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# HTS Magnet with Smart Insulation Method

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## Background

- When the normal zone occurs in the HTS wire → generate heat → the temperature rises → increase resistance

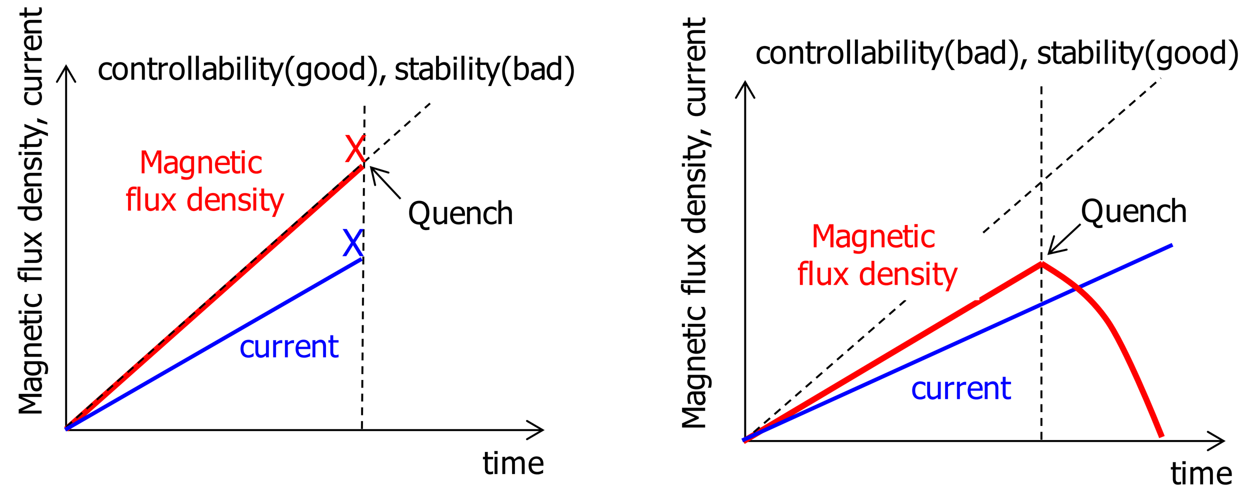
  LTS wire : normal zone increases rapidly → possible to detect → commercialized

  HTS wire : normal zone slowly increases → Burns before detecting → Not yet

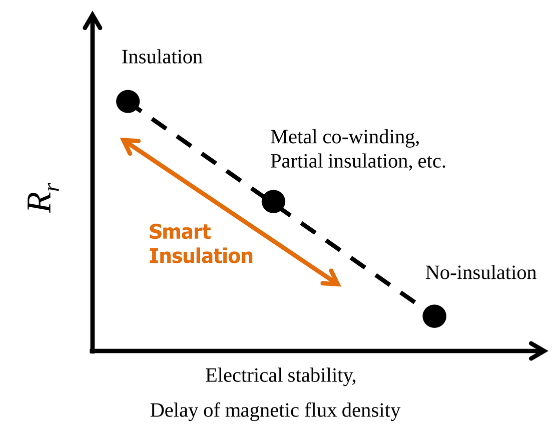
## Objectives

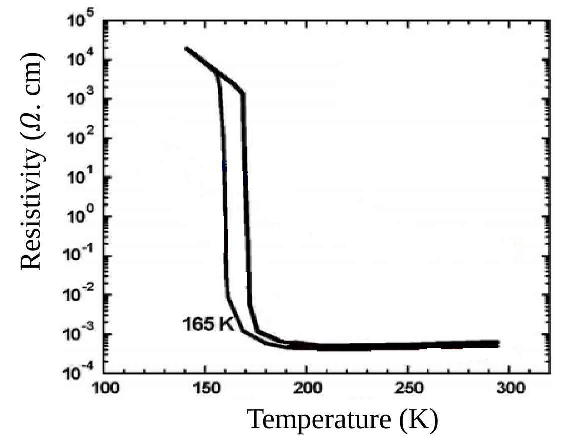
- This research proposes an advanced method to meet both an stability and controllability requirements of HTS magnets. It is a **Smart Insulation method**.
- Experimentally verified that the advantages of both the insulation magnet(in a normal state) and the no-insulation magnet(during quenching).

