by
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Recent Progress in Applications of High T_c Superconducting Materials in Japan

Today, superconductivity technology that realizes zero electrical resistance is receiving much attention from a viewpoint of energy saving and a reduction in CO_2 generation. This technology, which came to worldwide attention after the discovery of high critical temperature (T_c) superconducting (HTS) materials in 1986, possesses great technical potential in many fields of our life, not to mention those of energy and electronics. For example, it is applicable to compact power cables for large-capacity power transmission, super-express Maglev (magnetically levitated) trains and so on.

Recently, significant progress has been made at several institutes in Japan in the superconductivity technology both for material processing and applications. One of these examples, "Tests of a 500-m High-Temperature Superconducting Cable", was reviewed in this column, "News from Japan" of the Nov/Dec 2004 issue. Because there remain many other important examples, some of them are reviewed. As the first article, significant achievements accomplished by Sumitomo Electric Industries are introduced in the present issue.

Sumitomo has been promoting research and development on practical applications of superconductivity since the 1960s. Recently, the company has developed an innovative sintering method of bismuth-based superconducting wire. The bismuth-based HTS material BSCCO discovered in Japan consists of bismuth (Bi), lead (Pb), strontium (Sr), calcium (Ca), copper (Cu), and oxygen (O). The 2223 phase, of which composition ratio of (Bi, Pb), Sr, Ca, and Cu is 2:2:2:3, has a high critical temperature of 110 K. Therefore, it has been attracting much attention as a commercially viable HTS material since its discovery.

Because BSCCO2223 is composed of as many as six elements, synthesis of a desired superconductor is difficult. It also is difficult to obtain a dense structure using a sintering method. Sumitomo Electric Industries has been researching a powder-in-tube method for combined processing of silver and BSCCO2223, and it has developed an innovative process called "controlled over pressure (CT-OP)" sintering method. In the CT-OP process, the temperature, pressure, and ambient atmosphere are controlled in an integrated manner, especially during the last important heat treatment step in determining the superconducting characteristics of wires. As a result, the quality of BSCCO2223 has been improved with smaller and less defects as can be seen clearly in microscope images shown in Figure 1, and its density has reached almost 100% of the theoretical value from conventionally obtained values of 85%. The O concentration is also precisely controlled. In this way, the CT-OP process has solved most problems with the commercialization of HTS wires. The bismuth-based HTS wire developed by the CT-OP process has the following features: the critical current is 192 A, about two times larger than the conventional value of 100 A; the mechanical strength is improved by more than 50%; a unit length as long as more than 1,500 m compared to 500 m or less by the conventional method; the production yield is more than four times greater.

Because the BSCCO2223 processed by the CT-OP method has many advantages compared to the conventionally processed

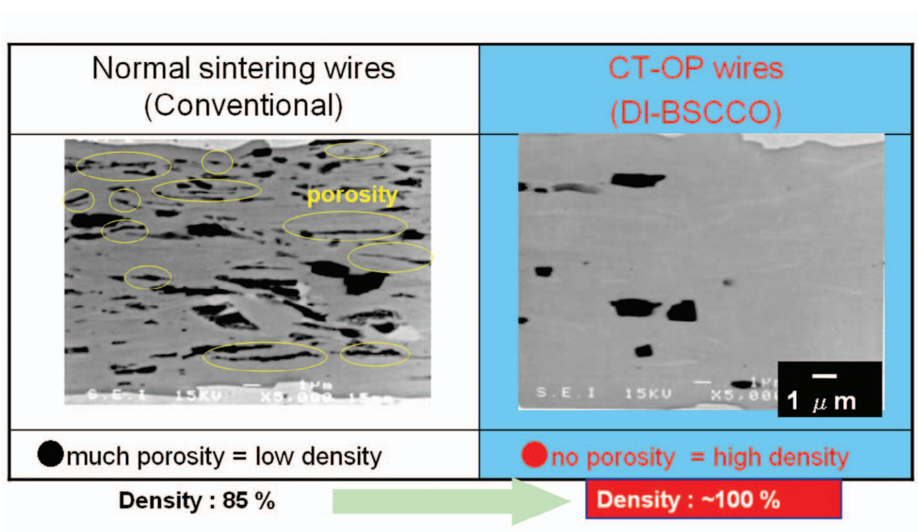

Figure 1.

*Japanese Frontier Group: Fuji Electric Systems Co., Ltd./ Hitachi, Ltd./ Ishikawajima-Harima Heavy Industries Co., Ltd./ Nakashima Propeller Co., Ltd./ Niigata Power Systems Co., Ltd./ Sumitomo Electric Industries, Ltd./ Taiyo Nippon Sanso Corporation/ University of Fukui (Professor Hidehiko Sugimoto) in alphabetical order.

