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# Progress Report on Superconducting Joint Technique for the Development of $MgB_2$ MRI Magnet

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Aug. 31, 2017

# Contents

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I. Introduction

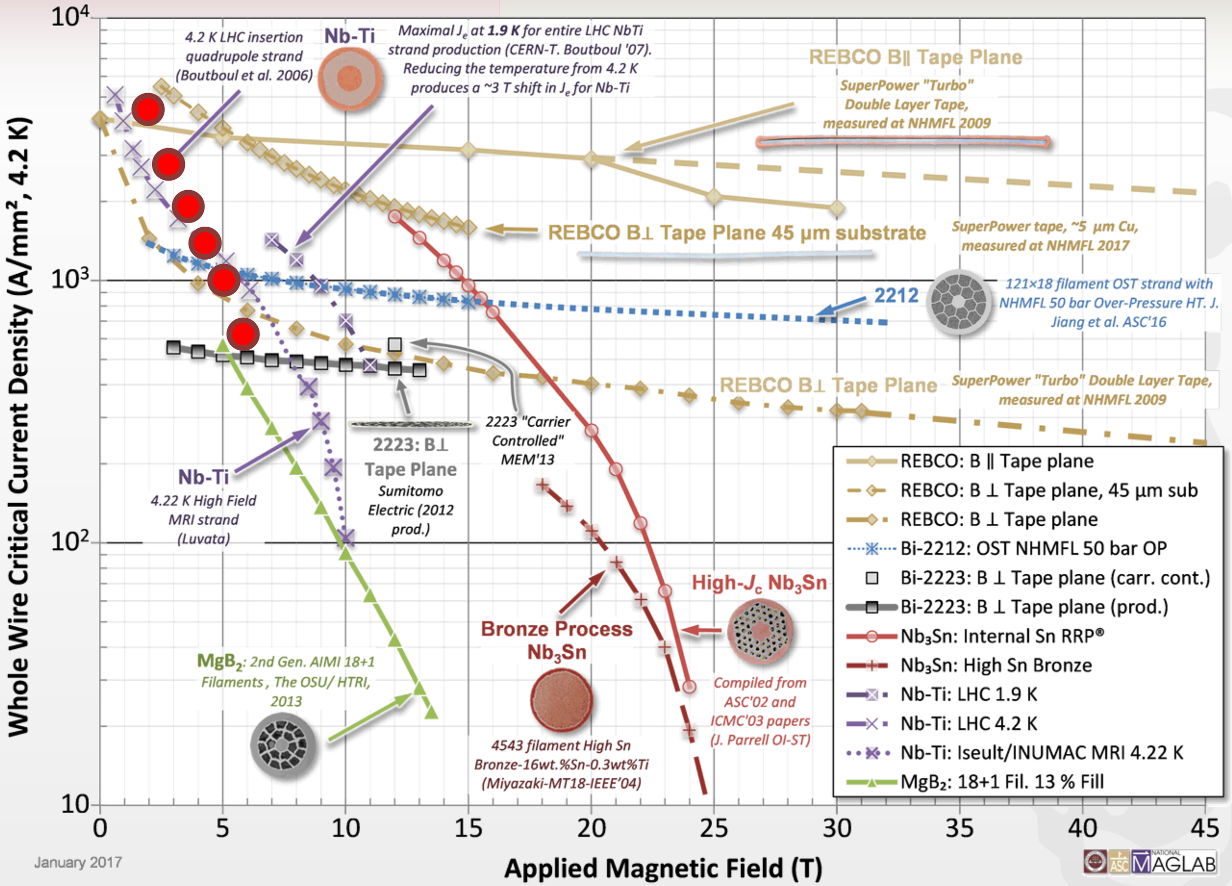
II. Stress & thermal analyses – validation for joint mold

