and increases for temperatures below the superconducting transition temperature ($T_c$). Most of work on k(T) are devoted to the understanding of the peak structure observed below $T_c$. While some authors believe that this peak is essentially due to the phonon contribution $k_{ph}$ [1-3], others try to explain this feature by considering an alternative interpretation based on an electronic model [4-6]. On the basis of thermal conductivity (k) and ρ data it can be estimated the phonon and electron part of thermal conductivity ($k_e$) in normal and superconducting (SC) state. This is especially interesting in HTS case, as so the mechanism of interaction of quasiparticles which reduce to pairing of charge carriers of HTS is not established at present. At the same time it is necessary to carry out the investigation of the superconductivity fluctuation contribution to transport coefficient, especially to the thermal conductivity near $T_c$.

## EXPERIMENTAL RESULTS AND DISCUSSION

Details of specimens' preparations are reported elsewhere [7]. The measurement current and heat flux from specimen were in perpendicular direction to the magnetic field. It was investigated the temperature dependence of thermal conductivity at various magnetic fields. The temperature stabilization was achieved within 65-77K to 0.05K and at T>77K to 0.1K. The temperatures of 65-77K were attained with the help of a pressure regulator for liquid nitrogen vapor.

Fig.1. shows the temperature dependence of k(T) for Bi-2212 at B=0 and B=2.2T. It should be noted, that the displacement of k(T) in magnetic fields was observed also in ceramic samples [8]. Above and below Tc we may describe the field dependence of the thermal conductivity according to the equation

$$k(T,B)=k_{ph}(T)+\frac{k_e(T)}{1+\beta_\varepsilon(T)B^n}$$

where the parameter $\beta_\varepsilon(T)\approx\sigma l_0/\varphi$ is proportional to the zero-field electronic mean-free-path $l_0$ of the quasiparticles (at β=0 and below $T_c$) and σ a transport cross section [3]. For the scattering of quasiparticles from vortices may be assume a power law $B^n$. The value n=1 is in general found when the quasiparticles scattering rate is proportional to the number of vortices [9].

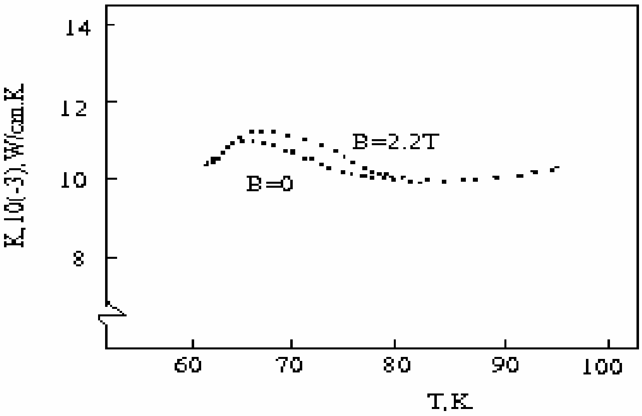

**Fig.1.**
The temperature dependences of thermal conductivity at B=0 and B=2.2 T magnetic fields.

The scattering process of vortices to the quasi-particles is based on the phase shift on their wave function due to the supercurrents around the vortex. At a certain distance of the quasiparticles from the vortex core, it energy may reach the energy gap value and an Andreev-scattering process occurs [10]. Since the number of vortices is proportional to the magnetic induction the electron-vortex scattering rate also increases when the magnetic induction is increased. At higher fields the strong interaction between vortices leads to the formation of a flux lattice and consequently phonon scattering by vortices diminishes. This happens when the penetration depth λ comparable to the separation of flux lines. The slow rise of k arises from increasing electronic contribution due to the continuous breakup of Cooper pairs as seen in fig.1 at 75K reach a maximum value than is decreased with temperature. It is stipulated by sufficiently increasing of upper critical field ($B_{c2}$). At such temperatures the magnetic fields up to 2.5T are fail to break of pairs. It was estimated the electron thermal conductivity $k_e$- calculated with the Wiedemann-Franz law. It was obtained that $k_e$~15% of total k.

