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CRITICAL TEMPERATURE AND MAGNETIC FIELD INDUCTION IN SOME HTSCS

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Abstract: *In this study, the importance of the application of some superconducting materials and the dependence of their critical temperatures on magnetic field inductions were studied.*

Keywords: *Superconductivity, critical temperature, magnetic field induction, critical current density, bismuth, strontium, calcium, copper.*

Superconductivity is the phenomenon of a drop in the resistance of a material to values indistinguishable from absolute zero at a temperature below a certain critical one. Even now, these materials are actively used in various fields: from medicine to high-energy physics. They are also associated with hopes for future breakthrough technologies, such as the transmission of electricity without energy loss for heating wires, the creation of trains on a magnetic cushion, levitating hoverboards, etc.

Superconductivity is an unusual combination of properties of some materials that manifest themselves at low temperatures. The main of these properties is the almost complete disappearance of electrical resistance in many metals and alloys, when they are cooled to a temperature below the critical one. Due to this circumstance, special attention to the study of the properties of superconducting materials is shown by the developers of a wide variety of electrical devices that find applications in the technique of physical experiment, in medicine, energy, transport, and other branches of science and technology. The absence of electrical resistance and, accordingly, the absence of energy losses during the flow of electric current through superconductors make it possible to achieve unique technical and economic characteristics of devices that are absolutely unattainable using conductors traditionally used in electrical engineering - copper, aluminum.

To date, it is customary to divide all superconducting materials into two large groups. The first of these are low-temperature superconductors, which have the property of superconductivity at temperatures ranging from fractions of a Kelvin to approximately 20 K. The second group of superconductors, called high-temperature superconductors (HTSCs), has no electrical resistance up to temperatures of the order of 100 K [1].

At present, systems and devices using HTSC are being created. These are superconducting separators, NMR tomographs, charged particle accelerators, etc. Promising are the creation and development of serial production of SQUIDs (superconducting quantum interference detector) - classes of electronic superconducting devices based on Josephson junctions.

At the beginning of the 21st century, the transition to the production and use of superconducting HTSC wires begins. These wires are ribbons as opposed to the more common round wires. HTSC wires pass into the superconducting state at temperatures above the nitrogen temperature, but have relatively low critical currents at the nitrogen temperature. In general, HTSC wires are characterized by a rather sharp temperature dependence of the critical current and magnetic field strength, and at temperatures of about 20 K they have a critical current density that exceeds the parameters of conventional low-temperature wires (NbTi and Nb_3Sn). The ability to operate at 20–25 K is a huge advance, since it allows the use of less powerful and cheaper cooling devices in applied devices, such as tomographs, for example [2].

After the discovery of HTSC cuprates in 1986, when the critical temperature T_C = 23.2 K (in the Nb_3Ge crystal), which was a record high for conventional superconductors, was significantly exceeded and the superconducting transition temperature T_C = 30 K was reached in $La_{2-n}Ba_nCuO_{4+x}$ ceramics, in within one year, the Tc record exceeded 90 K (YBCO). Further directed search and creation of new superconducting materials made it possible in 1994 to bring T_C to 138 K (in the Tl-doped $HgBa_2Ca_2Cu_3O_{8+x}$ compound) and to raise the question, perhaps even of room-temperature superconductivity [3].

Table 1 below shows the values of the critical temperature and magnetic field induction for some HTSCs.

Table 1 - Properties of some superconductors [1]

Elements	**T_c,K**	**B_c, TlatT=4 K**
Hg	4.15	0.041
Pb	7.2	0.080
Nb	9.25	0.206
NbTi	9.5 – 10.5	12
Nb_3Sn	18.1 – 18.5	22
Nb_3Al	18.9	30
Nb_3Ge	23.2	37
MgB_2	~40	50
$YBa_2Cu_3O_7$	92.4	60
$Bi_2Sr_2Ca_2Cu_3O_{10}$	111	~500
$HgBa_2Ca_2Cu_2O_8$	133	>1000