III. Experimental results for $MgB_2$ joints

IV. Conclusion

# Introduction





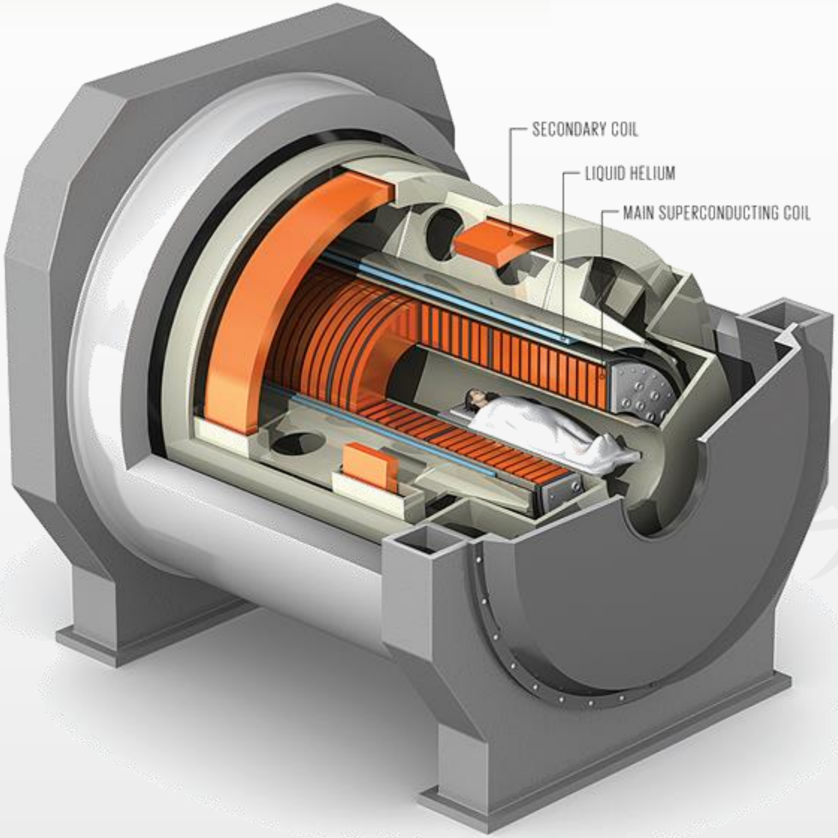

- High $J_e$ in low field (> 5 T)
- Liquid helium-free


*Ref: 1. http://fs.magnet.fsu.edu/~lee/plot/plot.htm

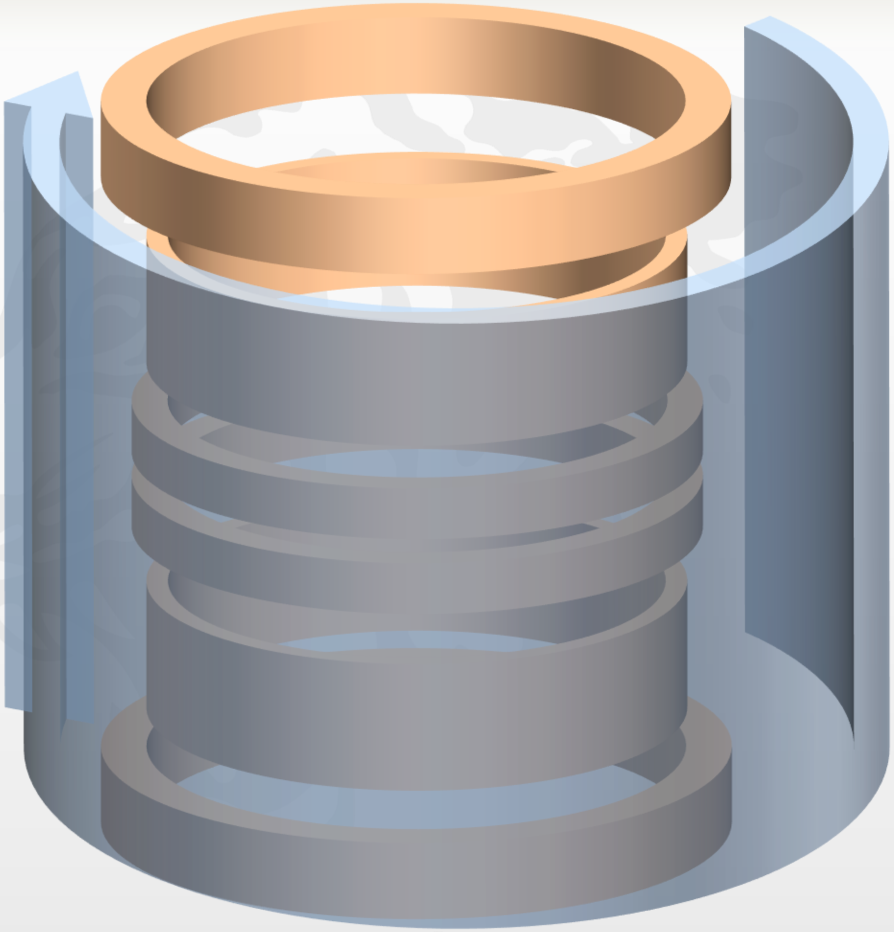
2. Guangze Li et al. "Transport critical current densities and n-values of multifilamentary $MgB_2$ wires at various temperatures and magnetic fields", IEEE Transactions on Applied Superconductivity, vol. 24, no. 3, 6200105 (2014).

# Introduction






*Ref: P. Vedrine et al. "The Whole Body 11.7 T MRI Magnet for Iseult/INUMAC Project", IEEE Transactions on Applied Superconductivity, vol. 18, no. 2, p. 868 (2008)



Persistent current

# Stress & thermal analyses

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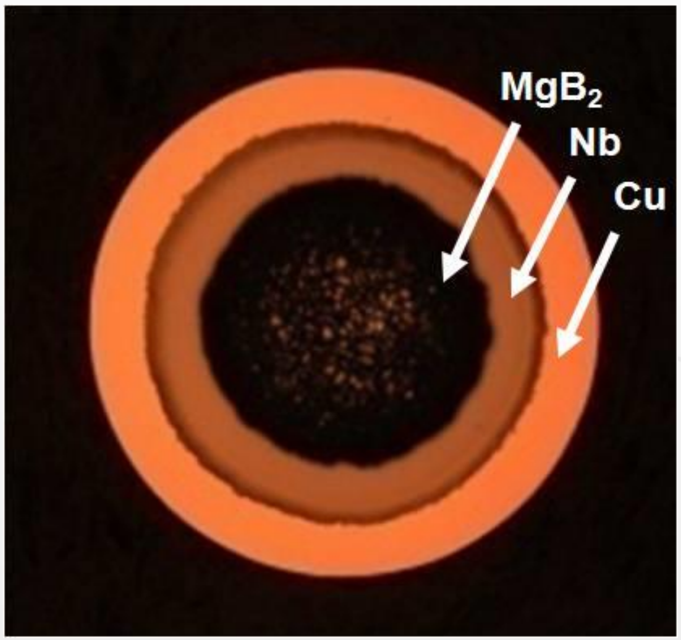
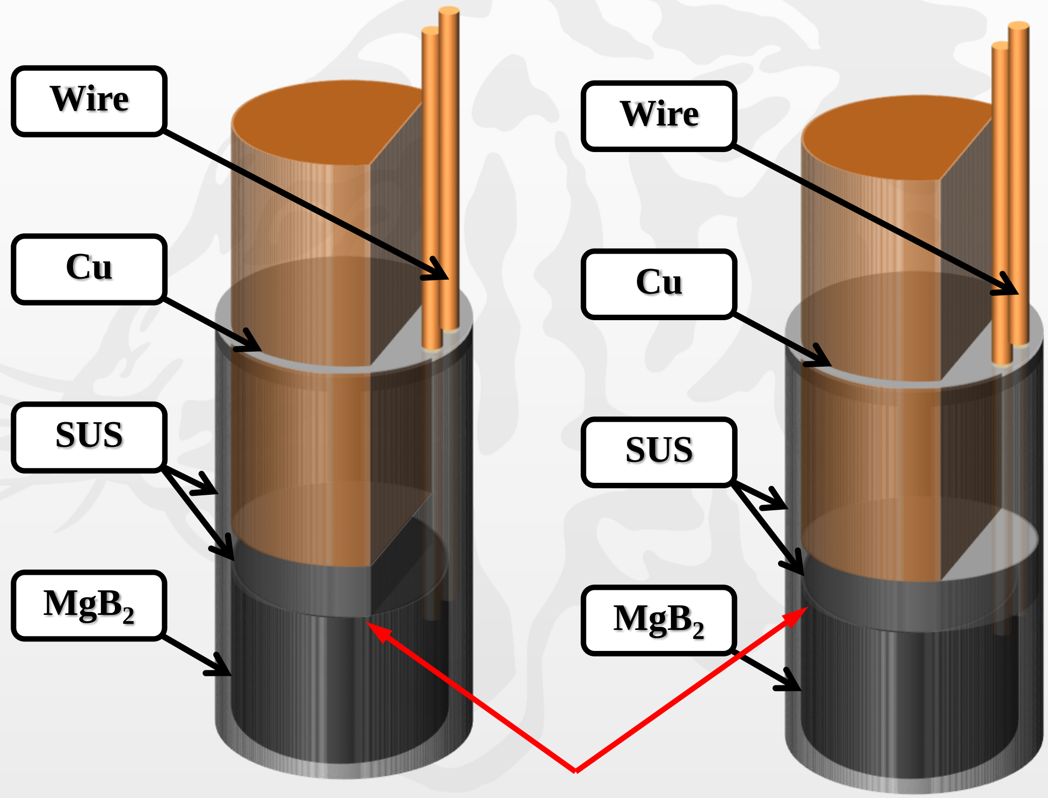
- Mold for the $MgB_2$ joint




