# THE INFLUENCE OF THE MAGNETIC FIELD ON THERMALCONDUCTIVITY AND THERMAL POWER IN Bi-BASED SUPERCONDUCTING CERAMICS NEAR PHASE TRANSITION POINT

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The influence of the magnetic field to thermal conductivity $(K)$ and thermal power $(S)$ in phase transition $(PT)$ region is investigated. The electron part of the thermal conductivity $(K_e)$ is calculated. It is shown, that the ratio $K(B)/K_o$ increases with the increase of $B$, that is stipulated by the thermal conductivity of despaired electrons. The decrease in $S(T)$ in the normal phase is associated with the simultaneous participation of electrons and holes in conductivity.

## INTRODUCTION

One of the peculiarities of $HTSC$ is that, the pushing force of magnetic fields is significantly weaker, and the second critical field $(B_{c2})$ is much higher, than in SC-1 $B_{c2}^{II} >> B_{c2}^{I}$. The magnetic force lines inside $SC$ create around themselves $SC$ -vortex fluxes. Starting from a certain value of $B$ (from $B_{c1}$ up to $B_{c2}$) a lattice by shrinking begins to destruct. The destruction of $SC$ is accompanied by formation of normal electrons, partial restoration of conductivity and as a consequence by the electronic part of thermal conductivity. Depending on defect concentrations and investigated temperature interval the vortices may exhibit themselves as the scattering centers of electrons and phonons. Such conditions are fulfilled at low temperatures when, the electrons and phonons mean free paths reach the size of vortices section. The destruction process of $SC$ under magnetic field is well studied by magnetoconductivity $\sigma(B)$ investigations and thermal power $S(B)$ and some peculiarities of $HTSC$ have been derived. In this connection it is interesting to investigate the magnetothermal conductivity and magnetothermal power $S(B)$ of $HTSC$. However, the experimental observation of the change of $K_{el}(B)$ becomes complicated by the fact that, in $HTSC$ in spite of high concentration of charge carriers, the lattice thermal conductivity is significantly larger than electronic part. Therefore for similar investigations it is necessary either to increase the concentration of charge carriers, or select an object with small $K_l$. Among known $HTSC$ the Bi-based ceramics have the smallest value of $K_l$.

Last years a number of theoretical and experimental work devoted to electron and phonon scattering on vortices as well as to restoration of electronic thermal conductivity in magnetic fields have been published [1-5]. In the present work, the influence of magnetic field on thermal conductivity and thermal power in bismuth ceramics of 2212 phase in phase transition region $(PT)$ has been analyzed.

## EXPERIMENTAL RESULTS AND DISCUSSIONS.

The details on ceramics preparations experimental method are reported in [5]. The measurements have been carried out in the magnetic field $B=2.2T$ in direction perpendicular to a heat flux. The temperature has been controlled within an accuracy of ± 0.05K and with a precision of 0.1K by carring out the measurement in the dynamical regime. Each measurement has been carried out twice by cooling down and heating up the sample. Any thermal hysteresis on dependencies of $K(T,B)$ and $S(T,B)$ have not been observed. The magnetic field dependencies of $K(B)$ and $S(B)$ have been measured at different temperatures. The temperature stabilization was achieved within 60-77 K with accuracy to 0,05 K and at $T>77K$ to 0,1 K accuracy. A temperature interval of 60-77 K has been obtained with a special pressure regulator of liquid nitrogen vapor.

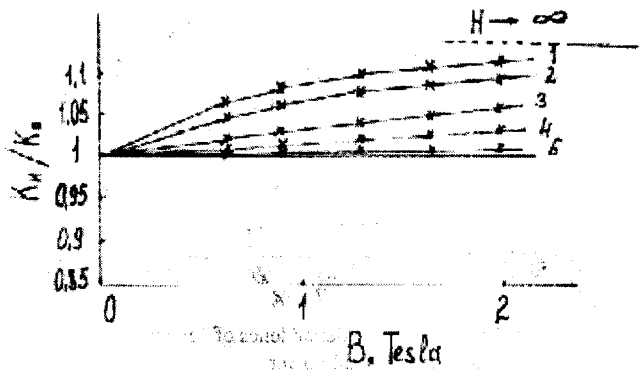


*Fig.1.* The magnetic field dependence of thermal conductivity 1-76K, 2-70K, 3-80K, 4-65K, 5-90 K.

In fig.1 the magnetic field dependence of thermal conductivity as $K(B)/K_o$ ($K_o$ - total thermal conductivity at a given temperature) ratio is shown. As it is seen the ratio $K(B)/K_o$ increases with increase of $B$. However, $\Delta K(B)$ increases only on the limit region of $T$ (65-95K). The vanishing of this effect above 90 K is stipulated by the low mobility of holes in normal phase state while the absence of this effect at $T<65$ K can be explained by sufficiently increase of $Bc2$. At such temperatures the magnetic fields up to 2,2T are failed to break a sufficient number of pairs. It is clearly seen from the temperature dependence of $K(B)$ at $B=2,2T$ (fig.2).

