# Investigation on Thermal and Electrical Characteristics of $MgB_2$ Magnet Using Partial-Insulation Winding Technique


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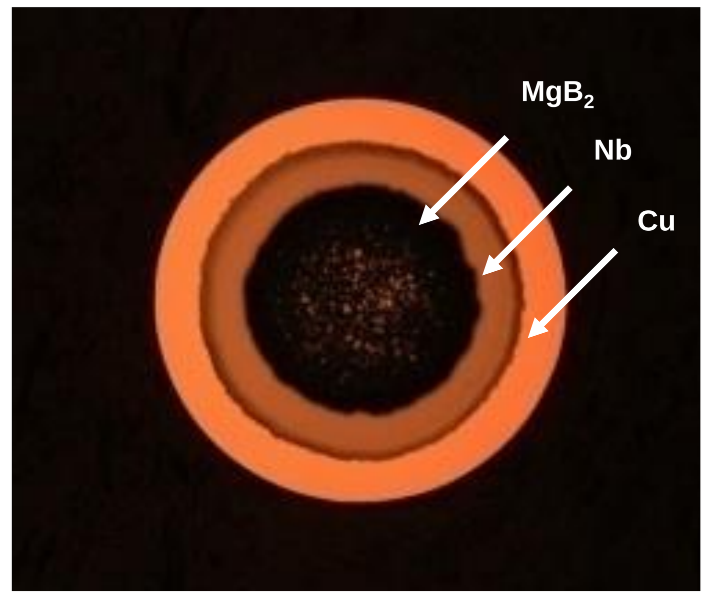
## Abstract

It is generally agreed that the development of a self-protective $MgB_2$ magnet may not be achieved because of the slow normal-zone propagation velocity of the $MgB_2$ wires, compared to their low-temperature superconductor counterparts. However, the use of the no-insulation (NI) winding technique can allow the $MgB_2$ magnet to be self-protecting, because the excessive heat and current generated by local quenching can be automatically bypassed through the uninsulated turns. Nevertheless, to utilize the NI winding technique for large-scale superconducting magnets such as whole-body MRI magnets, it is essential to ameliorate the charging/discharging delays observed in the NI windings. As an alternative solution, this study examines a partially insulated (PI) $MgB_2$ magnet that employs layer-to-layer insulations only, in the absence of turn-to-turn insulations. A monofilament $MgB_2$ wire manufactured by Kiswire Advanced Technology Co. Ltd., was used for the fabrication of the PI $MgB_2$ magnet. The charge-discharge and over-current characteristics of the PI $MgB_2$ magnet were investigated to demonstrate the feasibility of employing the PI winding technique to develop a self-protective $MgB_2$ MRI magnet with fast charging/discharging rates.


## Experimental setup

### ★ $MgB_2$ wires




< Optical microscope image of the $MgB_2$ wire fabricated by KAT Ltd. >

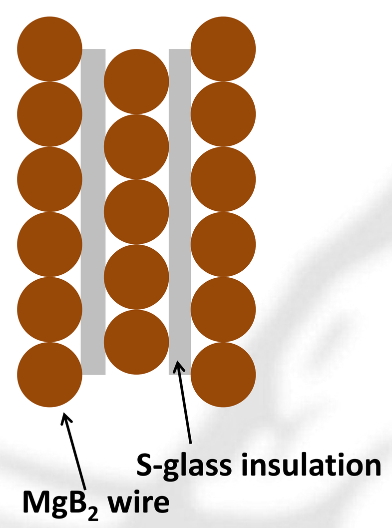
< Specifications of $MgB_2$ wire >

| Parameters | | Values |
|---|---|---|
| Company | | Kiswire Advanced Technology |
| Packing density | [g/cm³] | 0.31 |
| Diffusion barrier | | Niobium |
| Stabilizer | | Copper |
| Filament type | | Monofilament |
| Diameter | [mm] | 1.03 |
| Condition | | Un-reacted |
| Non-Sc/Sc | | 2.09 |
| Heat treatment temperature | [ºC] | 675 |
| Heat treatment time | [hr] | 1 |
| $I_c$ @ 4.2 K, 4 T | [A] | 283 |
| $I_c$ @ 4.2 K, 5 T | [A] | 138 |
| $I_c$ @ 4.2 K, 6 T | [A] | 66 |