<Cross-sectional view of the mono-filament $MgB_2$ wire manufactured by KAT Co., Ltd.>




Change in shape of SUS plate

# Stress & thermal analyses

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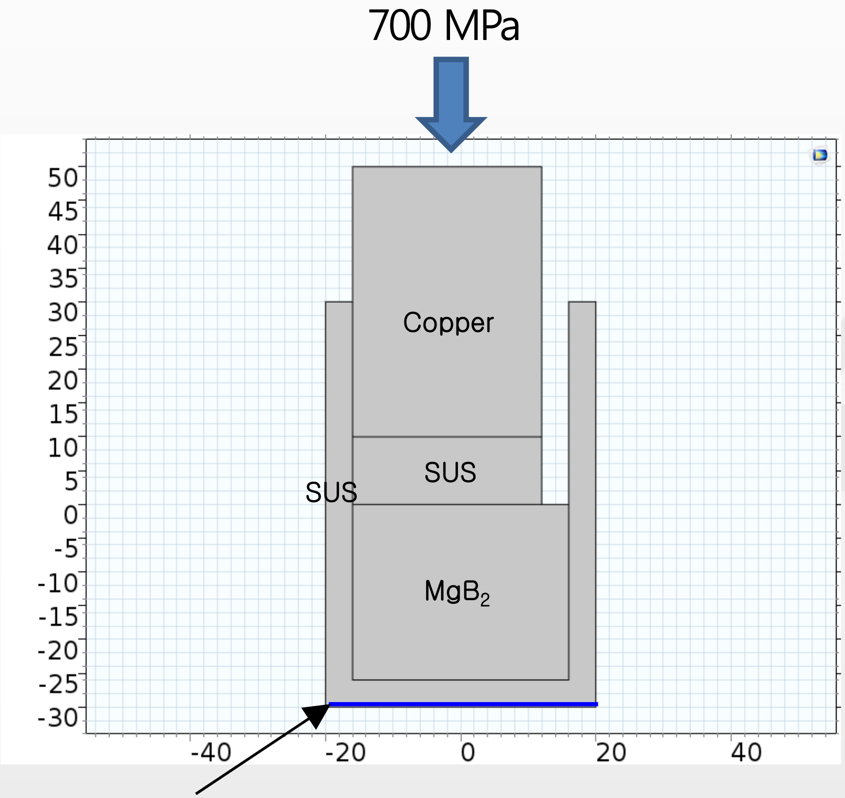
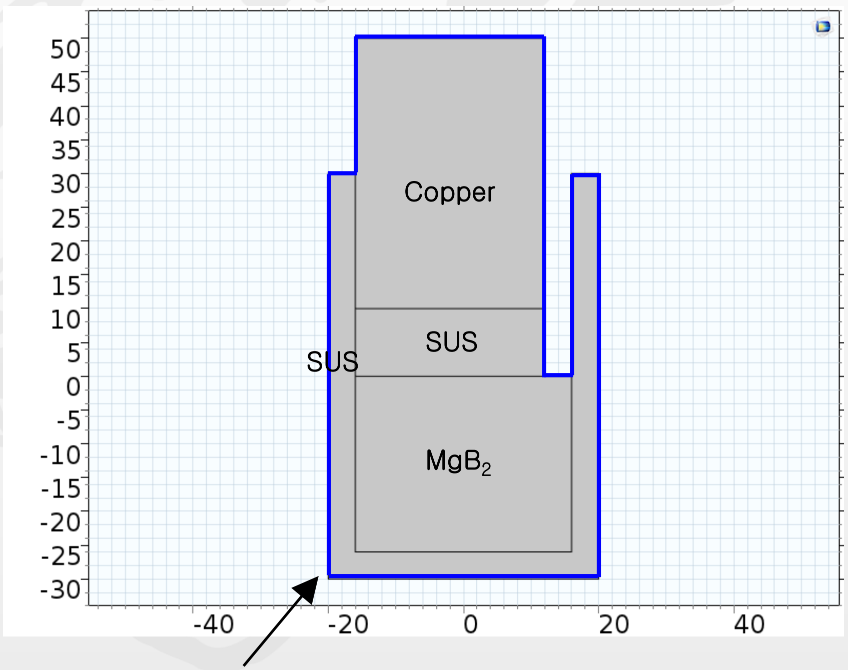
- **FEM model for stress & thermal analyses**




