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# Temperature rise in melt-textured large grain superconducting bulk magnets during their magnetizing operations

Tetsuo Oka [a,*], Kazuya Yokoyama [b], Hiroyuki Fujishiro [c], Koshichi Noto [d]

[a] *Niigata University, 2-8050 Ikarashi, Niigata 950-2181, Japan*
[b] *Ashikaga Institute of Technology, 268-1 Ohmae-cho, Ashikaga, Tochigi 326-8558, Japan*
[c] *Iwate University, 3-4-5 Ueda, Morioka, Iwate 020-8551, Japan*
[d] *Iwate University, 3-19-27 Chomeigaoka, Izumi-ku, Sendai 981-3212, Japan*

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**Abstract**

The temperature rises in the melt-processed RE–Ba–Cu–O (RE = Y, Sm, Gd) bulk superconductors were evaluated when the magnetizing operations were performed by the field cooling (FC), the zero field cooling (ZFC) and the pulsed field magnetization (PFM) processes. It is known that the field-trapping ability of the superconducting bulk magnets is restricted by the heat generation due to the flux motion inside the sample not only in the PFM but also even in the FC process. In this paper, the authors discuss the mechanism of heat generation and the flux motions by means of the temperature and resultant trapped field measurement during three magnetizing processes. The sample was cooled in a 5 T static field and then the field was removed with various descending rates (2.53–11.3 mT/s) in FC method. The fields were also applied and then removed with the same rates after setting the sample in the superconducting state in ZFC. These data were compared with the results obtained in the PFM. The temperature evolutions have shown apparent peaks that correspond to the heat generation in their magnetizing processes. The maximum temperature rises have reached 5.9 K in FC and 7.6 K in ZFC operated at 57.6 K and 51.5 K, respectively. The temperature rise exhibited 2 K even when the slowest rate of 2.53 mT/s was applied in FC mode. These data suggest it is crucial to take the heat generation into account in estimating the field-trapping ability of the high performance bulk magnets.


*Keywords:* Melt-process; Bulk superconductor; Trapped field; Heat generation; Magnetization

## 1. Introduction

We know that the melt-processed $REBa_2Cu_3O_y$ (RE = Y, Sm, Gd, abbreviated as RE123) bulk superconductors including $RE_2BaCuO_5$ (RE211) precipitates act as permanent magnets when they capture the magnetic field. The field-trapping ability of the compounds has been greatly improved through various fabrication processes. The maximum trapped field has reached 17.24 T (reported by Tomita et al. [1]) for Y123 sample with the size 26.5 mm in diameter. The data was obtained by the field cooling method (abbreviated as FC) and the referred temperature has risen up to 30 K from initial temperature 29 K before starting the magnetizing operation in spite of careful lowering of sweeping rate of provided magnetic field. The flux motion during the magnetization process, even in the FC, causes local heating in the sample, raises the temperature, lowers the critical current density, and subsequently degrades the trapped field.

In the report, the temperature changes during the FC and zero field cooling (ZFC) processes are estimated as functions of temperatures and the sweeping rates for bulk superconductors cooled by a Gifford–McMahon refrigerator.

## 2. Experimental

Fig. 1 shows the schematic views of the experimental setup. A bulk sample manufactured by Dowa Mining Co.

* Corresponding author. Tel.: +81 25 262 7668; fax: +81 25 262 7010.
*E-mail address:* okat@eng.niigata-u.ac.jp (T. Oka).

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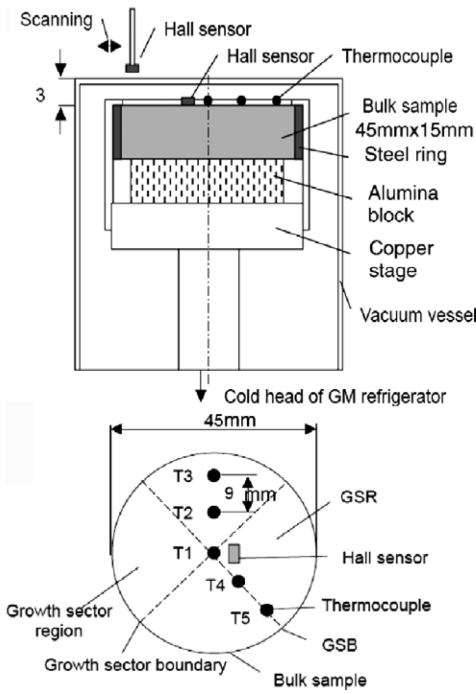


Fig. 1. Schematic views of experimental setup.

consisted of RE123 and RE211 with addition of Pt, and was impregnated by epoxy resin with glass fibers.

The temperature data were measured by five sets of fine chromel–constantan thermocouples with 76 μm in diameter attached on the sample surface. The heat capacities of them do not need to be taken into account.

In the FC process, a static field of 5 T was applied in the normal state, and the sample was cooled to the lowest temperature by a refrigerator, and then the magnetic field is removed with descending rates, −2.53, −5.06, and −11.3 mT/s. In the ZFC process, the magnetic field of 5 T was applied after cooling the sample below $T_c$ and was subsequently removed. The data were compared with those obtained by the PFM experiments [2].

## 3. Results and discussion

### 3.1. Temperature changes in FC process

When the magnetic fields started decreasing from 5 T to 0 T, the temperatures (T1–T5) of an Y123 sample drastically rose showing steep peaks of the temperatures. One can see that the faster the speed, the higher the temperature rises. The maximum averaged temperature rise was 5.9 K when the descending speed was −11.3 mT/s.

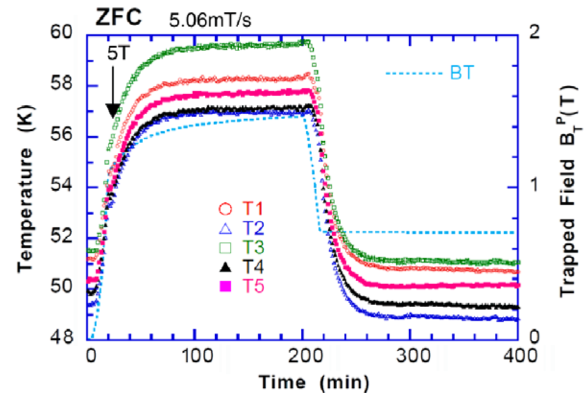


Fig. 2. Temperature change of Sm123 bulk during ZFC process operated up to 5 T with a sweep rate 5.03 mT/s.

### 3.2. Temperature changes in ZFC process

Fig. 2 shows the temperature changes in the ZFC process for Sm123 operated at 50 K. The profiles show that the temperatures at all the measured points rose for 7–8 K. The averaged temperature rise reached 7.6 K when the sweep rate was 5.06 mT/s. It is noted that the temperatures and the trapped field kept increasing for about 200 min after stopping the increase of field at 5 T. This indicates that the flux distribution reconstructs even in the static state for a long time. It suggests that heat propagation must be improved to suppress the temperature rises.

The temperature rises thus obtained are substantial in comparison with the data reported as about 21 K during PFM process when the pulsed field of 5 T was applied to the Sm123 sample at 40 K [2].

## 4. Conclusions

The temperature measurements revealed that the temperature rises reached 5.9 and 7.9 K in FC and ZFC magnetization processes operated at 50 K, respectively. They are not negligible in estimating the field-trapping ability of bulk superconductors.

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