## Smart insulation



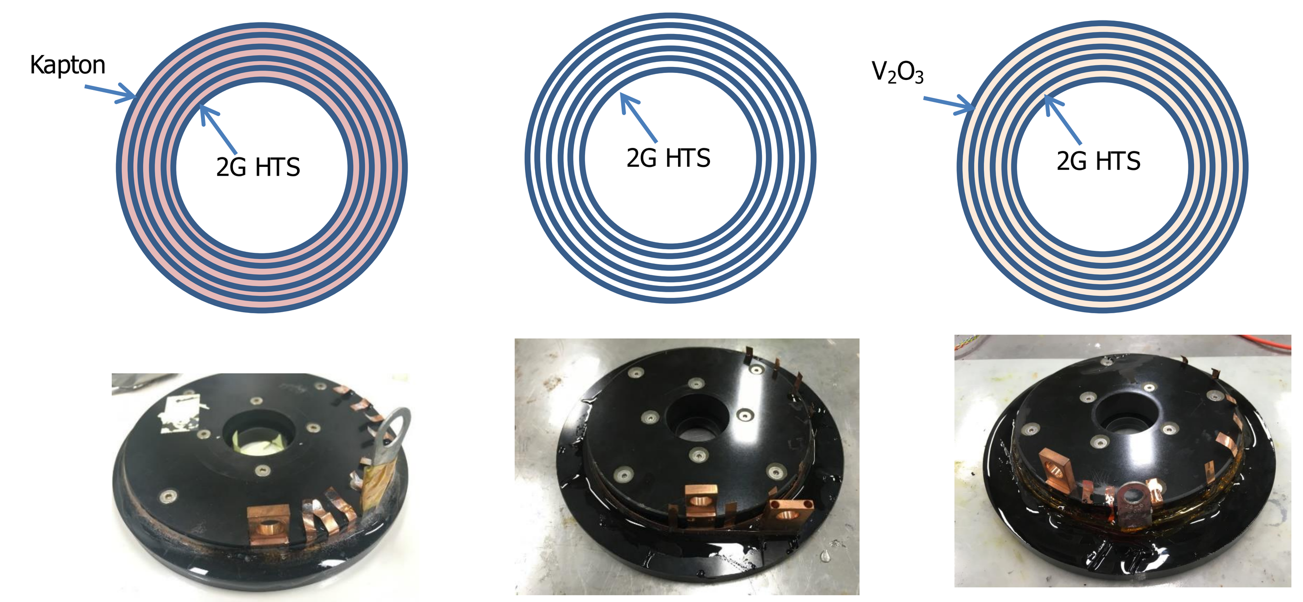

- Since the insulation coil has electrical insulation between the turns, it does not have current bypass. Thus, the number of coil turns remains the same, and there is no output magnetic field reduction. However, they burn during quenching process in most cases.
- In coils with no-insulation, it is difficult to maintain the number of turns because there is no electrical insulation between the turns. Therefore, the output magnetic field decreases. However, even during quench, if a very large current flows using the current bypass, they do not burn.