It is expected that in HTS superconducting fluctuations can substantionally influence the thermal conductivity near the $T_c$. In this paper we investigate data on the thermal conductivity near the $T_c$ in order to explain the contribution of fluctuations to this transport coefficient. The experimental results were analyzed by using the theoretical model of Varlamov and Livanov [6]. These authors derived the fluctuation contribution $k_{fl}$ to the thermal conductivity of high-$T_c$ superconductors by considering a Lowrence-Doniach model to account for the layered structure of these materials.

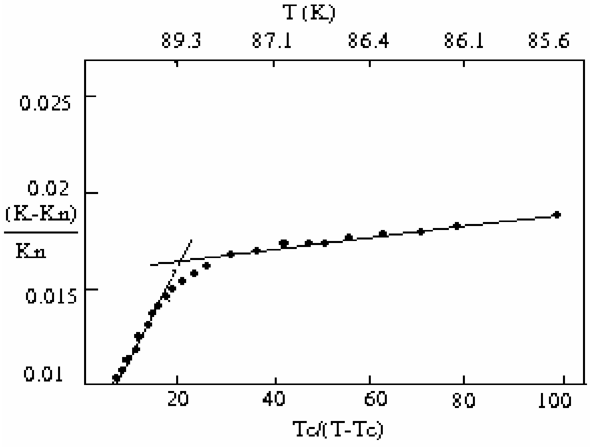

**Fig.2.**
The temperature dependences of normalized fluctuation thermal conductivity

The fluctuation contribution $k_{fl}$ is obtained as usual by subtracting this normal contribution from the total thermal conductivity $k_{fl}=k-k_n$. The normalized fluctuation contribution $k_{fl}/k_n$ to the thermal conductivity is shown in Fig.2. as a function of $\varepsilon^{-1}$, where $\varepsilon=(T-T_c)/T_c$.

According to [6] in the clean limit, for $T>T_c$

$$k_{fl}\sim\delta_o^{-1}\varepsilon^{-1/2},\quad \varepsilon<<\delta_0^2 \qquad (3D)$$

$$k_{fl}\sim\varepsilon^{-1},\quad \varepsilon>>\delta_0^2, \qquad (2D)$$

where $\delta^2\approx0.11(\omega/T_c)^2$ and $\omega$ is an overlap integral characterizing the interlayer coupling. One can see from Fig.2. that a crossover to 3D behavior from 2D occurs at the temperature $T_{VL}=92.7K$ ($T_c=90K$). This is in good agreement with the value obtained above from the thermal power and resistivity data [7]. The interlayer coupling energy ($J_c$) in the sample is experimentally estimated to be $4.7\cdot10^{-3}$eV. Fixing the Fermi energy to be $\varepsilon_F=0.08$eV[4] we obtain $\tau=3.5\cdot10^{-12}$s for transport relaxation time.

I would like to thank prof.S.A.Aliev for interesting discussions.

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## YUXARI TEMPERATURLU İFRATKEÇİRİCİ $Bi_2Sr_2CaCu_2O_{8+x}$-də MAQNİT SAHƏSİNİN İSTİLİKKEÇİRMƏYƏ TƏSİRİ

**S.S.RƏHİMOV**

Faza keçidi ətrafinda vismut (2212) yuxaritemperaturlu ifratkeçiricidə maqnit sahəsəsinin istilikkeçirməyə təsiri tədqiq edilmişdir. İfratkeçirici halında maqnit sahəsinin artımı ilə istilikkeçirmənin artması müşahidə edilmlşdir. Ümumi istilikkeçirmənin elektron ($k_e$) və fluktuasion ($k_{fl}$) hissələri qiymətləndirilmişdir.

## ВЛИЯНИЕ МАГНИТНОГО ПОЛЯ НА ТЕПЛОПРОВОДНОСТЬ ВЫСОКОТЕМПЕРАТУРНОГО СВЕРХПРОВОДНИКА $Bi_2Sr_2CaCu_2O_{8+x}$

**С.С.РАГИМОВ**

Проведено исследование влияния магнитного поля на теплопроводность висмутового (2212) сверхпроводника вблизи фазового перехода. Обнаружено, что в сверхпроводящем состоянии теплопроводность увеличивается с ростом магнитного поля. Оценены электронный ($k_e$) и флуктуационный ($k_{fl}$) вклады в общую теплопроводность.

Редактор: А.Халилова