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Smart Insulation That Enables Calculation Of Operating Current Of ReBCO Coil

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Background

It is well-known that the first step for developing an application system is calculating the operating current with regards to the rating. In second-generation high-temperature superconducting applications, however, asymmetric wires and other vulnerabilities make it difficult to calculate the operating current.

Therefore, this study proposes a smart insulation (SI) coil as a method to improve the stability of the 2G HTS coil. Based on the high electrical stability of the SI coil com-pared to the insulation coil, this paper also discusses the reliability of the operating current determined within the allowable current density. The electrical stability is verified through coil experiments, and a method to determine the operating current is discussed.

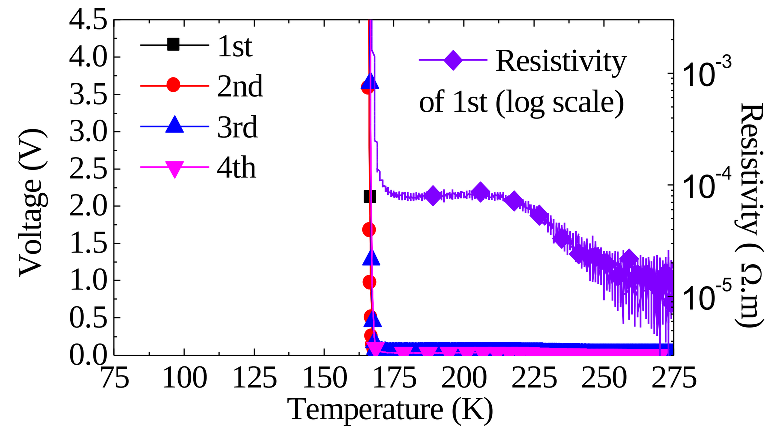
Objectives

This study discusses the operating current calculation process of a ReBCO coil based on the high electrical stability and controllability of the SI coil.

Conclusion

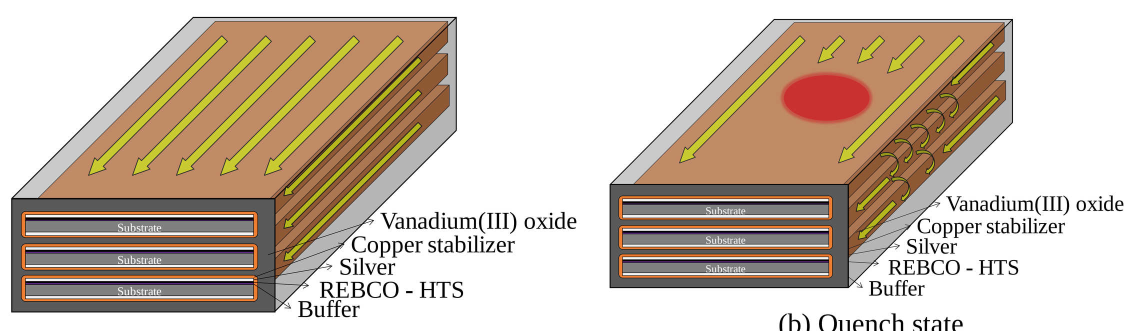
- This study proposes a calculation method through experiment and simulation with an 8-turn coil to reduce the analysis variables. However, the proposed method may not be suitable if thermal and mechanical problems are introduced, such as by increasing the number of turns or increasing the width of the wires. However, it is important to note that the SI coil proposed in this study is more electrically stable than conventional insulation coils. Thus, less margin can be applied than in the insulation coil to achieve stability.
- Though not mentioned in this paper, when the magnetic field decreased due to current bypass in an extreme transient state through a 100-turn SI racetrack coil test, the magnetic field value was detected and the input power was cut-off, thus successfully protecting the coil. This is one solution to the problem of permanent damage to coils in high-temperature superconducting applications.
- In the future, in HTS application system design, data-bases should form the basis of predictable operating cur-rent calculation according to the type of application system and the operating conditions.

THE SMART INSULATION



MIT characteristic refers to an instant change in material property from metal to insulator or from insulator to metal due to the change in the resistance under certain conditions.

Among the many materials with an MIT characteristic, vanadium (III) oxide (V_2O_3) was used in this study because its temperature transition range was considered appropriate for the required conditions in this study. V2O3 is a material whose resistivity in a pure singlecrystal state sharply changes by 1/600,000 times at approximately 150–170 K.



(a) Steady state (b) Quench state

Current flow diagram of SI ReBCO coil in (a) steady state and (b) quench state.

