Proceedings of the Korean Superconductivity Society Meeting 1999
(KSS 99), YongPyung, Kangwondo, Korea, Aug. 18-20, 1999

APPLICATIONS OF BULK HIGH TEMPERATURE SUPERCONDUCTORS

Masato Murakami
Superconductivity Research Laboratory
1-16-25, Shibaura, Minato-ku, Tokyo 105-0023 Japan
e-mail murakami@istec.or.jp

After the discovery of La-Ba-Cu-O, many kinds of oxide superconductors with isomorphous structure were discovered. These high temperature superconductors (HTS) can be characterized by the layered structure which is essentially the stacking of CuO2 superconducting planes and blocking layers. It is possible to change the critical temperature (Tc) mainly by changing the structure of the blocking layers. So far the highest Tc has been achieved in Hg-Ba-Ca-Cu-O which exhibits Tc of 135K in ambient pressure and Tc of 160K under high pressures.

However, it is also true that only two systems in HTS family can be used for power applications at present. Those are Bi-Sr-Ca-Cu-O and RE-Ba-Cu-O (RE: rare earth elements) systems. For Bi-Sr-Ca-Cu-O, there are two different superconducting phases: Bi2Sr2CaCu2Ox with Tc around 85K; and Bi2Sr2Ca2Cu3Ox with Tc of 110K. Both of these superconductors can be made in long tapes over 1km in length using the powder-in-tube method, in that precursor Bi-Sr-Ca-Ca-O powders are stacked in silver or silver alloy sheath and pressed and rolled into the form of tape. A superconducting magnet which can generate 7T has successfully been constructed with pancake coils made from Bi-Sr-Ca-Cu-O tapes. Superconducting cables have also been made by several groups [5] and will be installed for public use in the US. In Bi-Sr-Ca-Cu-O, however, due to weak coupling between CuO2 layers, their pinning performance at temperatures above 30K is really poor so that power applications at 77K will be difficult. In contrast to Bi-Sr-Ca-Cu-O, flux pinning is already sufficient for practical applications at 77K in RE-Ba-Cu-O, although long tape fabrication is difficult. These two groups of practical superconductors have ironical features in their intrinsic properties. Bi-Sr-Ca-Cu-O superconductors are highly anisotropic materials in the crystal structure, which makes it easy to fabricate highly textured long tapes, but it causes weak pinning. In RE-Ba-Cu-O it is easy to introduce flux pinning centers active even at higher temperatures due to a small anisotropy in the crystal structure, which then makes the fabrication of long textured tapes extremely difficult. Therefore, the present status of high temperature superconducting materials is not really successful in regard to wire applications at high temperatures.

Compared to low temperature superconductors (LTS), one of the greatest advantage of HTS is their high stability against quenching. Due to a small thermal conductivity at low temperatures, bulk LTS is not stable so that although there were many challenges to use bulk LTS for practical applications, they were unsuccessful. On the contrary, bulk HTS is very stable due to a large thermal conductivity as long as HTS is used at high temperatures, which has opened novel application areas, that is, bulk applications. One of the most successful bulk applications is the current lead made of Bi-Sr-Ca-Cu-O sintered rod which are used to supply large currents to the LTS superconducting magnet. With the employment of HTS current leads, the consumption of liquid helium has been greatly suppressed. It is also important to note that cryocooling of LTS coils became possible by using HTS current lead, which made it possible to develop so-called helium free superconducting magnets.

The other interesting materials for bulk applications are melt textured RE-Ba-Cu-O. Recent progress in melt processing has enabled us to fabricate large grain RE-Ba-Cu-O superconductors with high critical current density (Jc) values. Such bulk superconductors can exhibit a large electromagnetic force through the interaction with magnetic fields. A heavy object can be suspended in midair using bulk superconductors. Many prototype devices such as magnetic bearing, flywheel energy storage, load transport have been constructed and now subjected to the field tests. A significant large magnetic field over several teslas can also be trapped by a large single grain superconductor exhibiting high Jc values. Such trapped field magnets are attractive for various applications, since they can generate fields much higher than those of permanent magnets in almost the same dimensions. In this review, I will summarize the present status of bulk HTS applications.