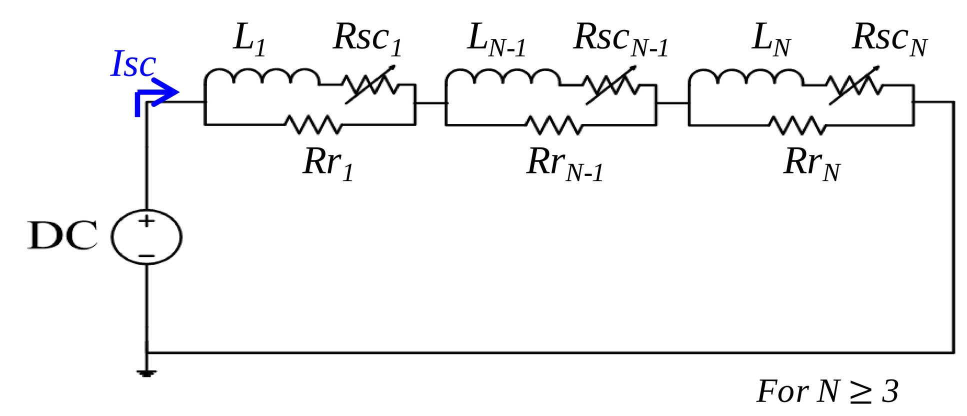




- The SI method implies that the resistance value between the turns of the coils remains similar to that of the insulation coils, but changes rapidly into a low resistance value similar to that of no-insulation coils when heat is generated after a quench.

## Experimental setup




Insulation coil No-insulation coil Smart insulation coil




- To compare the new SI method proposed in this research against the existing insulation and no-insulation methods, three coils were fabricated.

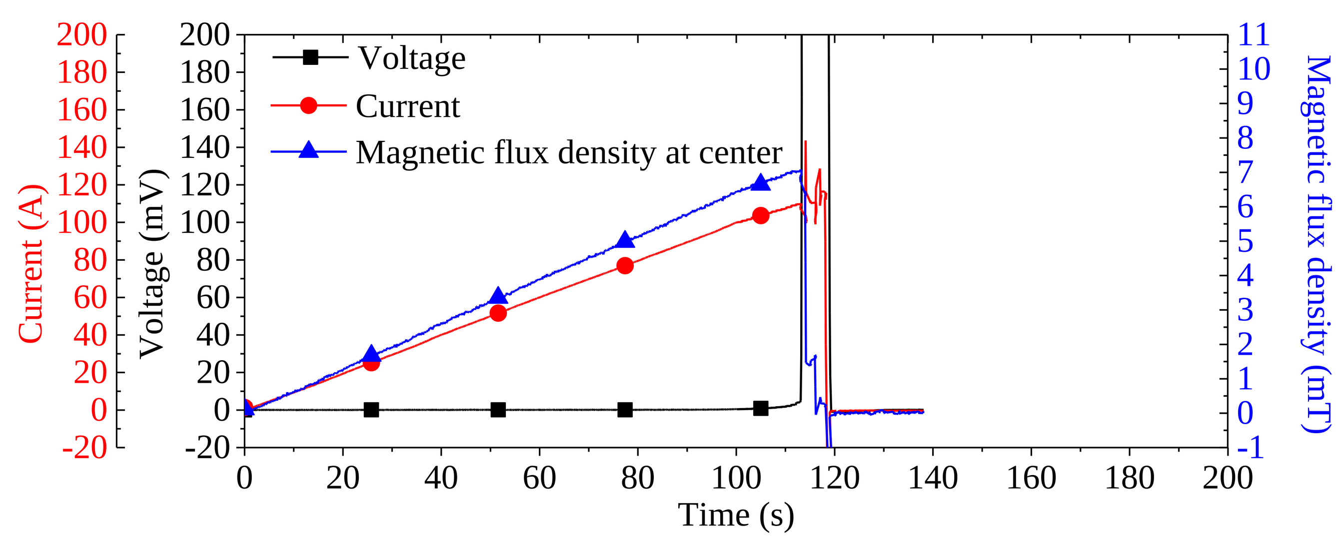
## Conclusion

- The coil with no-insulation presented the highest Ic value, but the SI coil presented a maximum output magnetic field value, which was about 30% higher than that of the coils with insulation and no-insulation.
- The output magnetic field characteristics of the 2G HTS coil with SI method are somewhat similar to those of the coil with insulation below the coil's Ic value, and similar to those of the coil with no-insulation above the coil's Ic value.