As it is seen the maximal effect corresponds to 75 K. Therefore, it can be concluded that the thermal conductivity increasing effect in magnetic field is stipulated by despaired electrons in a heat transport.

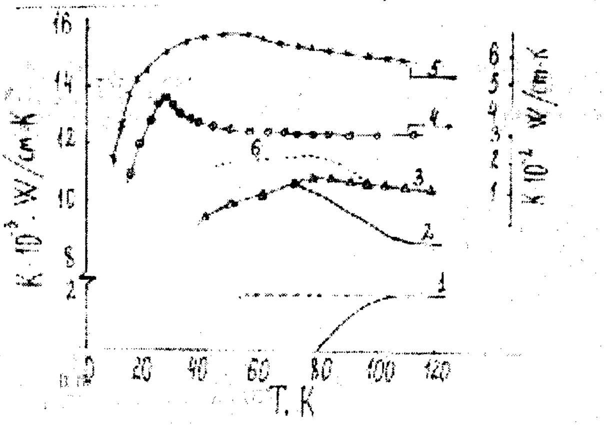


*Fig.2.* The temperature dependence of thermal conductivity 1- $K_{el}$, 2-$K_{lat}$, 3-$K_o$, 4- bismuth, 5-yttrium.

The temperature dependence of experimental and calculational data of total $K_o(B)$ (3), lattice $K_l(T)$ (2) and electron part $K_e(T)$ (1) of thermal conductivities is presented in fig.2. In the same figure also the temperature dependence of total thermal conductivity of crystalline Bi-type $SC$ (4) and yttrium ceramics (5) is presented.

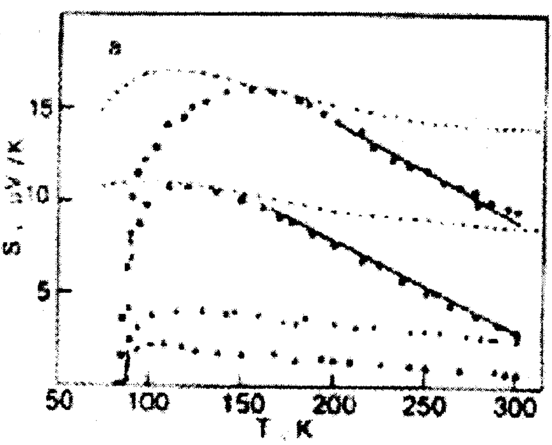


*Fig.3.* The temperature dependences of experimental and calculated thermal power.

The calculation of electron part $K_e(T)$ was carried out by Wideman-France law ($K_e=L\sigma T$) in the electron elastic scattering approach. The dotted curve (1) corresponds to the calculation in the absence of $SC$ (taking into accound $\rho n(T)$). Lattice part of thermal conductivity at $T>80$K is determined as $K_l=K_o-K_e$ and at temperatures lower than $PT$, $K_o(T)$ (at $B=0$) was taken as lattice $K_l$ since the electrons do not take part in thermal conductivity. In this fig.3 the curve (6) corresponding to total thermal conductivity $K(T)$ is presented in the case if the superconductivity is absent in the sample. As it is seen from temperature dependences of $K(T)$(1) for the sample with high value of the $K_e$ the at $SC$ transition condition its decreasing is observed while in crystalline sample (4) of Bi-type $SC$ and in yttrium ceramics the tendency to decrease of $K_o$(5) is absent. In crystalline sample it is related to the high value of ρo and $K_o$, and in $Y$-ceramics to relatively high value of $K_l$ one. The gap between curves (4) and (6) is stipulated by superconductivity phenomenon. Between these curves in small temperature interval data of $K(B,T)$ at 2,2 $T$ are presented. It is seen that, as $B$ increase the $K(T)$ curve rises to $K_o(T)$ curve (6).

What the temperature dependence of thermal conductivity of HTSC ceramics is concerned one can notice that it strongly differs from $K(T)$ of metals, semiconductors and dielectrics. In particular, they have very weak temperature dependence up to low $T$, as well as high value $T_{max}$ and in several ceramics the maximum on $K(T)$ is not arised, in particular for bismut ceramics also. These pecularities of $K(T)$ are inherent to amorphous and glasslike semiconductors. This is related to the absence of strict crystallic lattice. Probably, this may be addressed to ceramic condition too. The temperature $S(T)$ and field $S(B,T)$ dependences are presented in fig.3 and fig.4. It is seen that $S(T)$ and $S(B,T)$ curves are of similar character. Approximately 10 K below the phase transition, the value of $S$ passes through a peak and then decreases with temperature.