Another type of frequently used HTSC are bismuth-strontium-calcium-copper complex oxides, or BSCCO for short, belonging to the family of high-temperature superconductors with the generalized chemical formula $Bi_2Sr_2Ca_{n-1}Cu_nO_{2n+4+x}$ (compounds with n=1, n= 2 and n=3). HTSCs of these compositions were discovered as a general class in 1988 and BSCCO was the first high temperature superconductor to be free of rare earths.
Specific types of BSCCO are usually denoted by a sequence of metal ion numbers. Thus, Bi-2201 is n=1 compound ($Bi_2Sr_2CuO_{6+x}$), Bi-2212 is n=2 compounds ($Bi_2Sr_2CaCu_2O_{8+x}$), and Bi-2223 is n=3 compounds ($Bi_2Sr_2Ca_2Cu_3O_{10+x}$) [4].

Although $Bi_2Sr_2Ca_2Cu_3O_{10+x}$ BSCCO is superior in performance to YBCO, its use is less preferred due to manufacturing difficulties.

A crystallographic cell of Bi-2212 (Figure 1) consisting of two repeating units is offset. The remaining members of the BSCCO family have very similar structures: 2201 has one less CuO_2 in its top and bottom and no Ca layer, while 2223 has an extra CuO_2 and a Ca layer in each half.

One of the important parameters characterizing a superconductor is the value of the critical current I_C. The microstructure of the sample and the pinning force of magnetic vortices have a very important effect on this parameter. Effective pinning centers can be inclusions of non-superconducting phases in a superconducting matrix.

For the $Bi_2Sr_2Ca_2Cu_2O_{8+x}$ (Bi-2212) phase, an increase in the critical current was observed with the addition of magnesium oxide, strontium sulfate, and strontium zirconate. If, in most cases, an increase in Ic is associated with an increase in the pinning force, then, upon doping with strontium sulfate, the observed changes are associated with an improvement in the microstructure of the sample [5].

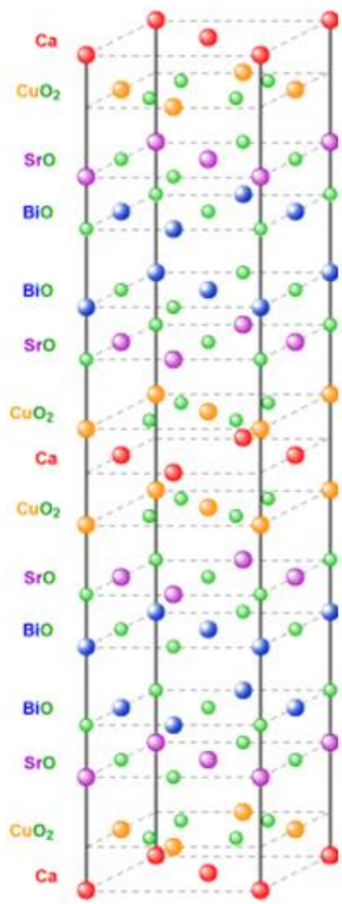

Figure 1. Structure of the crystallographic cell BSCCO-2212 [4].

The superconductors of the compound in the Bi-(Pb)-Sr-Ca-Cu-O system, $Bi_2Sr_2CaCu_2O_{8+5}$ and $Bi(Pb)_2Sr_2Ca_2Cu_3O_{10+5}$, also referred to below as Bi-2212 and Bi-2223, respectively, are especially promising for creating long-length superconducting products - tapes, wires, rods. This is due to the formation of highly anisotropic lamellar crystallites by them, which makes ceramic texturing easier and reduces its brittleness. At the same time, the anisotropy of the crystal lattice leads to strong electromagnetic anisotropy, which in practical terms is expressed in a low pinning energy of magnetic vortices and, accordingly, in a sharp drop in the critical current density with increasing temperature and magnetic field.

Therefore, increasing the pinning efficiency in such materials by introducing foreign inclusions into the superconductor matrix seems to be very important [6].

Thus, promising superconducting materials largely determine the development of the electric power industry in the near future. The study and establishment of the regularities of physical processes occurring in the volume of superconducting materials is of particular importance from the point of view of the use of superconductors in modern micro- and nanotechnologies.

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