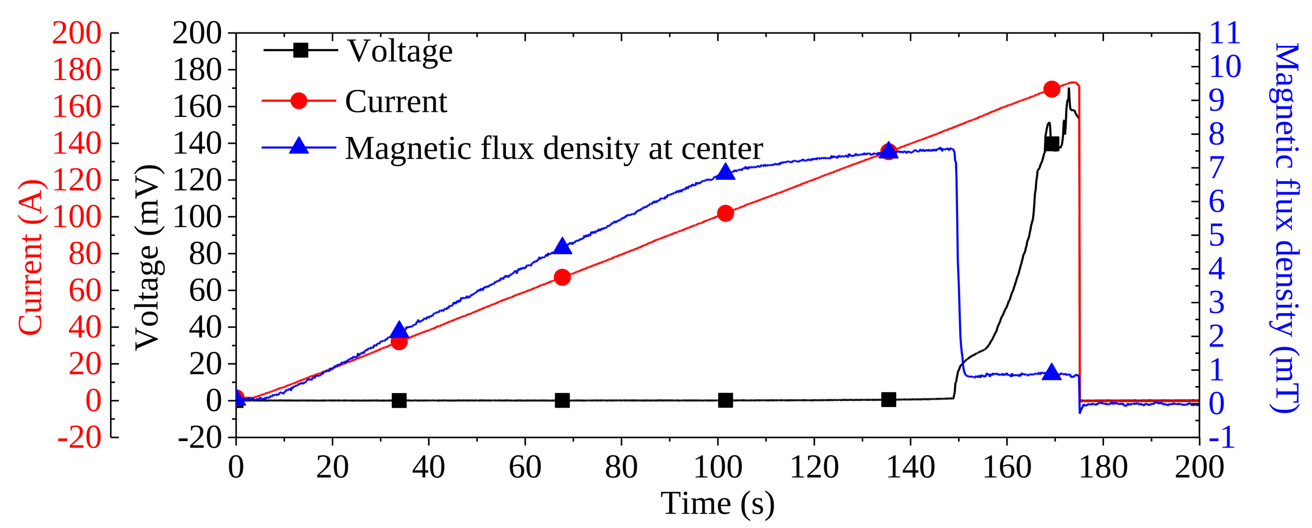
  → It is expected that, if the 2G HTS tape used in the SI coil is coated with a thinner film of $V_2O_3$ (thereby reducing the thickness by several μm), and the stabilizer thickness is made thinner, more current would bypass (compared to the test observations) after exceeding the SI coil critical current.

## Results

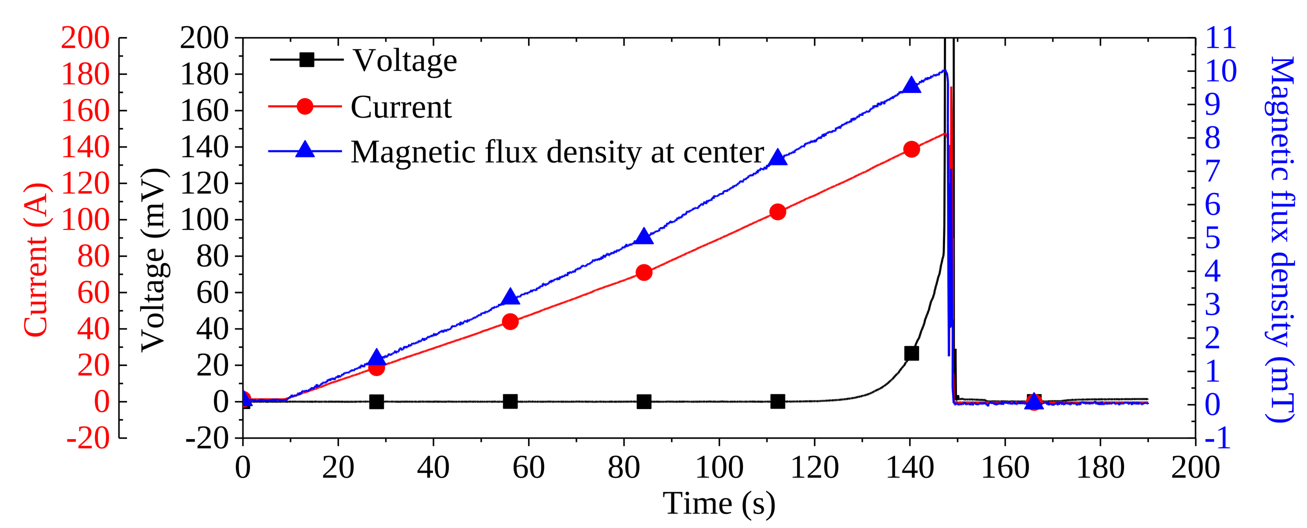
### Overcurrent test results three coils




