# THE INFLUENCE OF THE SUBSTITUTION OF CALCIUM BY ZINC ON THERMAL CONDUCTIVITY AND THERMAL POWER OF $Bi_2Sr_2Ca_2Cu_3O_X$

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It was investigated the influence of Ca substitution by Zn on the thermal conductivity, thermal power, spesific resistivity of $Bi_2Sr_2Ca_2Cu_3O_X$ in the 70-300K temperature interval. It was established that the Ca substitution by Zn leads to increase of lattice thermal conductivity and conductivity type from (+) to (-). It was shown, that these chances are stipulated by improvement of quality of $Bi_2Sr_2Zn_2Cu_3O_x$ ceramics.

Despite of the reached successes in research of HTSC, search of materials though in what that, surpassing existing still proceeds. One of ways of reception of new materials is replacement of one of complex component HTSC, other analogue. Therefore, in the presented work in $Bi_2Sr_2Zn_2Cu_3O_x$ system full replacement of atoms Ca by atoms Zn is made.

With the purpose of finding-out of efficiency of replacement of atoms Ca by Zn in Bi-based HTSC system it was carried out research of factor of thermal conductivity and electric properties of new structure 2223 with initial system.

Thermal conductivity is one of the most sensitive physical properties not only to structural changes of a crystal, but also for various types of defects in them. As defects in HTSC there can be deviations from stechiometry, borders of grains, dispositions isotopes and others of heterogeneity. Is known also that in HTSC materials, especially in ceramics, in view of absence in them of strict crystal structure and presence of high concentration of defects, free length of phonons is slightly change in wide temperature interval.

The thermal conductivity was measured by a stationary method in cryostat, allowing to spend measurement in an interval 2-300K.

As in the 150-300K interval the thermal conductivity in HTSC possesses rather low value it is necessary to enter the amendment on the losses of heat radiated from a surface of the sample and the heater, and also bringing assembly wires. The technique of the account losses on radiation is based on the theory of thermal radiation of an absolute black body. The given technique is developed in work [1] for bodies of grey color and approved in [2]. According to it the thermal conductivity k was calculated by:

$$k = \frac{W - \varepsilon}{\Delta T} \cdot \frac{l}{s}$$

where W=IU-capacity of a heater, S-cross-section of the sample, *l*-distance between thermocouples, $\Delta T$ is a difference of temperatures between the top and bottom thermocouples, $\varepsilon = Q_{rad} + Q_{wire}$ warmly, radiated by a lateral surface of the sample and a heater, and also outflow by bringing wires. $Q_{rad}$ is calculated under the formula:

$$Q_{rad} = \left\{S_{sam}\left(T_{av}^4 - T_e^4\right) + S_{heat}\left(T_{heat}^4 - T_e^4\right) \cdot \sigma\right\}$$

Where $S_{sam}$–is the area of lateral surface of sample, $S_{heat}$ is area of a surface of a heater, $T = (T_1 + T_2) / 2$ -is an average temperature of the sample,$T_1$ is temperature of a casing of the device,$T_2$ – is temperature of a heater, $\sigma = A\sigma_0$- is factor of emission of the sample for a grey body $\sigma_0$=3,45.10 W/cm.K – of Stephan-Bolsmann constant.

Outflow of heat from bringing wires takes place at all temperatures and is defined by the formula: $\Delta Q = kS\Delta T/l$, where k-thermal conductivity of thermocouples, the *S*-area of cross-section, l-length of wires from the sample up to the top part of volume of a casing, $\Delta T$-difference temperature between the sample and a casing of the device.

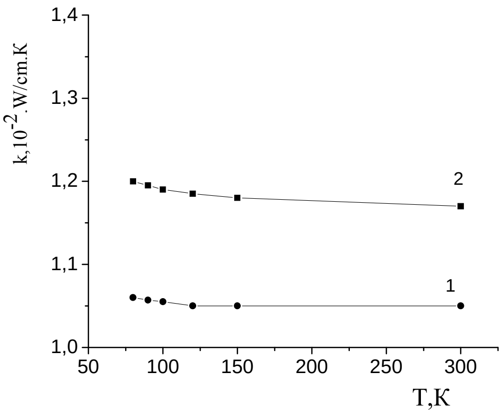


*Fig.1.* The temperature dependences of thermal conductivity: 1- $Bi_2Sr_2Ca_2Cu_3O_X$, 2- $Bi_2Sr_2Zn_2Cu_3O_X$.

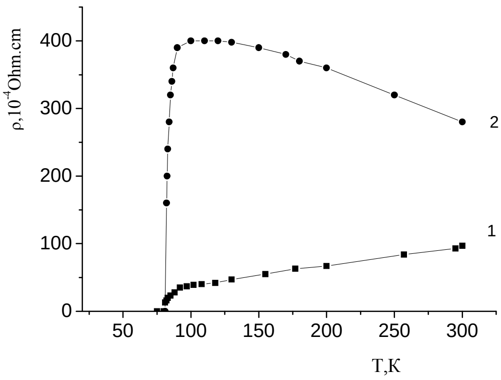


*Fig.2.* The temperature dependences of specific resistivity: 1 - $Bi_2Sr_2Ca_2Cu_3O_X$, 2- $Bi_2Sr_2Zn_2Cu_3O_X$

The calculations have shown, that the maximal losses connected with radiation at *T*=300K for the investigated sample reaches 15-20 %, and outflow on wires does not exceed 3-4 %. The Fig.1 show the temperature dependences of lattice k above described amendments, and the fig.2 show specific resistance of the investigated samples respectively.

