HIGH T_c SUPERCONDUCTOR CONTACT UNIT HAVING LOW INTERFACE RESISTIVITY

RELATED APPLICATION

This application is a division of U.S. patent application Ser. No. 07/274,881, filed Nov. 22, 1988, now, U.S. Pat. No. 5,015,620, and entitled "HIGH-Tc SUPERCONDUCTOR CONTACT UNIT HAVING LOW INTERFACE RESISTIVITY, AND METHOD OF MAKING", issued May 14, 1991 as U.S. Pat. No. 5,015,620, which application was a continuation-in-part of U.S. patent application Ser. No. 117,259, filed Nov. 6, 1987, and issued Oct. 16, 1990 as U.S. Pat. No. 4,963,523.

FIELD OF THE INVENTION

This invention relates to a high-T_c superconductor, and, more particularly, relates to a high-T_c superconductor contact unit having low interface resistivity, and the method for making the same.

BACKGROUND OF THE INVENTION

In superconductors, there is a critical temperature, or T_c, at which resistance to the passage of electricity disappears. Conventional superconducting metals, alloys, and compounds, however, have critical temperatures ranging from just above absolute zero to about 15–20 K, and practical applications for such superconductors are therefore limited because they are operative only at extremely low temperatures.

A new class of superconductors, designated high-T_c superconductors, has recently been discovered and is being extensively investigated. The members of this class have much higher critical temperatures making it possible to use them in devices of commerce. One such high-T_c superconductor, a rare-earth based superconductor, $Y_1Ba_2Cu_3O_7$, for example, has a critical temperature of about 93 K. Other rare-earth based superconductors with different rare earth elements substituted for Y have approximately the same T_c and have substantially the same crystal structure. Two new types of high-T_c superconductors with critical temperatures higher than the rare-earth based compounds are bismuth-based high-T_c superconductors (such as $Bi_2Ca_1Sr_2Cu_2O_9$, for example) with critical temperatures up to about 115 K, and thallium-based superconductors ($Tl_2Ca_2Ba_2Cu_3O_x$, for example) with critical temperatures up to about 125 K.

In most commercial applications, superconductors are, or will be, electrically connected to other components of the device containing them. It is essential that the resistivity of the connections be low, particularly where high currents are to be carried, such as, for example, in transmission lines, generators and motors, energy storage devices, and other magnetic applications. Low resistivity connections are also required, for example, for superconductors which are part of an integrated circuit, for example, in high density, high speed computers to reduce the heatloads in such computers.

Low resistivity contacts are especially important for high-T_c superconductors, since even moderate resistance-caused heating can raise the temperature of a superconductor enough to significantly lower its critical-current density. Low resistivity contacts are required for high-T_c superconductors in both bulk applications, such as electromagnets, and in thin-film devices, such as computers.

Contact resistivity is expressed in terms of surface resistivity $\rho\square = RA$, where R is the contact resistance, and A is the contact area. For small magnet applications at liquid nitrogen temperatures, contact resistivities less than about $10^{-5}\Omega\text{-cm}^2$ are required to limit heating at the contact to acceptable levels. Contact resistivities less than about $10^{-7}\Omega\text{-cm}^2$ are required for integrated circuit package interconnect applications and less than about $10^{-9}\Omega\text{-cm}^2$ for on-chip interconnect applications. Low resistivity ohmic contact interfaces such as those described herein are also needed to form superconductor-normal-superconductor junctions, superconductor-normal-semiconductor junctions, as well as other superconducting integrated circuit elements.

Contacts made with indium solder, silver paint, direct wire bonds and pressure contacts have a contact surface resistivity typically in the range 10^{-2} to $10\Omega\text{-cm}^2$, and such contacts are therefore several orders of magnitude too high for practical applications.

It is known to deposit metals on ceramic components to provide a situs for electrical connections to leads fabricated of copper or other conductive metal. Deposition by sputtering is particularly desirable because the metal deposited strongly adheres to the ceramic substrate. It is known from U.S. Pat. No. 4,337,133 to use sputtered gold as the metal to prepare conductive electrical contact surfaces. It is also known from the paper titled "Metallization of Ceramics For Electronic By Magnetron-Plasmatron Coating" by Schiller et al, appearing in Thin Films, Volume 72, pages 313–326 (1980), that ceramics having silver deposited thereon exhibit good solderability. Various other methods of joining or soldering metals to refractory materials are disclosed in U.S. Pat. Nos. 3,915,369 and 3,993,411.

Typical connecting components in an electrical device or system are made of copper or silver, aluminum, gold-plated conductors, and the like. However, connecting such components to high-T_c superconductors by conventional means such as direct pressure, soldering using flux-containing solders of the type described in U.S. Pat. No. 3,703,254, or even with indium-based solders, results in a relatively high resistivity connection which can adversely affect desirable properties of the superconductor. High resistivity connections can result even if the superconductor contains a metal contact pad.

It has also been heretofore suggested that silver epoxy contacts can be printed on a high-T_c superconductor with the resulting unit then being annealed in streaming oxygen at 900° C. (see "Improved low contact resistance in high-T_c Y-Ba-Cu-O ceramic superconductors" by J. Van der Maas et al., appearing in Nature, Volume 328, pages 603 and 604 (August 1987). In addition, it has been suggested that when silver is evaporative-deposited on a high-T_c superconductor, and then heat treated at 500° C. for up to five hours in an O_2 environment, contact resistance is decreased by more than two orders of magnitude (see "High performance silver ohmic contacts to $YBa_2Cu_3O_{6+x}$ superconductors", by Y. Tzeng et al, appearing in Applied Phys. Letters, Volume 52, pages 155 and 156 (January, 1988)).

SUMMARY OF THE INVENTION

It has been discovered that an improved low resistivity contact to u high-T_c superconductor is obtained