

HIGH-TEMPERATURE CUPRATE SUPERCONDUCTORS AND THEIR APPLICATIONS

O.G. Turayev

Asia International University, Bukhara, Uzbekistan, 200100

Email: ozodjon.turayev1327@mail.ru

Abstract: This paper presents information on high-temperature superconductors (HTSCs) and their practical significance. Special attention is given to HTSCs synthesized using solar energy. Interest in these materials arises due to the phase transitions observed at relatively high, even room and above-room temperatures. Additionally, the critical transition temperatures (T_c) to the superconducting state, synthesis technologies, external influences, and structural changes are of significant scientific and practical importance.

Keywords: high-temperature superconductors, critical temperature, resistance, magnetic field, cuprate, structure, bonding, research, technology.

Introduction

More than thirty-five years have passed since Karl Müller and Georg Bednorz discovered a new class of high-temperature superconductors and were awarded the Nobel Prize for their work. However, to date, no comprehensive theory has been developed to fully describe metal oxide-based HTSCs. Therefore, scientific research in this field remains highly relevant.

Historically, the first cuprate superconductor, lanthanum-strontium-copper-oxide (La-Sr-Cu-O), exhibited zero electrical resistance at 36 K. Shortly afterward, superconductivity was observed at temperatures above the boiling point of liquid nitrogen (77.4 K) in yttrium-barium-copper-oxide (Y-Ba-Cu-O). Further research revealed that superconductivity could be achieved in mercury-barium-calcium-copper-oxide (Hg-Ba-Ca-Cu-O(F)) ceramics at 138 K and, under pressure (400 kbar), up to 166 K. Currently, materials with such properties are being investigated for applications in science, technology, industry, defense, medicine, and many other fields.

Literature Review and Methodology

The critical temperatures (T_c) of some cuprate-based HTSCs and their compositions are listed below:

Compound	T_c (°C)	T_c (K)
La-Ba-Cu-O	-240	35
Y-Ba-Cu-O	-215	93
Bi-Sr-Ca-Cu-O	-180	95
Tl-Ba-Ca-Cu-O	-150	125 (up to 166 under pressure)
Hg-Ba-Ca-Cu-O	-140	133 (highest T_c cuprate)

The discovery of materials that remain superconducting at or above room temperature could revolutionize various fields, including energy, electrical engineering, electronics, information technology, and transportation.

Discussion

Chinese scientists proposed a novel type of superconducting joint. Using a connector tape combined with separated YBCO layers from buffer stacks allowed perfect lattice alignment between two YBCO superconductors, enhancing current-carrying performance. The superconducting parameters, phases, and surface morphologies of the YBCO layers were studied before and after heat treatment. After a relatively short oxygen annealing period (40 hours), a high critical current (I_c) of 116 A was achieved, with over 98% superconducting connectivity and a junction resistance (R_j) below $1.8 \times 10^{-15} \Omega$ at 77 K. Finally, the interfacial microstructure and the mechanism of bonding between the two YBCO layers were also investigated [4].

Results

The connecting tape was placed on top of the YBCO layer of the superconducting sample, followed by diffusion bonding and oxygen annealing. Specific temperatures and pressures were applied in the furnace during the bonding and oxygen diffusion processes. In this way, oxygen rapidly diffused through the upper Ag layer into the YBCO layer, thereby restoring the superconductivity of the joint.

The voltage–current characteristics obtained from the above-mentioned materials are presented in the graphs, indicating the critical transition points at which the materials enter the superconducting state.

Chinese researchers paid particular attention to the practical significance of cuprates. They aimed to fabricate highly conductive cables by coating metallic conductors with metal-oxide cuprate superconductors. This represents a significant breakthrough in the energy sector, providing the potential for remarkable energy savings.

In the warm climatic conditions of Uzbekistan, the use of such cryogenic systems requires special attention. Despite the technical challenges associated with cooling systems, interest in the field of superconductivity continues to grow—not only among scientists worldwide but also among researchers in our Republic. It is equally important to engage young scientists in understanding the fundamentals and achievements of this phenomenon, as it is directly related to the issues of energy generation and transmission and is characterized by unique and valuable physical properties.

When an object is placed in a magnetic field, it can itself become a source of a magnetic field. Diamagnetic materials possess unique properties in their interaction with external magnetic fields. When a diamagnetic material is placed in an external magnetic field, it interacts with the field in such a way that the induced internal magnetic field compensates for the external field at its surface [1].



Figure 1. The Meissner effect in a YBCO sample.

Conclusion

The analysis of both local and international research on cuprate superconductors indicates that Chinese scientists have focused primarily on the practical aspects of production and application. In Uzbekistan, several experimental studies have been conducted on the synthesis of cuprate superconductors, yielding promising results. Further improvement and industrial implementation of these materials could bring major advancements in the energy sector.

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