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This Week's Citation Classic

Maeda H, Tanaka Y, Fukutomi M & Asano T. A new high-r. oxide superconductor without a rare earth element. *Jpn. J. Appt. Phys. Pt. 2* 27:L209-10, 1988. [National Research Institute for Metals. Tsukuba Laboratories. Ibaraki. Japan]

We discovered a new high-r_c superconductor of the Bi-Sr-Ca-Cu-O system without any rare earth element. The oxide $BiSrCaCu_2O_X$, has T_c of about 105 K, higher than that of $YBa_2Cu_3O_7$, by more than 10 K. In this oxide, the coexistence of Sr and Ca is necessary to obtain high T_c. [The *SCI*® indicates that this paper has been cited in more than 1,900 publications, making it the most-cited paper published in this journal.]

High-T_c Bi-Based Oxide Superconductors

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In late 1986, J.G. Bednorz and K.A. Muller at IBM Zurich Research Laboratory discovered a new, outstanding superconductor in the La-Ba-Cu-0 system, $(La,Ba)_2CuO_4$, with a critical temperature, T_c,of 30K.[1] Withinafewmonths, M.K. Wu et al. at the Universities of Alabama and Houston discovered superconductivity at 90 K, above liquid nitrogen temperature, in $YBa_2Cu_3O_7$, a compound in the Y-Ba-Cu-0 (YBCO) system.[2] The discovery of the 90 K superconductivity stimulated a worldwide race to achieve even higher T_c. The T_c value of YBCO, however, had not been exceeded even by the substitution of any other rare earth elements for Y.

When it seemed that the revolutionary developments on T_c had reached a plateau, we discovered a new class of high-f_c superconductors in the Bi-Sr-Ca-Cu-O (BSCCO) system, which include no rare earth elements, at 5 p.m. on Christmas Eve 1987. The electrical resistance curve as a function of temperature of the compound with a nominal composition of $BiSrCaCu_2O_X$ showed at least two stepwise transitions; the high one exhibiting a projected zero resistance value at approximately 105 K and the lower one at about 80 K. We also confirmed the stepwise Meissner effect, suggesting the coexistence of the high-T_c phase and low-T_c phase. After the discovery, we worked around the clock for about a month to fabricate samples with the single high-T"$_c$ phase. However, we could not succeed in reproducibly isolating the high-7^ phase from the low-T_c phase. This frustrating result overcame our patience and brought us to announce our findings publicly on January 21, 1988. Soon after the announcement, we identified the crystal structures of the low-T_c and high-T_c phases as having the chemical formulas $Bi_2Sr_2CaCu_20_x$ and $Bi_2Sr_2Ca_2Cu_3O_y$, respectively, and found an interesting structure modulation which we had never encountered.[3] I gave the first key talk about this work at one of the biggest conferences on high-T_c.[4] This presentation so excited all the paticipants that they discussed the new superconductors until midnight. Since then, BSCCO has played the most important role from the viewpoints of studies on both high-T_c mechanisms and applications. For the discovery, I was awarded the 1991 Bernd Matthias Prize.

A key point to having attained high-T_c in the Bi oxides is the coexistence of two kinds of alkaline earth elements, Sr and Ca. The Ca ion, by allowing CuO_2 layers to stack up, is responsible for the increase in T_c. BSCCO has a T_c higherthan YBCO by more than 15K and is more stable and ductile. Furthermore, this discovery has stimulated many researchers once again to hope to discover a compound with a still higher T_c and is one of the turning points in high-T_c superconducting research.

It took four further months to isolate the single high-T_c phase: M. Takano et al. achieved it by the substitution of Pb for part of the Bi.[5] Moreover, we have developed useful methods to greatly improve grain alignment, which allow a high critical current density, J_c, in BSCCO polycrystalline materials.[6] These show promise for future applications of Bi-oxide superconductors; for instance, Bi-oxide wires and tapes 100m in length have been prepared so far, showing a practical level of J_c. In the near future, we shall be obligated to develop some useful applications, such as high-field superconducting magnets operated in liquid nitrogen, because these excellent superconductors have been presented to all of us by God on Christmas Eve.

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