### ★ Prototype PI $MgB_2$ magnet

< Specifications of the prototype PI $MgB_2$ magnet >

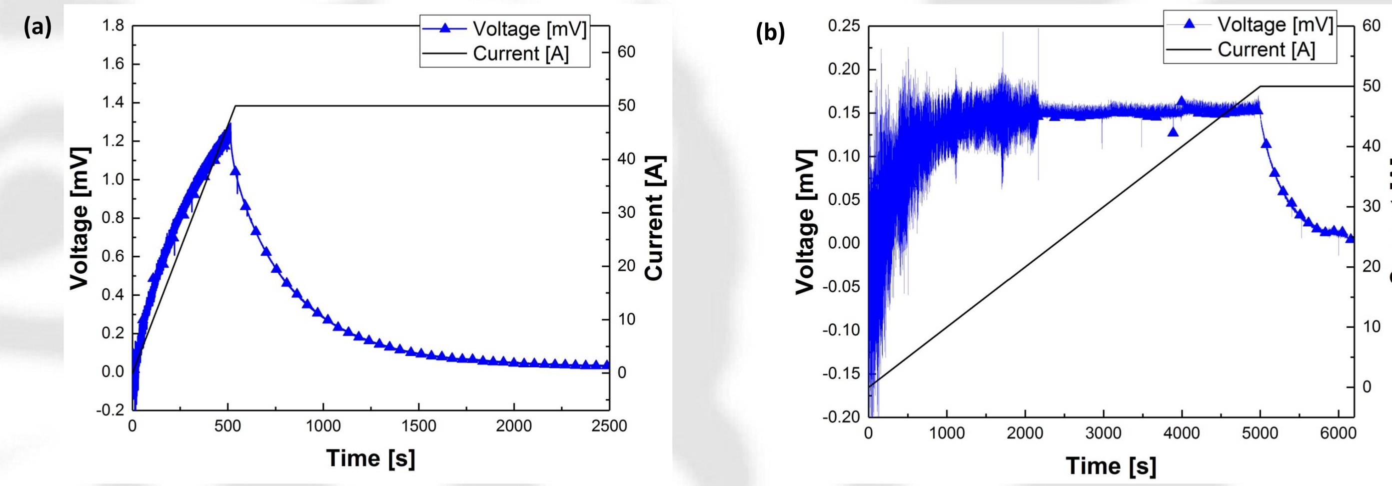
| Parameters | | Values |
|---|---|---|
| *Conductor* | | |
| Material | | $MgB_2$ |
| Diameter | [mm] | 0.98 |
| Manufacturer | | K.A.T |
| *Magnet* | | |
| Inner diameter | [mm] | 52.74 |
| Outer diameter | [mm] | 71.24 |
| Total height | [mm] | 100 |
| Turns; Layers | | 97; 8 |
| Total conductor length | [m] | 145.5 |
| Operating temperature | [K] | 4.2 |
| Coil constant | [mT/A] | 8.16 |
| Inductance | [mH] | 15.55 |