Fixed constraint

<Stress analysis>

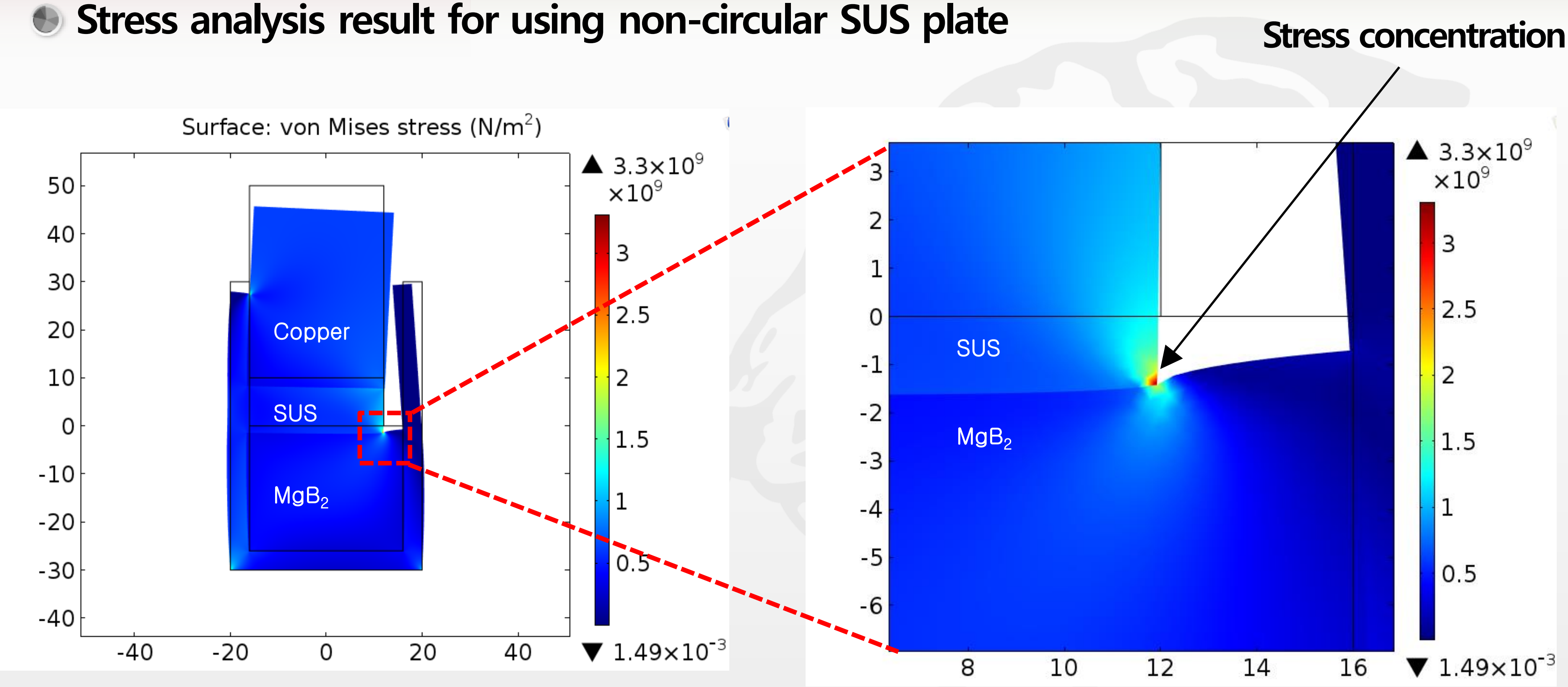



T = 293.15 + (5/60)*t*(t<=8100) +675*(t>8100)[K]

<Thermal analysis>

# Stress & thermal analyses

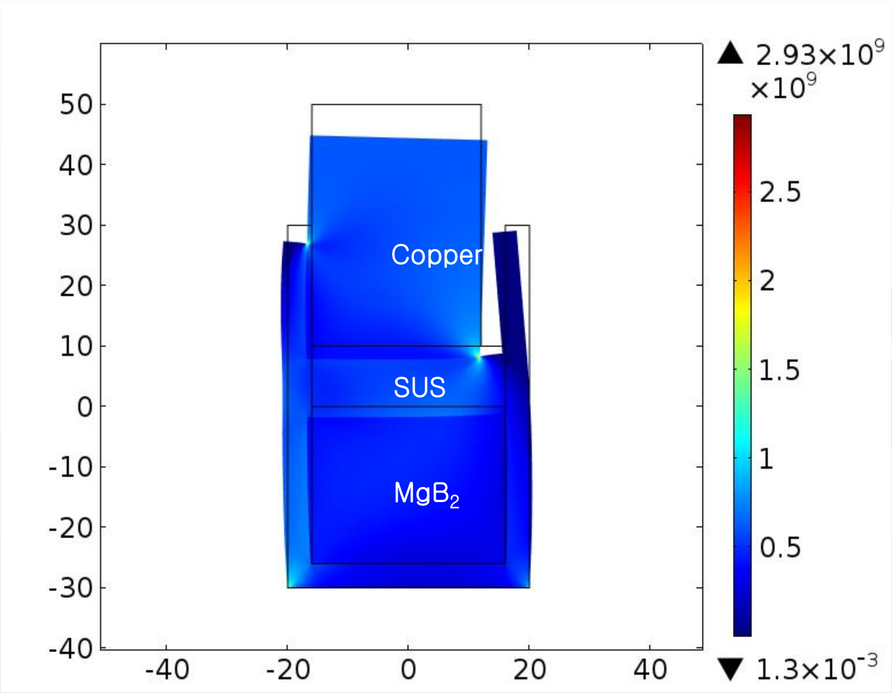
- **Stress analysis result for using non-circular SUS plate**

