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Controllability of the contact resistance of 2G HTS coil with metal insulation

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BACKGROUND

- To apply to applications such as **superconducting field coil** for the rotating machine, magnet for the DC induction heating machine, big-sized HTS coils with **relatively rapid charging and discharging ramp rates**, **mechanical strength**, and some turn-to-turn resistance were needed to be robust. ➔ **MI coils: less stable than NI coils.**
- **NI coils**: low contact resistance ➔ long time to excite the coil.
- **Quenching** ➔ bypass current ➔ **Joule heating** ∝ **turn-to-turn contact resistance**.

OBJECTIVES

- **Advanced Metal Insulation** for enhancing the coil's thermal and electrical stability with relatively rapid charging and discharging rates than 2G HTS NI coils.

➔ Idea : Using **soft metal plated SS tape in MI coils**

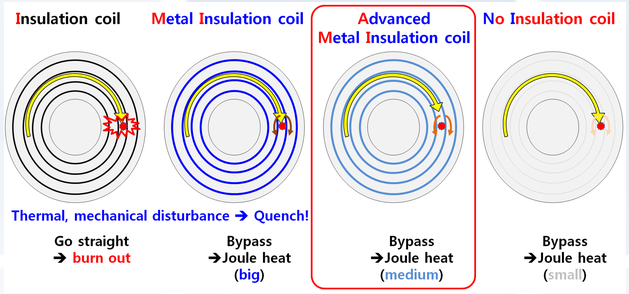


Fig. 1. Schematic diagram of four types of HTS coils.

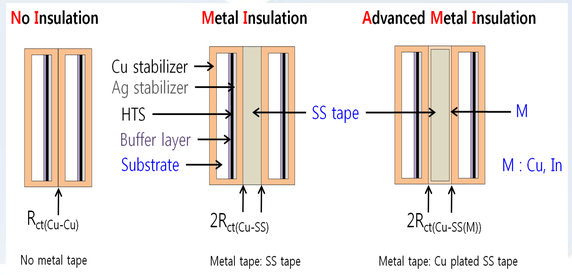


Fig. 2. Schematic cross-section view of three types of three types of HTS coils.

EXPERIMENTAL

A. Metal tapes and HTS tape

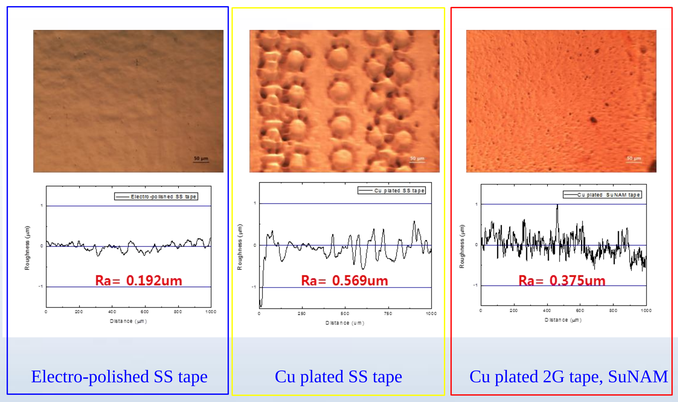


Fig. 3 Optical view and surface roughness of the surface of three types of tapes. **R_a:** center line average height

B. Preparation of Model coils

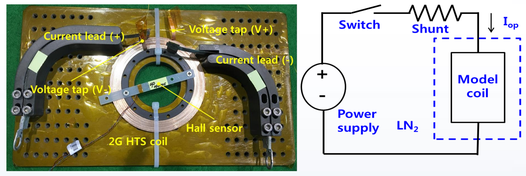


Fig. 4. Photo of model coils and measurement array, and schematic drawing of the test circuit

TABLE I
Specifications of three type of tapes

Type	Thickness [mm]	Width [mm]	Cu stabilizer [mm]	Ic [A]
2G HTS tape	0.138	4.04	18.7	>200
SS tape (310S)	0.106	4.00	-	-
Cu plated SS tape (310S)	0.144	4.10	17.3	-

CONCLUSIONS

- Contact surface resistances were measured
  - $R_{ct(Cu-Cu)}$: **6.3 μΩcm²** - $R_{ct(Cu-SS)}$: **362.4 μΩcm²** - $R_{ct(Cu-SS(Cu))}$: **7.9 μΩcm²**
- **Dramatically reduction** of turn-to-turn contact surface resistance in model coil (MI50-SS(Cu))
- Possibility of changing the contact surface resistance is proved
- **Controllability of contact surface resistance will be useful for designing the MI magnet**