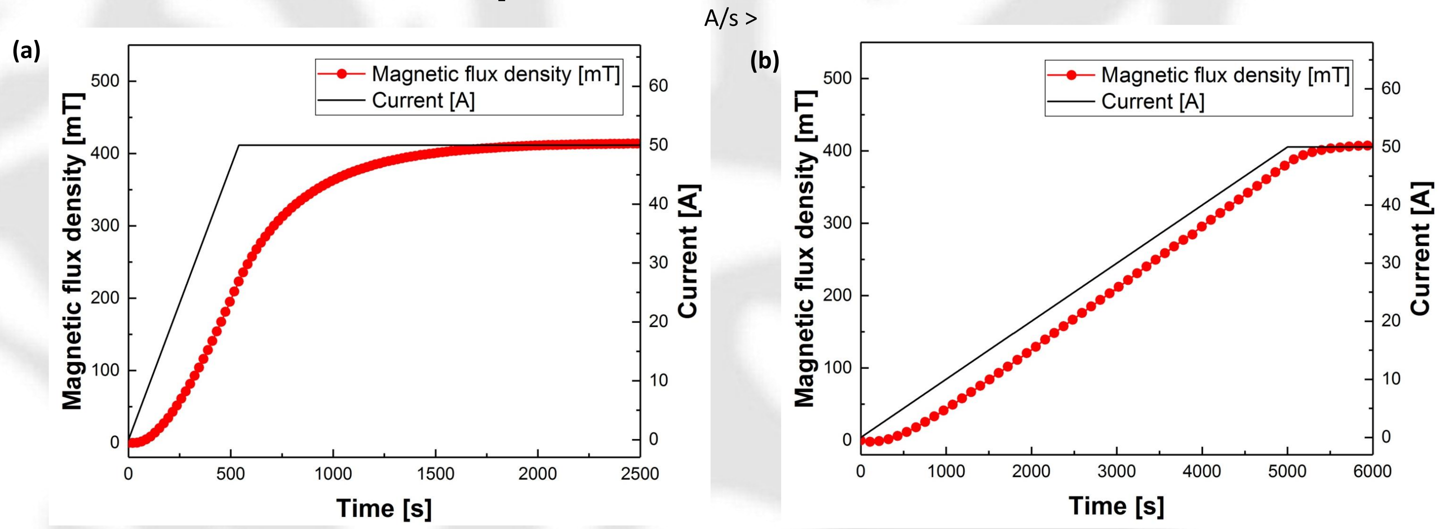

< Fabrication details for the prototype PI $MgB_2$ magnet >

## Results & discussion

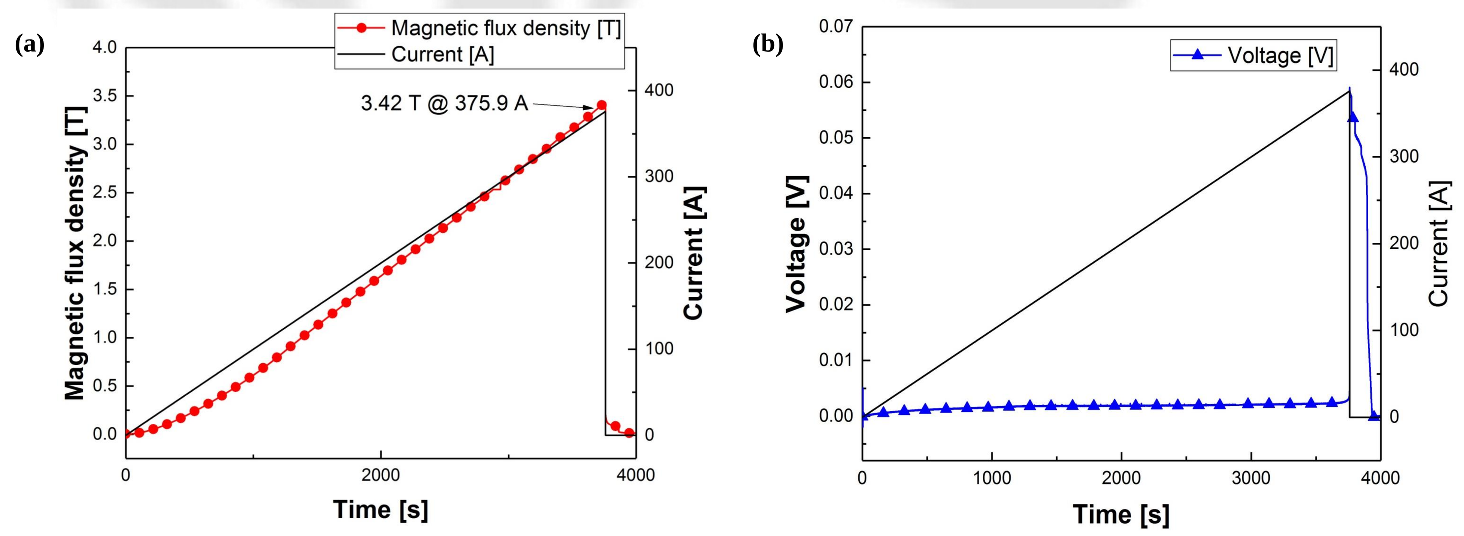
### ★ Test results for PI $MgB_2$ magnet



< Voltage for the prototype PI $MgB_2$ magnet measured during the charge-discharge test at: (a) 0.1 A/s and (b) 0.01 A/s >

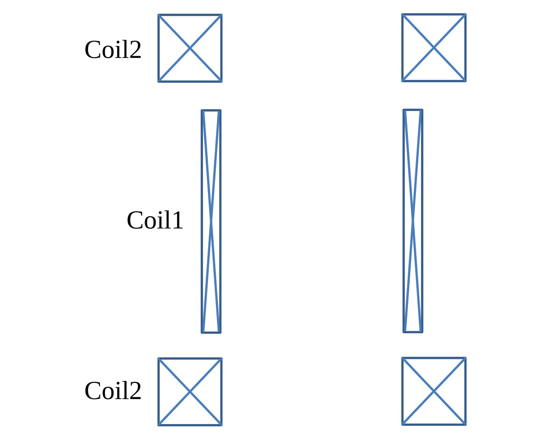


< Magnetic flux density for the prototype PI $MgB_2$ magnet measured during the charge-discharge test at: (a) 0.1 A/s and (b) 0.01 A/s >




< Magnetic flux density (a) and voltage (b) for the prototype PI $MgB_2$ magnet measured during the over-current test >