Insulation coil



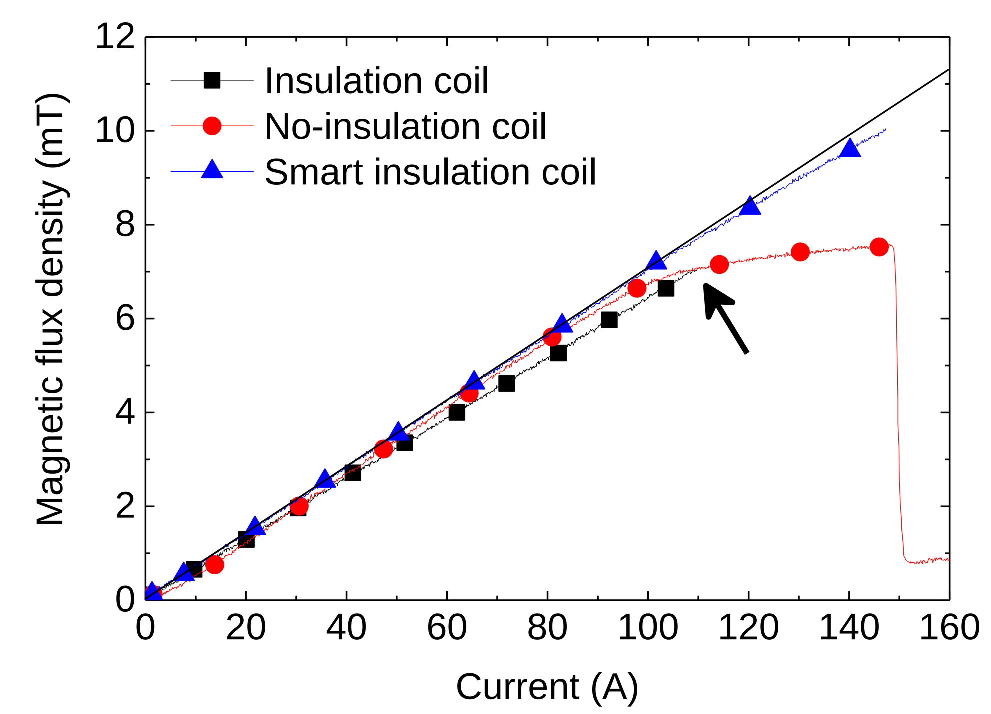

No-insulation coil




Smart insulation coil

- The insulation coil generated a magnetic field of 7.1 mT at 109.8 A. No changes in the output magnetic field slope was observed as a result of the input current until the coil was burned.
- The coil with no-insulation generated a magnetic field of 7.5 mT at 148.6 A. Above 100 A, the output magnetic field slope lowered. This happened because inside the coil, the current bypass occurred partially, lowering the number of the valid turns of the coil. Since the total number of coil turns was low, the inductance was also low, and no time delay was observed. The coil burned after 148.6 A.
- The SI coil generated a magnetic field of 10.1 mT at 147.3 A.
- The output magnetic flux density of each coil at 100 A of input current is 6.4 mT (insulation coil), 6.7 mT (no-insulation coil), and 7.1 mT (SI coil), respectively.
- The maximum output magnetic flux density of the coils were 7.1 mT at 110 A (insulation coil), 7.5 mT at 148.6 A (no-insulation coil), and 10.1 mT at 147 A (SI coil).

### Characteristics of Magnetic flux density




- Characteristics of SI coil similar to those of the insulation coil, it endured a higher current than the insulation coil, and generated a magnetic field higher than the no-insulation coil.
- The slope of SI coil's magnetic flux density changed slightly at the vicinity of the coil's Ic value.