Cryogenfree Superconducting Magnets

Kazuo Watanabe [a,b,1], Satoshi Awaji [a,b], Mitsuhiro Motokawa [b]

[a] *High Field Laboratory for Superconducting Materials, Institute for Materials Research, Tohoku University, Sendai 980-8577, Japan*

[b] *CREST, Japan Science and Technology Corp., Tsukuba 305-0077, Japan*

Abstract

Various kinds of cryogenfree superconducting magnets such as a wide bore 8 T, a split-pair 5 T, and a high magnetic field 15 T magnet have been developed successfully at Tohoku University. A cryogenfree 23 T hybrid magnet composed of a cryo-cooled outer superconducting magnet and a water-cooled inner resistive magnet is being tested for the first time. Further, new construction projects of a cryogenfree 30 T hybrid magnet and a cryogenfree 19 T superconducting magnet have just started.

Key words: $Bi_2Sr_2Ca_2Cu_3O_{10}$;current leads;cryogenfree superconducting magnet;cryo-cooler

1. Introduction

A GM-cryocooler with a small refrigeration capacity has been utilized to realize a practical cryogenfree superconducting magnet (CSM) using high temperature superconducting current leads [1]. Since CSM can provide a high magnetic field generation for a long time such as a few weeks or a few months, it is a great convenience for the crystal growth and the chemical reaction experiment to utilize CSM. It is expected that conventional superconducting magnets immersed in liquid helium will be replaced by easy-operational CSM in near future. Recently, new materials development in magnetic fields using CSM attracts much attentions in relation to a nano-technology. Container-less melting process in magnetic levitating condition [2] is being desired to make a sphere fine glass by a CO_2 infrared laser combined with CSM. This paper describes the new process developments using various kinds of CSM at the High Field Laboratory for Superconducting Materials (HFLSM), IMR, Tohoku University.

2. Various cryogenfree superconducting magnets

Since we succeeded in constructing the world's first practical CSM with a 38 mm room temperature experimental bore using 500 A $Bi_2Sr_2Ca_2Cu_3O_{10}$ current leads in 1992 [1], a wide bore, a split-pair, a high magnetic field, and a functional CSM have been demonstrated splendidly. Table 1 lists various types of CSM installed at HFLSM, Tohoku University. 5 T-CSSM combined with an X-ray diffractometer is available for a direct measurement in the field-induced phase transformation such as Mn oxides system. Further, a split-pair cryogenfree superconducting magnet was easily extended to a neutron diffraction experiment [3]. The high magnetic field of 15.1 T in a 52 mm room temperature experimental bore was achieved by 15 T-CSM [4], and a new construction project aiming to generate 19 T in a 52 mm room temperature bore has just started. 19 T-CSM will consist of a 2.5 T Bi-system high temperature superconducting insert coil and a back up magnet of a 16.5 T Nb_3Sn/NbTi outer coil. Moreover, a cryogenfree hybrid magnet of 23 T-CHM is being tested, and tentatively a magnetic field of 20 T was performed by the combination of a 4.5 T-360 mm warm

[1] E-mail:kwata@imr.tohoku.ac.jp

Table 1
Cryogenfree superconducting magnets developed at HFLSM

	warm bore [mmϕ]	B [T]	I_{op} [A]	remarks
5T-CSM	38	4.6	465	first practical CSM
6T-CSM	220	5.7	138	chemical reaction
11T-CSM	52	10.7	149	1200 °C furnace
5T-CSSM	ϕ50×10 gap	5.0	67	X-ray diffraction
8T-CSM	220	7.0	210/64	being tested, 1600 °C furnace
11T-CSM	52	11.0	149	CVD
15T-CSM	52	15.1	154/95	1200 °C furnace
19T-CSM	52	(19)		under construction
23T-CHM	52	20.1	198	being tested
30T-CHM	32	(30)		under construction

bore CSM and a 15.5 T water-cooled resistive magnet, as shown Fig. 1. Finally, a 3.5 T Nb_3Sn insert coil has to be added in a 4.5 T-360 mm warm bore CSM. As a next step, a 30 T-CHM construction project composing of a 12 T-360 mm warm bore CSM and a 19 T-32 mm warm bore water-cooled resistive magnet has also started. In these projects, highly strengthened Nb_3Sn superconductors have to be developed. It is required that the next phase Nb_3Sn wires with ϕ1.8 mm in diameter have a high critical current, a good conductive copper stabilizer of RR = 100 and a high strength of σ = 250 MPa in fields of 10-15 T.

3. New process developments

A heat-treatment in fields is carried out using a 1600 °C electric furnace installed in a 220 mm room temperature bore of 8 T-CSM and 1200 °C electric furnaces in 11 T-CSM or 15 T-CSM. Magnetic alignment effects are intended using such an in-field heat-treatment. Especially, a CVD process for $YBa_2Cu_3O_7$ reveals an interesting morphology change in high fields [5]. It is found that the magnetic field influences the grain size during deposition. In addition, the magnetic field orientation effect appears in anisotropic materials even in high temperature around 1000 °C. A new hybrid magnet system of 23 T-CHM and 30 T-CHM will provide a large magnetic levitation force. A CO_2 laser and a YAG laser combined with CHM will be utilized as a melting method in magnetic levitation.

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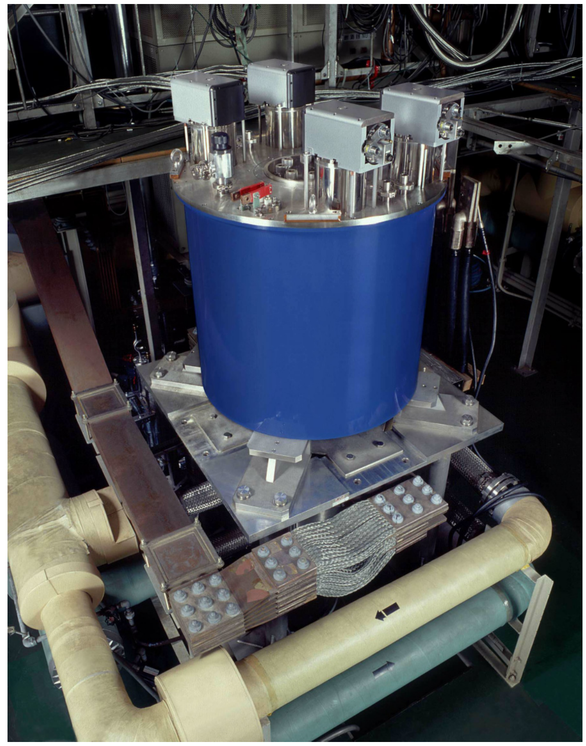

Fig. 1. Construction of the cryogenfree 23 T hybrid magnet at HFLSM, Tohoku University.

References

[1] K. Watanabe, Y. Yamada, J. Sakuraba, F. Hata, C. K. Chong, T. Hasebe and M. Ishihara, Jpn. J. Appl. Phys. (1993) 32, L488.

[2] M. Motokawa, M. Hamai, T. Sato, I. Mogi, S. Awaji, K. Watanabe, N. Kitamura and M. Makihara, Physica (2001) B294-295, 729.

[3] K. Watanabe and M. Motokawa, IEEE Trans. Appl. Supercond. (2000) 10, 489.

[4] K. Watanabe, S. Awaji, M. Motokawa, Y. Mikami, J. Sakuraba and K. Watazawa, Jpn. J. Appl. Phys. (1998) 37, L1148.

[5] Y. Ma, K. Watanabe, S. Awaji and M. Motokawa, Appl. Phys. Lett. (2000) 77, 3633.