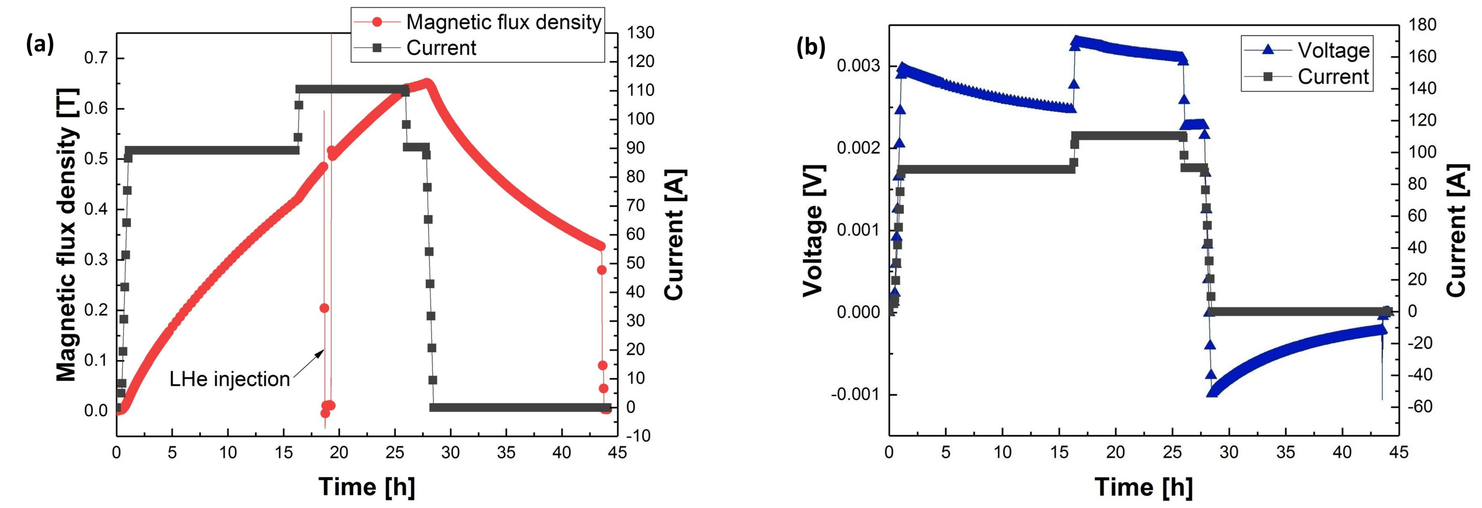
### ★ 0.5-T/300-mm PI $MgB_2$ magnet



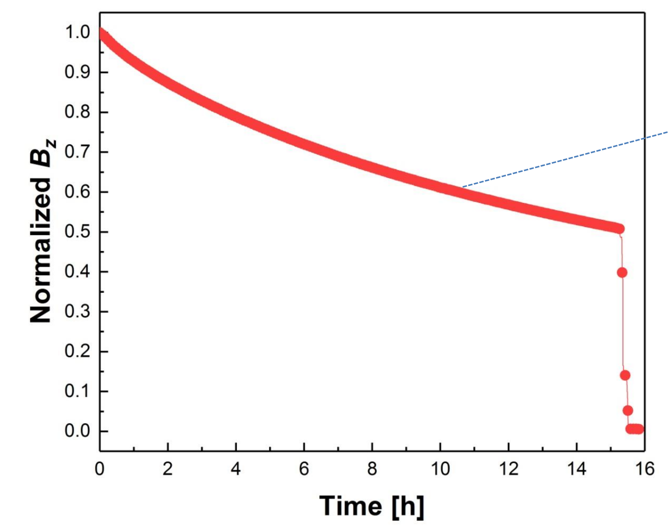

< Schematic drawing of the 0.5-T/300-mm $MgB_2$ magnet >

< Specifications of the 0.5-T/300-mm $MgB_2$ magnet >

| Parameters | | Coil1 | Coil2 |
|---|---|---|---|
| Inner diameter | [mm] | 300 | |
| Outer diameter | [mm] | 309.16 | 335.23 |
| Height | [mm] | 199.5 | 76.6 |
| Turns per layer | | 199 | 76 |
| Layers | | 4 | 16 |
| Number of coils | | 1 | 2 |
| Operating current | [A] | 89.3 | |
| Coil constant | [mT/A] | 5.6 | |
| Coil inductance | [H] | 2.11 | |




< Magnetic flux density (a) and voltage (b) for the 0.5-T/300-mm PI $MgB_2$ magnet >



< Sudden discharge test results for the 0.5-T/300-mm PI $MgB_2$ magnet >

$$B(t) = B(t_0)e^{-(R_c/L)t}$$

$$R_c = 2.6\times10^{-5}\,\Omega$$

$$\tau = L/R_c = 81153\ \text{s} = 22.54\ \text{h}$$

$$5\tau = 112.7\ \text{h}$$

**Requires ~ 5 days for charging the 0.5-T/300-mm PI $MgB_2$ magnet!**