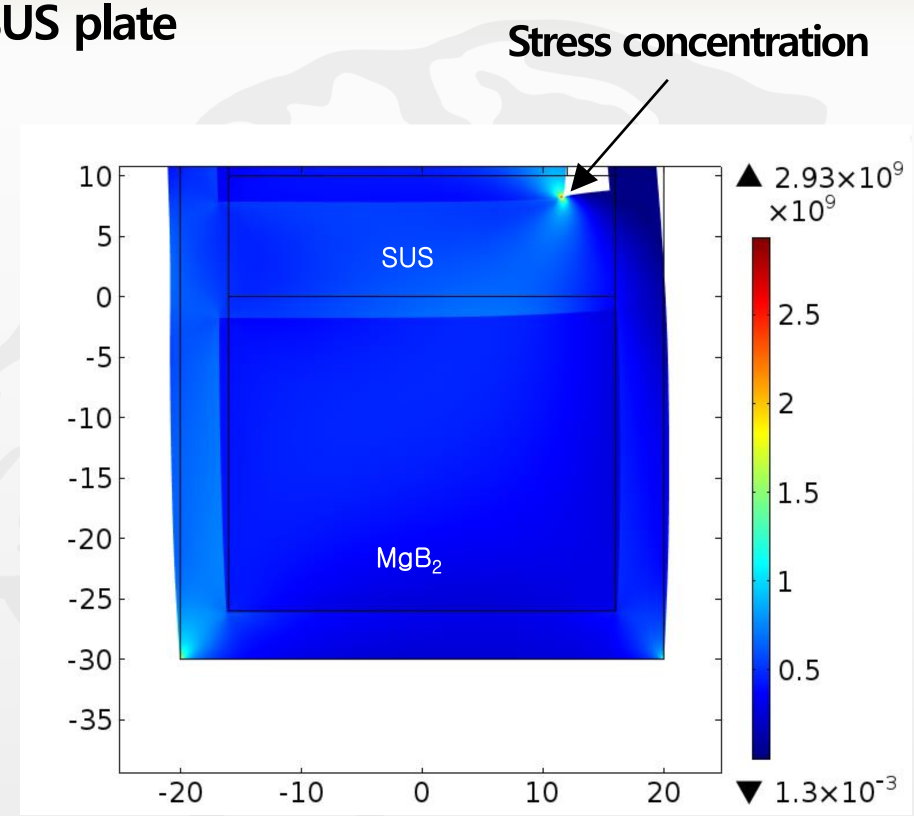



**Stress concentration occurs at $MgB_2$ powder**

# Stress & thermal analyses

- **Stress analysis result for using circular SUS plate**




**Stress concentration occurs at SUS plate**

# Stress & thermal analyses

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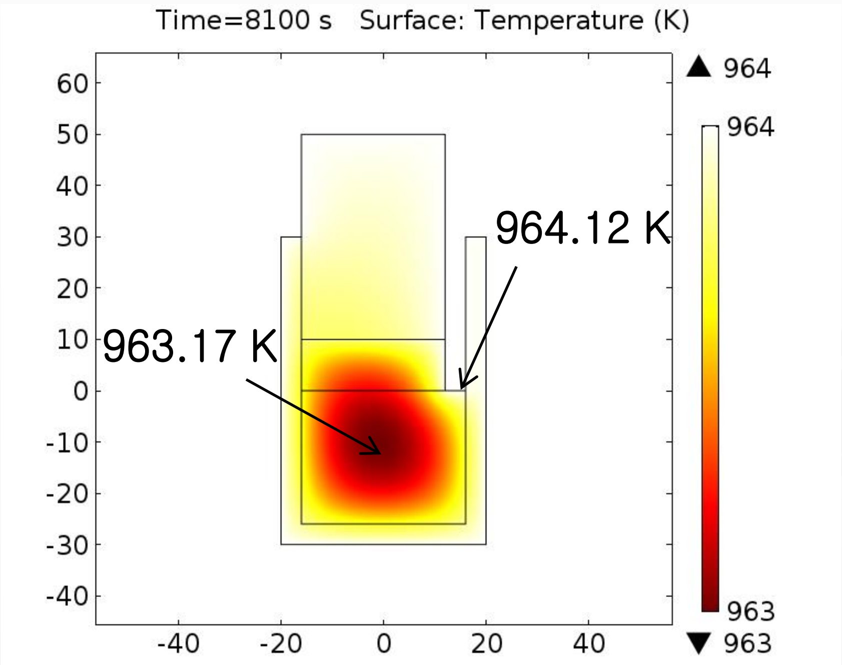
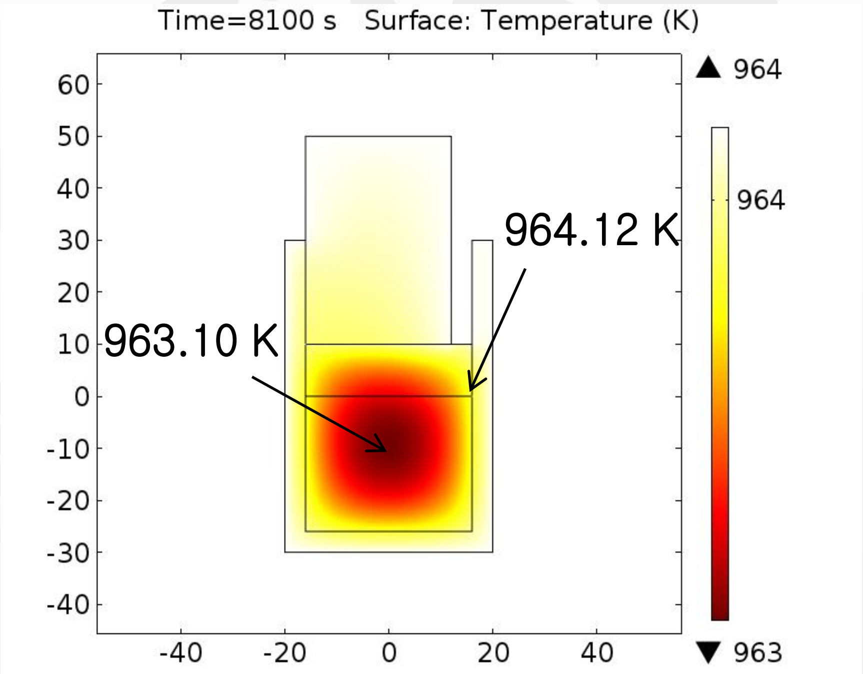
- **Thermal analysis with respect to shape of SUS plate**