RESULTS

A. I-V characteristics

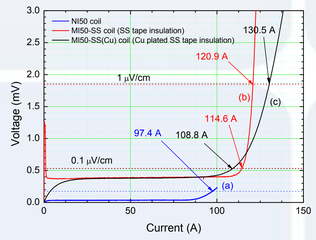


Fig. 5. I-V characteristic curves of three types of model coils. (a) NI50 coil, (b) MI50-SS coil, (c) MI50-SS(Cu) coil

B. Contact resistance

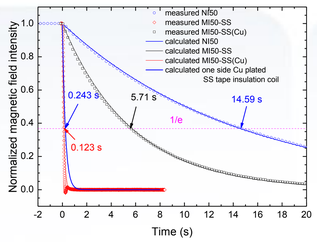
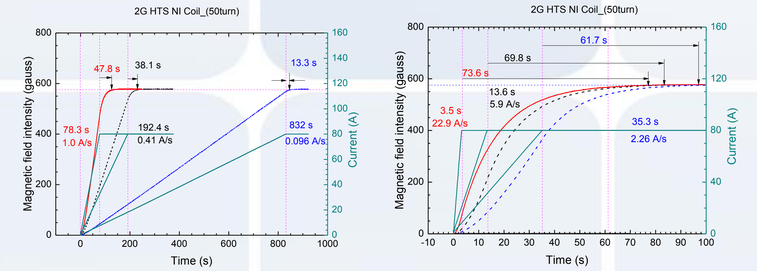


Fig. 6. Variation of normalized magnetic field intensity in three models. Symbol: experimental, line : calculated

C. Charging tests



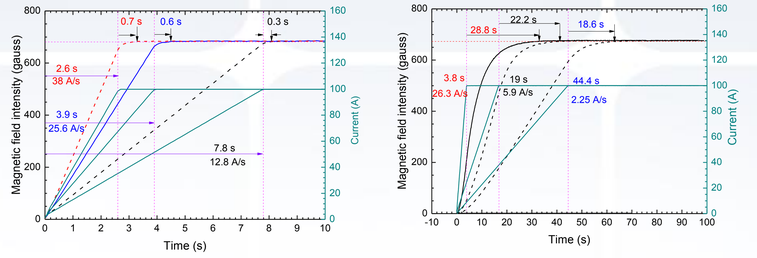


Fig. 7 Magnetic field intensity-time curves of three models with respect to current ramping rate

✓ From the measured decay time constants, the characteristic resistances of the three coils as calculated by equation

$$R_c = \frac{L_{coil}}{\tau}.$$

✓ Characteristic resistance R_c, for the NI coils,

$$R_c = \sum_{i=1}^{N_t-1} R_i = \sum_{i=1}^{N_t-1} \frac{R_{ct}}{2\pi r_i w_d}$$

✓ Since the MI coils have two boundaries between turn-turns, characteristic resistance R_c, for the MI coils,

$$R_c = \sum_{i=1}^{2(N_t-1)} R_i = \sum_{i=1}^{2(N_t-1)} \frac{R_{ct}}{2\pi r_i w_d}$$

R_{ct}: contact surface resistance, N_t: total number of turns, w_d : width of 2G HTS tape.

TABLE II
Specifications of three model coils

Type	NI50	MI50-SS	MI50-SS(Cu)
2G HTS tape	SuNAM	SuNAM	SuNAM
Metal tape	-	SS 301S	Cu plated SS 310S
i.d./o.d. [mm]	80/93.8	80/104.4	80/108.2
Length [m]	13.6	14.5	14.8
No. of turns	50	50	50
Inductance [μH]	411.1	376.0	373.5
Characteristic resistance R_c [μΩ]	28.18	3057	65.42
Decay time constant (τ) [s]	14.59	0.123	5.71
Critical current [A]*	97.4	114.6	108.8
Contact surface resistance R_{ct} [μΩcm²]	6.3	362.4	7.9
Turn-to-turn contact surface resistance R_{ct} [μΩcm²]	6.3	724.8	15.8

* Criteria: 0.1 mV/cm