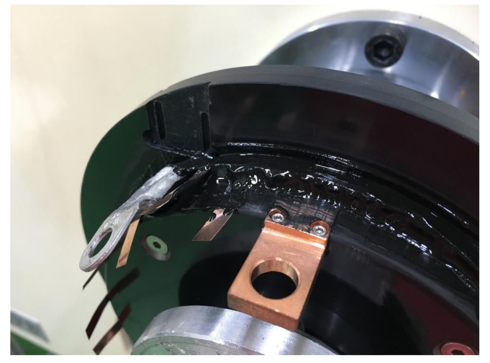
The SI coil is quench occurs and the temperature increases above the transition temperature, then the SI gains the electrical conductivity of a metal and turn-to-turn current bypass occurs.

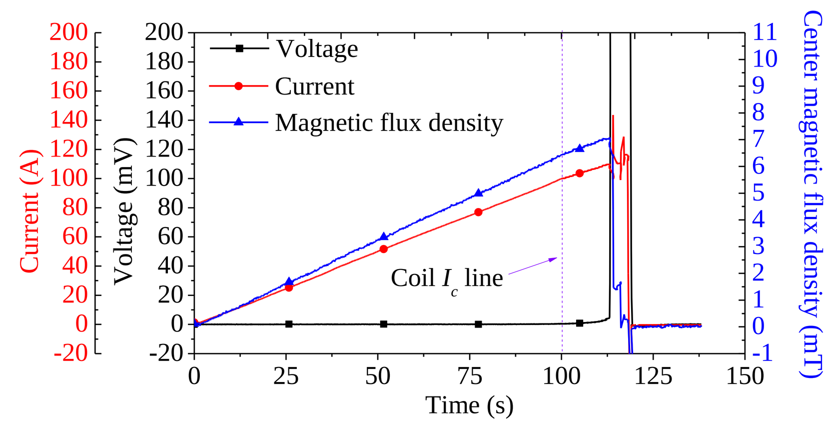
During the initial quench, there is little delay in the magnetic field due to partial current bypass.

OVERCURRENT CHARACTERISTICS OF SMART INSULATION COIL

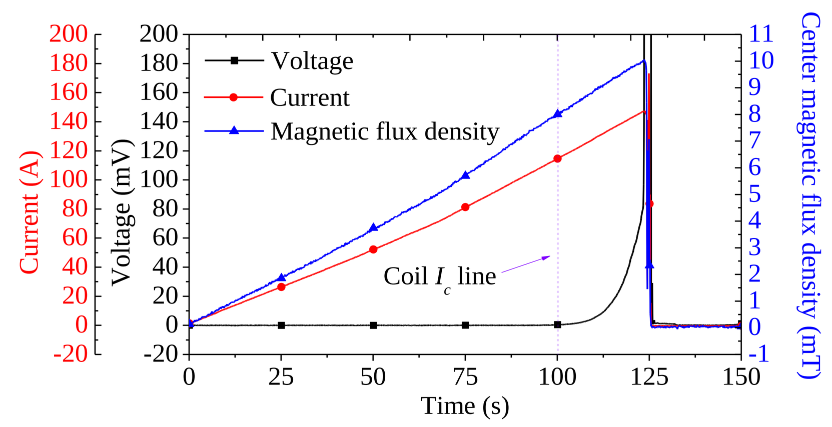
TABLE I
SPECIFICATIONS OF THE DESIGNED COIL

Parameters	Values
Superconducting wire	SCS4050-AP-M4
Width (mm)	4
Thickness (mm)	0.094
Wire I_c @ 77 K, self-field (A)	135.5
Inner diameter of coil (mm)	140
Turn number	8
Winding tension @ R. T (N)	40