Delta_T = 0.95 K




Delta_T = 1.02 K

**Temperature deviation within the mold was ~ 1 K in both cases.**

# Experimental results for $MgB_2$ joints

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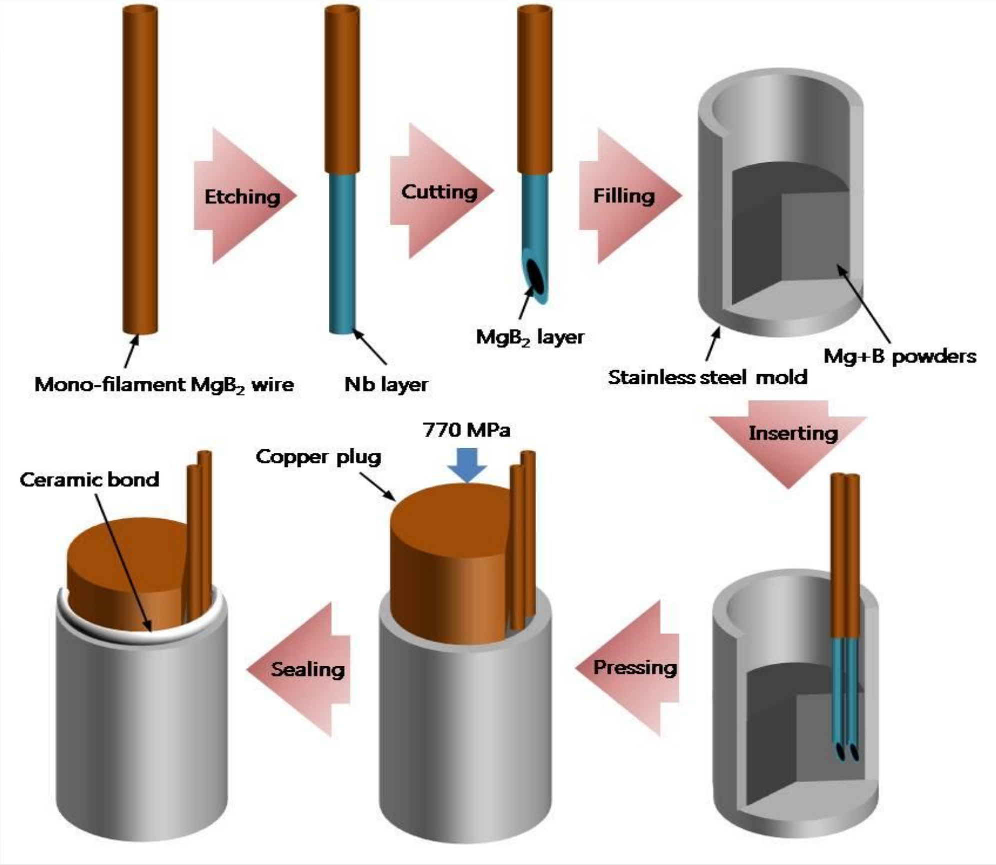
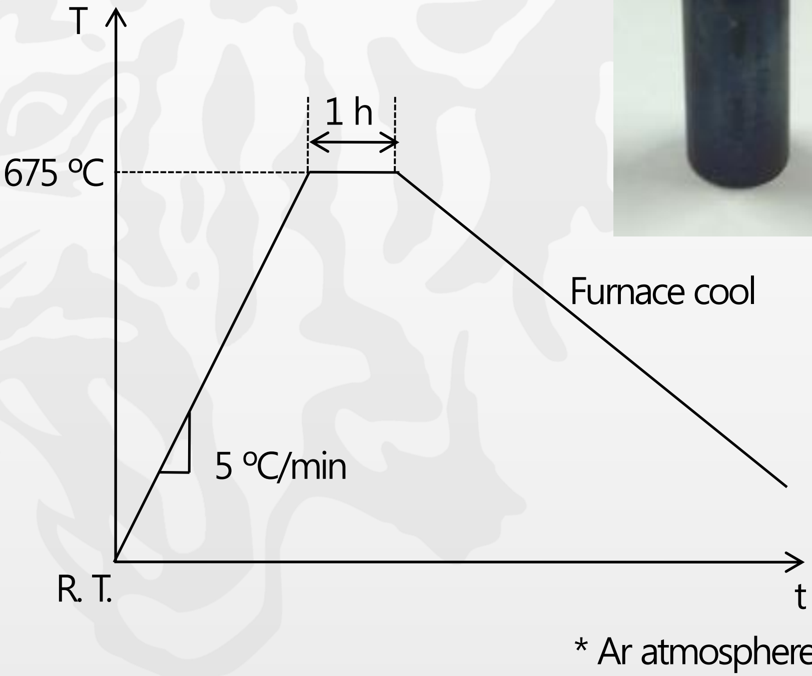
## Fabrication process for $MgB_2$ joint