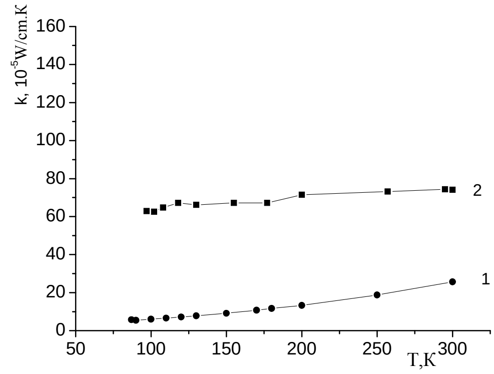


*Fig.3.* The temperature dependences of electronic thermal conductivity: 1 - $Bi_2Sr_2Ca_2Cu_3O_X$, 2- $Bi_2Sr_2Zn_2Cu_3O_X$

The electronic part of thermal conductivity $k_e$ has been estimated according to Widemann-Frants relation ($k = LT/\rho$) by the account of a degree degeneration and the electron scattering mechanism at which Lorenz's number accepted value 1,8.10 Ohm.K. The calculations have shown, that $k_e$ in $Bi_2Sr_2CaCu_3O_x$ does not exceed 4 %, and in $Bi_2Sr_2Zn_2Cu_3O_x$, it is insignificant is small (fig.3). These data give the basis to accept k(T) for temperature dependence lattice thermal conductivities. From fig.3 it is visible, that in bismuth HTSC with Ca k(T) slightly depends on temperature, whereas it should decrease proportionally $k \sim T$.

The temperature dependences of thermal power of $Bi_2Sr_2CaCu_3O_x$ and $Bi_2Sr_2Zn_2Cu_3O_x$ is presented in fig.4. As seen, in $Bi_2Sr_2Zn_2Cu_3O_x$ the thermal power S has a positive sign and has small value, with decrease of $T$ it slightly increases and at phase transition (PT) sharply falls up to $S$=0. In the sample with Zn value S is more, than in the sample with Ca, also has $n$-type of conductivity, with decrease of $T$ the $S$ decreases and at PT also falls up to $S$=0. These data indicated on strong degeneration of holes in $Bi_2Sr_2Zn_2Cu_3O_x$, it leads to metal temperature course of S (T).

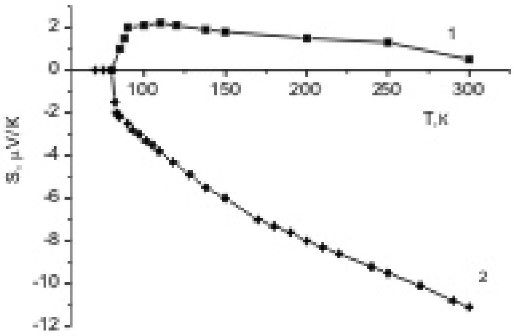


*Fig.4.* The temperature dependences of thermal power: 1 - $Bi_2Sr_2Ca_2Cu_3O_X$, 2- $Bi_2Sr_2Zn_2Cu_3O_X$.

The increasing of lattice thermal conductivity of $Bi_2Sr_2Zn_2Cu_3O_x$ gives the basis to conclude, that full replacement of atoms Ca by Zn reduces concentration of defects and improves quality of Bi-based HTSC. It testify also the fact of change of a sign of S from hole conductivity on electronic and removal of degeneration of charge carriers.

It is necessary to note, that in the literature exists different representations about value and a sign of thermal power in the Y-, Ta-, Bi and Hg-based cuprates [3]. In particular it is indicated, that negatively charged CuO-planes cause hole conductivity, and positively charged BiO-planes cause electronic one [3]. In [4] the authors consider, that the value and sign of S are defined, basically, not number of CuO-planes, and concentration of charge carriers in these planes also. Our data give the basis to consider, that the replacement Ca on Zn leads to a formation of donor levels. Certainly, it is difficult to indicate on a concrete element creating such levels, but it is possible to believe, that it is caused by some deviation from stoichiometry such complex structure of Bi-based HTSC.

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## KALSİUMUN SİNKLƏ ƏVƏZ EDİLMƏSİNİN $Bi_2Sr_2Ca_2Cu_3O_X$ -DƏ İSTİLİKKEÇİRMƏYƏ VƏ TERMOE.H.Q. TƏSİRİ

70-300K temperatur intervalında kalsiumun sinklə əvəz edilməsinin $Bi_2Sr_2Ca_2Cu_3O_X$-də istilikkeçirməyə, termoe.h.q.-nə və xüsusi müqavimətə təsiri öyrənilmişdir. Göstərilmişdir ki, Ca-un Zn ilə əvəz edilməsi nəticəsində materialın istilikkeçiriciliyi artır və keçiriciliyin işarəsi (+)-dən (-)-ə keçir. Təyin edilmişdir ki, alınan nəticələr $Bi_2Sr_2Zn_2Cu_3O_X$ keramikasının keyfiyyətinin yaxşılaşması ilə əlaqədardır.

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## ВЛИЯНИЕ ЗАМЕЩЕНИЯ КАЛЬЦИЯ ЦИНКОМ НА ТЕПЛОПРОВОДНОСТЬ И ТЕРМОЭДС В $Bi_2Sr_2Ca_2Cu_3O_X$

Проведено исследование влияния замещения кальция цинком в $Bi_2Sr_2Ca_2Cu_3O_X$ на теплопроводность, термоэдс и удельное сопротивление в интервале температур 70-300K Установлено, что замещение Ca на Zn приводит к повышению решеточной теплопроводности и к смене знака проводимости от (+) на (-). Показано, что эти изменения обусловлены улучшением качества висмутовых керамик $Bi_2Sr_2Zn_2Cu_3O_x$.

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