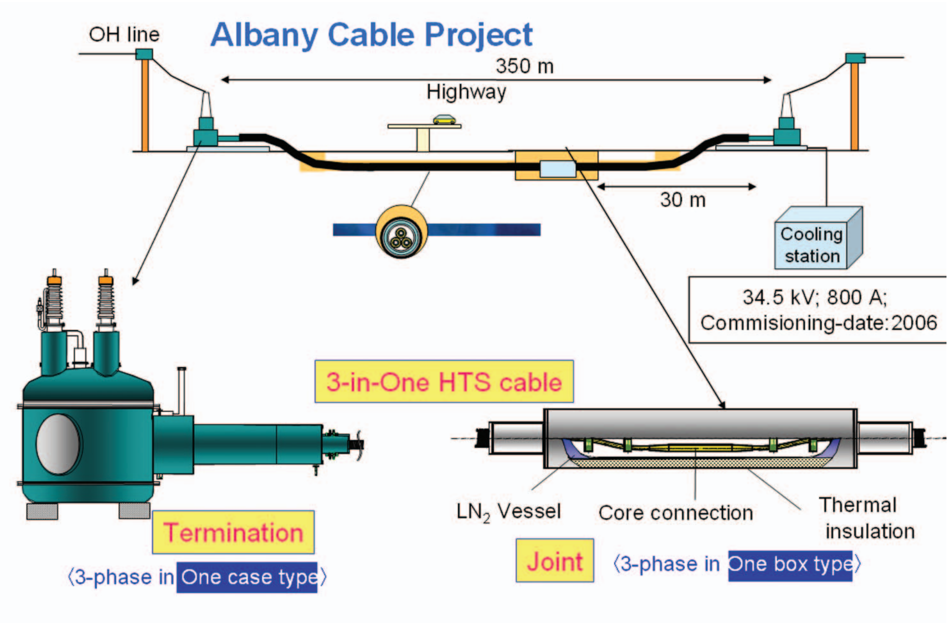

Figure 2.

material, Sumitomo named it DI-BSCCO (drastically innovative BSCCO). Sumitomo has started commercial sale of DI-BSCCO wires and development of their applications. The following lists several examples of recent applications.

The first example is a superconducting cable, which is expected to solve the shortage of transmission capacity in metropolitan areas. Its advantages are as follows: large transmission capacity in compact dimension, small transmission loss, no leakage of electromagnetic field outside the cable, and small impedance.

These features are effective to improve the reliability and economical competitiveness of electrical networks. Recently, several demonstration projects have started around the world in order to accelerate the applications of superconducting cable to real network systems. In the United States, three projects are presently running. They are superconductivity partnership initiative (SPI) projects funded by the Department of Energy (DOE). One of these projects, the Albany Project, also is funded by New York State Energy R & D Association (NYSERDA). It is being conducted by SuperPower Inc. (main contractor), National Grid (utility company), BOC (cooling system company), and Sumitomo Electric Industries. Sumitomo, which is in charge of the manufacture and installation of 350-m long DI-BSCCO cables, development of terminals and joints, and the implementation of the long-term test, has developed compact cables, termination design, and intermediate joint design, as shown in Figure 2. The project is planned for 4 years from 2002 to 2006.

The second example is a superconducting motor. The Japanese Frontier Group* has developed the world's first practical-level HTS motor using DI-BSCCO wires cooled by liquid nitrogen, and has successfully completed fabrication of a pod propulsion system with this motor. The pod propulsion, which is employed in passenger and other vessels and is attached outside the ship, allows effective use of interior space, reduction in onboard noise, and improvement in ship maneuverability. When a conventional motor is used in a large pod propulsion system with a high output, the outer diameter of the propulsion system becomes too large for practical use. Under the conventional superconductivity technology, when liquid nitrogen is used for cooling, it is difficult to obtain a magnetic field high enough for large-capacity motors. The Japanese Frontier Group has succeeded in solving this problem and has developed a compact, large-capacity, HTS motor by employing DI-BSCCO wires.

The pod incorporating this HTS motor is 0.8 m in width and 2 m in length, and the diameter of propulsion propeller is 1 m. The propeller rotation speed can be freely controlled in a range of 0 to 100 rpm in both the clockwise and counterclockwise directions. The Japanese Frontier Group has developed the HTS field winding motor and all-HTS motor (Figure 3) with a capacity of 12 kW at 100 rpm. It also has a plan to develop 400-kW motors for a real ship propulsion system.

Because the new HTS motor has achieved a revolutionarily small size, high efficiency, and low energy consumption, it is expected to be used as a railcar motor, generator for a wind power system, and large industrial motor such as for a steel rolling mill.

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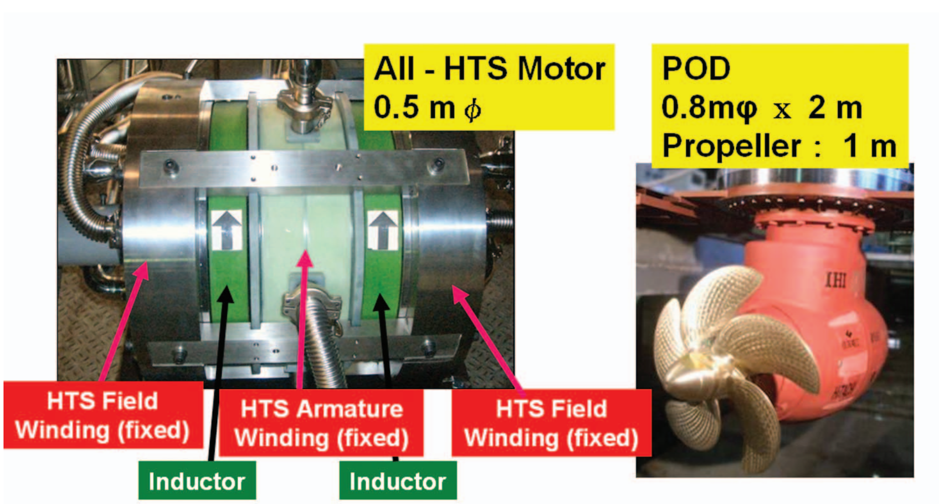

Figure 3.