<Schematic of the fabrication of a superconducting joint for $MgB_2$ wires>




<Temperature profile for heat-treatment of $MgB_2$ joint>

# Experimental results for $MgB_2$ joints

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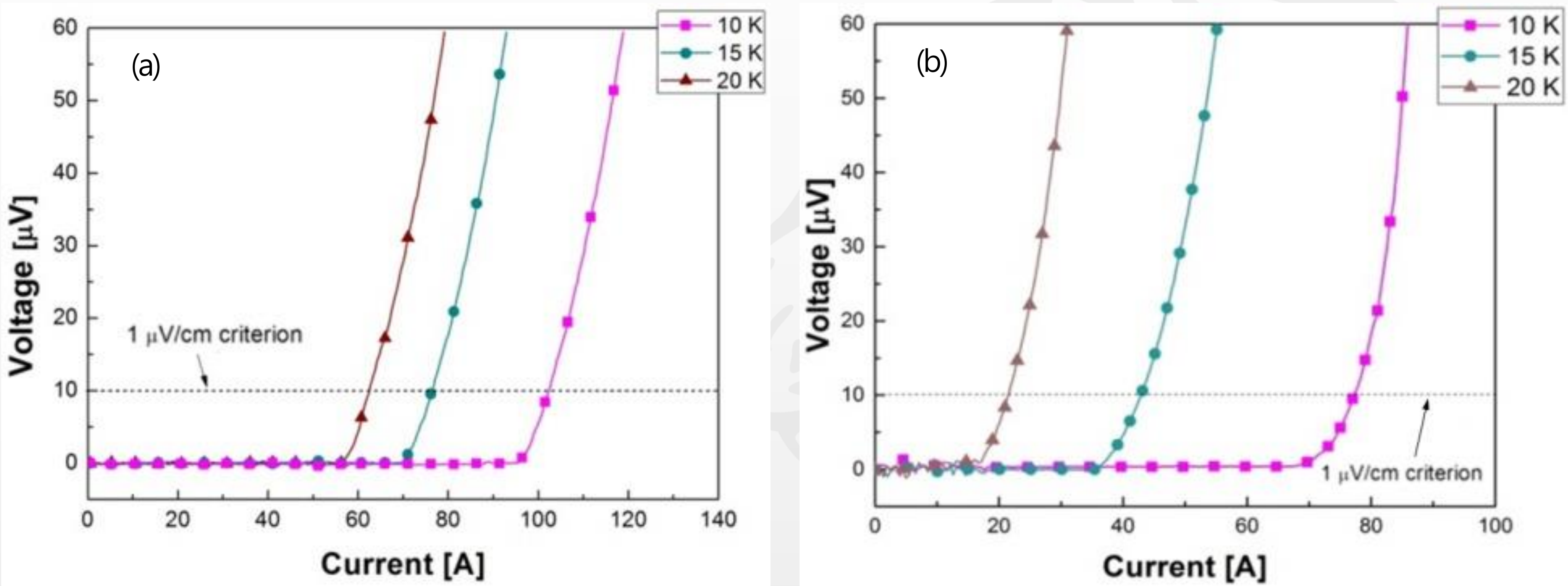
- **Critical current of the $MgB_2$ wire before and after joint process**




< *V-I* curves of the virgin (a) and jointed (b) $MgB_2$ wires measured at various temperatures>

**The critical current values of the joint sample measured at 10, 15, and 20 K showed a 35, 56, and 75 % decrease, respectively.**

# Experimental results for $MgB_2$ joints

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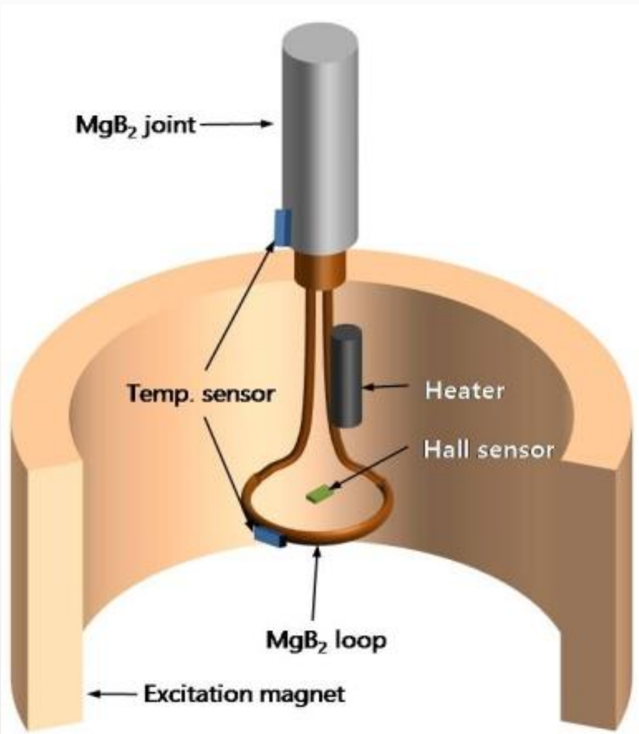
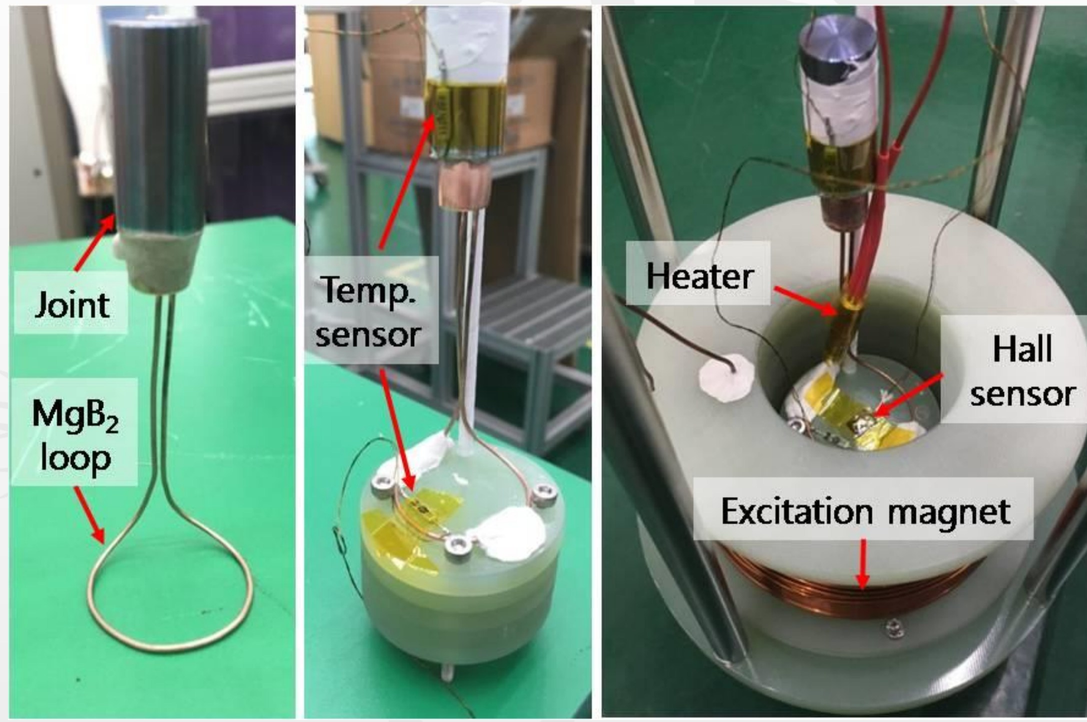
- **Field-decay test set-up**