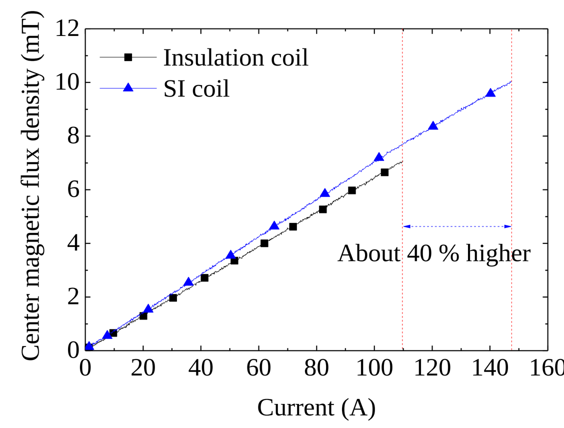




Insulation coil



Smart insulation coil

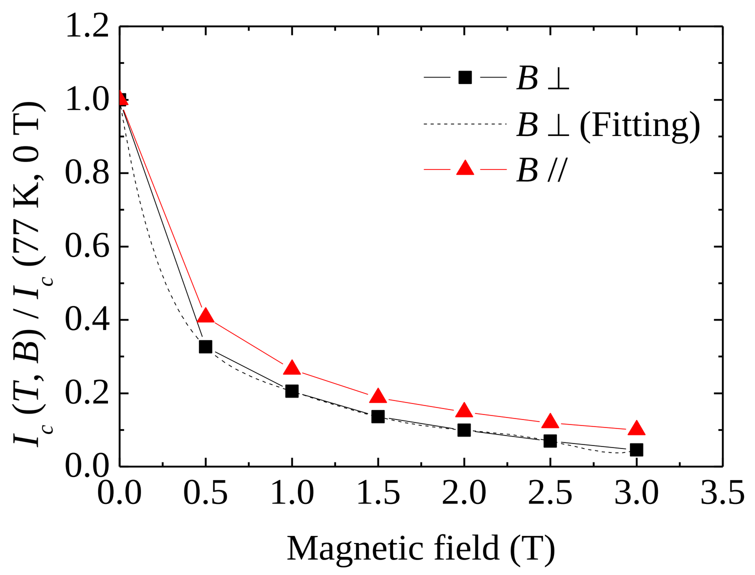


Comparison to B-I curve

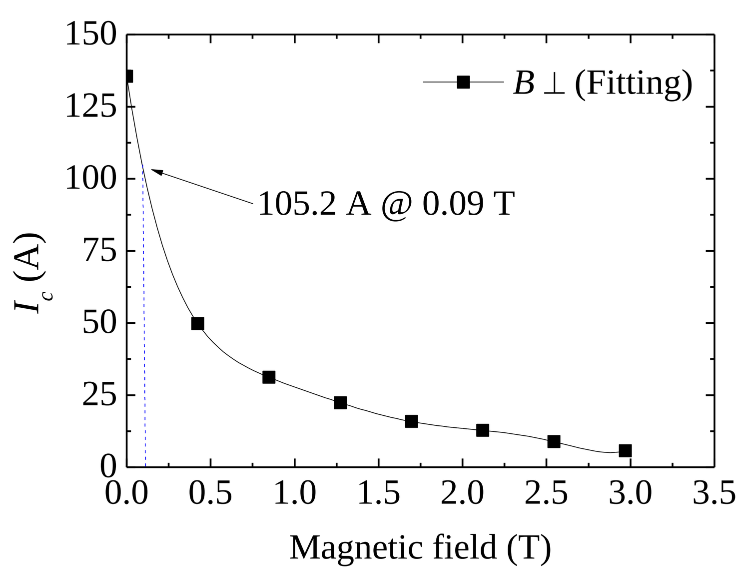
CALCULATION OF MAXIMUM OPERATING CURRENT

TABLE II
EXPERIMENTAL RESULT

Parameters	Insulation coil	SI coil
Coil I_c , μV/cm (A)	99.9	114.4
Center B @ 100 A (mT)	6.42	7.08
Center B_{max} (mT)	7.082 @ 109.8 A	10.05 @ 147.3 A