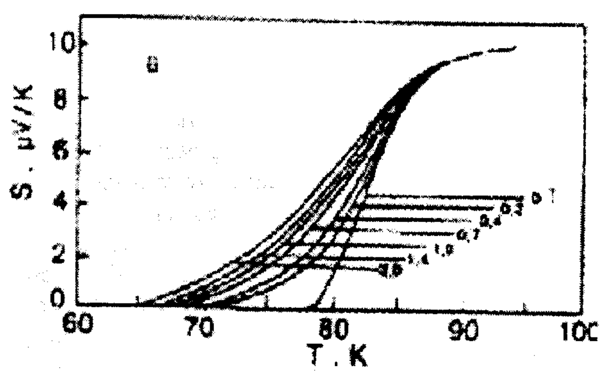


*Fig.4.* The temperature dependences of thermal power at various magnetic fields..

The value of $S$ in Bi-based $SC$ decreases sharper, than in $Y$-based $SC$. It can be seen that the transition width $\Delta T(B)$ increases with $B$. The arising of $S$ under magnetic field is related to dispairing of Cooper's pairs. It can be seen that this effect significantly decreases with $T$ disappears ($T<70$K). The change of $S(B)$ disappears at $T>90$K also. The data of S(B) are confirmed by data of $K(T)$.The results of $S(T)$ in normal phase have been interpretated according to the theory [6]. According to [6] the Fermi level for these materials lies near the narrow peak $\Delta E$ at the density of states $g(e)$ due to overlapping $p$-and $d$-band of oxygen and copper. Taking this circumstance into account, the authors of ref. [7] obtained the expressions for $S$ in the cases when $\Delta E>kT$ in analogy with electron prosesses in noncrystalline materials. In ref. [8], this model was developed for an arbitrary $\Delta E$, which made it possible to describe the results for $S$ and $\rho$ quantitatively and to determine the allowed band width $\Delta E$ in each individual case. The dashed curves in fig.3 show the results of calculations of $S(T)$. It can be seen that $S(T)$ of Bi-based ceramics strongly differs from the calculation. We believe that this is due to electrons which simultaneously take part in conductivity In this case the two-band model was applited. The parameters of electrons were obtained from Hall and specific electroresistivity data. The results of calculations of $S$ are represented by solid curves in fig.3a. Thus, the participation of electrons in conduction of Bi-based $HTSC$

materials is beyond doubt , although the question on the nature of electrons and holes is disputable. This problem is analized in [9] where it was proposed that holes were the main charge carriers in negatively charged $CuO_2$ planes, whole electrons play the major role in positively charged $(BiO)_2$ planes. Holes dominate in the conduction of single crystals in the direction of the c-axis, while charge transfer in a direction perpendicular to the c- axis can be executed both by holes in the $CuO_2$ plane and by electrons in the $(BiO)_2$ layers.


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## FAZA KEÇİDİ YAXINLIĞINDA BİSMUT İFRATKEÇİRİCİ KERAMİKALARDA MAQNİT SAHƏSİNİN İSTİLİKKEÇİRMƏ VƏ TERMOEHQ TƏSİRİ

Faza keçidi *(FK)* oblastında maqnit sahəsinin istilikkeçirmə *(K)* və termoehq *(S)* təsiri tədqiq edilmişdir. Istilikkeçirmənin electron hissəsi *(Ke)* hesablanmışdır. Maqnit sahəsinin artması ilə qırılmıs electron cütlərinin istilikkeçirməsi nəticəsində $K(B)/K_o$ nisbətinin artması göstərilmişdir. *S(T)* normal fazada azalması keçiricilikdə eyni zamanda həm elektron, həm də deşiklərin iştirakı ilə əlaqədardır.

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## ВЛИЯНИЕ МАГНИТНОГО ПОЛЯ НА ТЕПЛОПРОВОДНОСТЬ И ТЕРМОЭДС В ВИСМУТОВЫХ СВЕРХПРОВОДЯЩИХ КЕРАМИКАХ ВБЛИЗИ ФАЗОВОГО ПЕРЕХОДА

Исследовано влияние магнитного поля на теплопроводность *(K)* и термоэдс *(S)* в области фазового перехода *(ФП)*. Вычислена электронная доля теплопроводности *(Ke)*. Показано, что отношение $K(B)/K_o$ растет с увеличением магнитного поля, что обусловлено теплопроводностью распаренных электронов. Уменьшение *S(T)* в нормальной фазе обусловлено одновременным участием в проводимости электронов и дырок.

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