(a)




(b)

<Schematic (a) and photographs (b) of the field-decay test set-up>

# Experimental results for $MgB_2$ joints

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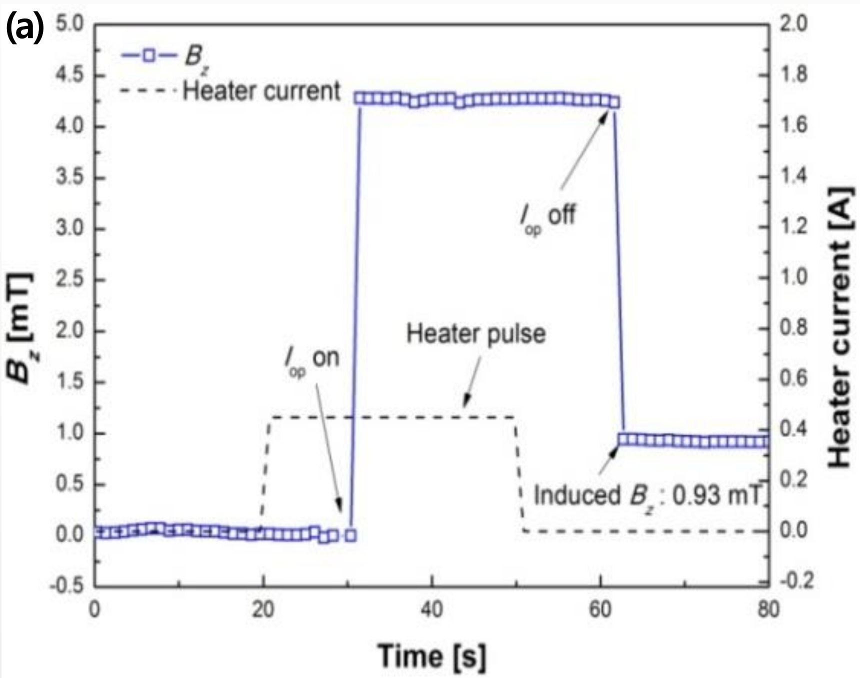
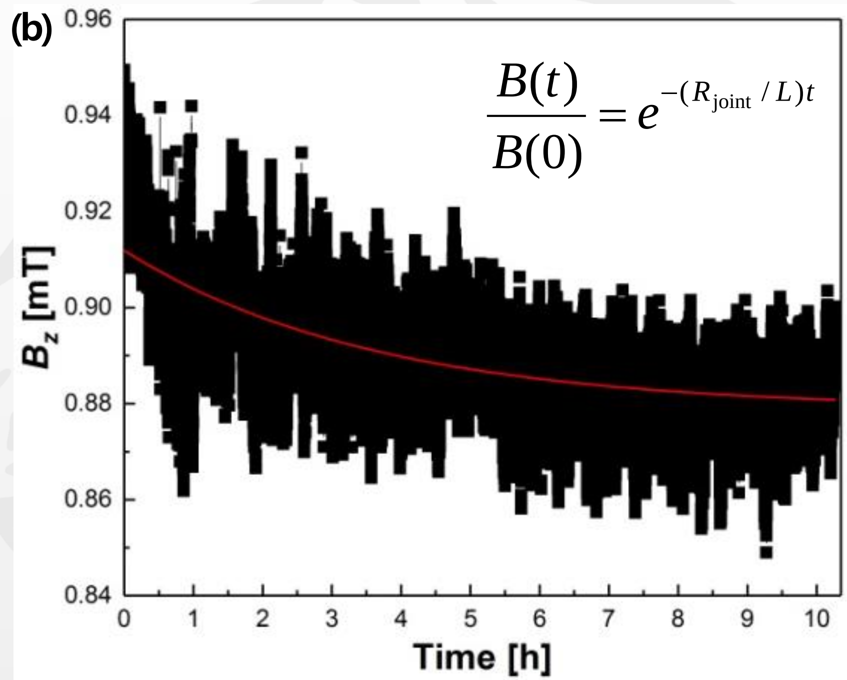
- **Field-decay test results**




<Field-decay test results for the $MgB_2$ loop containing the superconducting joint: (a) $B_z$ measured during the field cooling process; and (b) time-dependent decay of induced $B_z$ at the $MgB_2$ loop>

**Resistance of the $MgB_2$ joint was calculated to be < $9.7 \times 10^{-14}$ Ω.**

# Conclusion & future work

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## Conclusion

- The use of a circular SUS disk was more suitable for the homogeneous stress distribution within the $MgB_2$ powder, which may lead to a enhancement of the reproducibility for the $MgB_2$ joint.
- The critical current ($I_c$) values of the joint sample measured at 10, 15, and 20 K showed a 25, 44, and 65 % decrease compared to those of virgin sample, which implied that the $I_c$ of the joint sample needs to be improved further for practical applications.
- A joint resistance of < $10^{-13}$ Ω was achieved, as measured by the field-decay test, demonstrating that the proposed joint technique could be used for the development of "next-generation" $MgB_2$ MRI magnets operated in persistent current mode.

## Future work

- The optimization of the cutting angle and applied pressure for the $MgB_2$ joint will be investigated to enhance the $I_c$ of the joint sample.
- The superconducting joint technique for multi-filament $MgB_2$ wires will be examined.