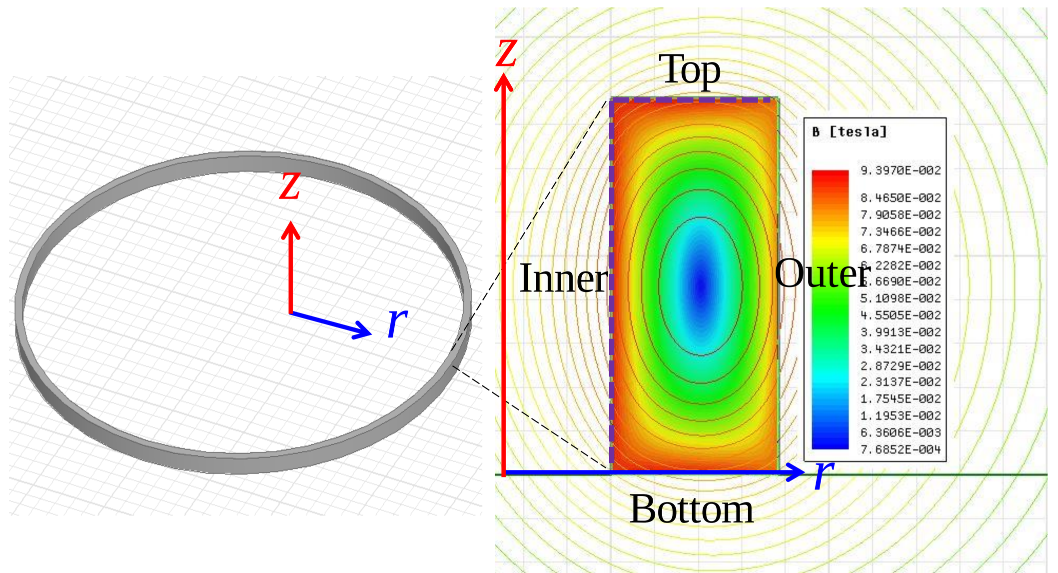


Normalized curve

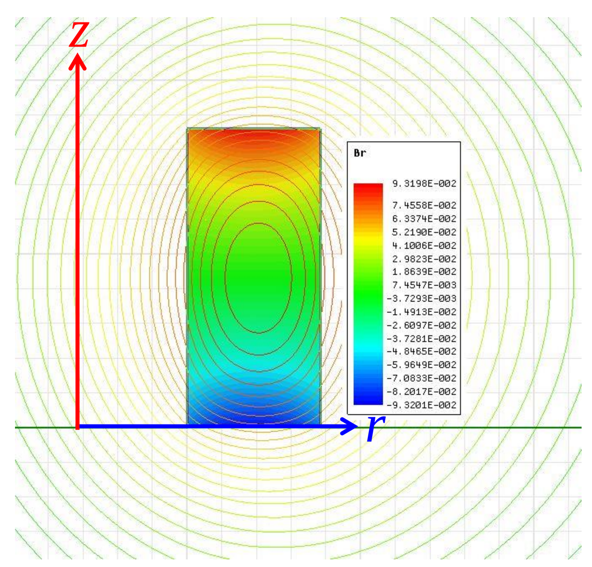


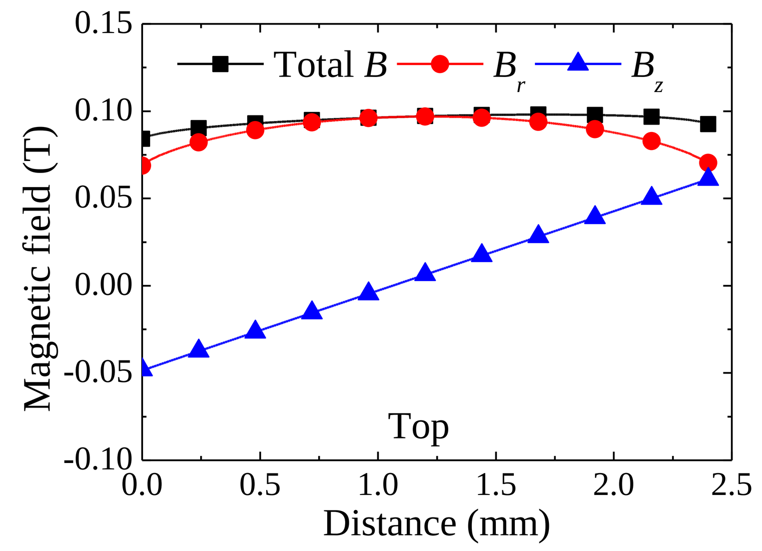
Multiplied value to normalized B⊥ and short sample I_c

Measured I_c-B curve at the 77 K of SCS4050-AP-M4 by Superpower



Measured I_c-B curve at the 77 K of SCS4050-AP-M4 by Superpower





Magnetic field distribution at the top surface of a B-radial direction

Flux distribution is calculated by with 2D analytic method. In order to analyze the magnetic field of the magnet using the Biot–Savart's law, its calculation has been performed by (1), and the Imax of the coil can be estimated based on the Ic-B data.

$$\vec{A} = \frac{\pi_0 I}{4\pi}\int_{-L}^{L}\frac{d\acute{r}}{\sqrt{(r'-r)^2+R^2}}\vec{a_r}.$$

$$\vec{B} = \nabla \times \vec{A} = \frac{1}{R}\frac{\partial A_r}{\partial \emptyset}\vec{a}_R - \frac{\partial A_r}{\partial R}\vec{a}_\emptyset.$$

where $\vec{A}$, L, R, $d\acute{r}$, $\vec{a_r}$, and π_0 are the magnetic vector po-tential due to a current I, Length of a HTS coil, radius, ele-ment of , direction vector of r and permeability of free space, respectively.