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Invited presentation 1-MO-CS-03S given at EUCAS, 01 - 05 September 2019, Glasgow, UK.

1-MO-CS-03S

Fabrication of 1m long multi Superconducting layered coated conductor for high engineering critical current density

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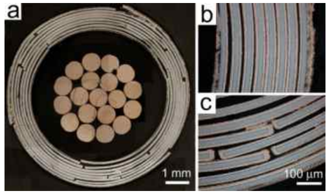
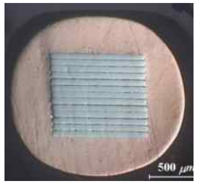
Introduction

In order to realize large applications (Accelerator, Fusion reactor, NMR…)
➔Need high Je and high transport current wire under high magnetic field
➔Many kinds of HTS cable conductors have been developed

High current



CORC (ACT)
(7500A @77K @ 10mmd.)

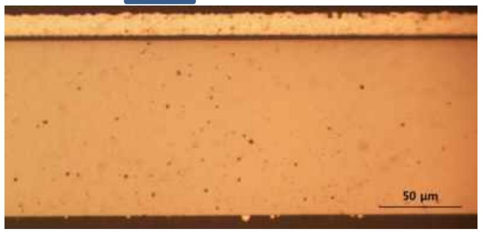


Round wire(KERI)
(180A @77K,1.5mmd.)

TSTC (MIT)
(4000A @4.2K, 12T @ 40wires, 5 x 5mm^2)

Roebel (KIT)
(2800A @77K @ 30wires, 12 x 2mm^2)

Various types of HTS conductors have been developed to transport large current for large applications



Cross-section of coated conducto

High Je conductor ➔ SN2/LN2 cooled magnet applications

High Je

High Jc	**High portion of SC**	**Multi S.C. layer**
- APC	- thicker SC	- multi-layer by deposition
- high texture	- thinner substrate	- multi-layer by soldering
- Process	- remove substrate	- **multi-layer by diffusion bonding**
- ….		

deposition process

Post process

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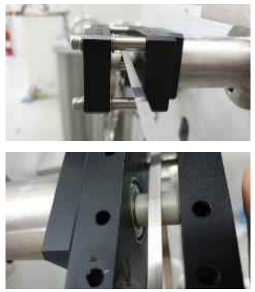
Substrate removing method for high Je & Ic

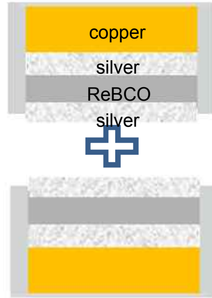
Brookhaven Technology Group Inc. has developed the exfoliated filament stacking method to improve current sharing path and engineering critical current density by removing the substrate.

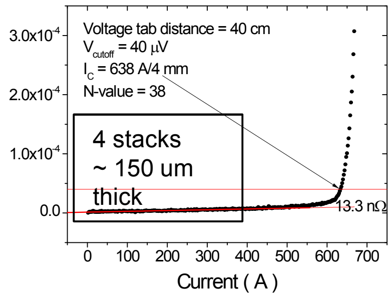
presented at MEM2018, Andong, Korea

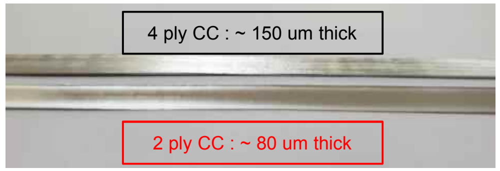
Substrate removal for high Je CC

→ Can remove substrate more than 100 meters without loss









2 ply or 4 ply + Cu plating hastelloy CC
→ 3 ply or 5 ply CC
→ Enough mechanical strength

presented at CEC-ICM2019,Connecticut, USA

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These technologies use solder to make multi superconducting layers in a wire and laminate high strength metal tape on superconducting wire.

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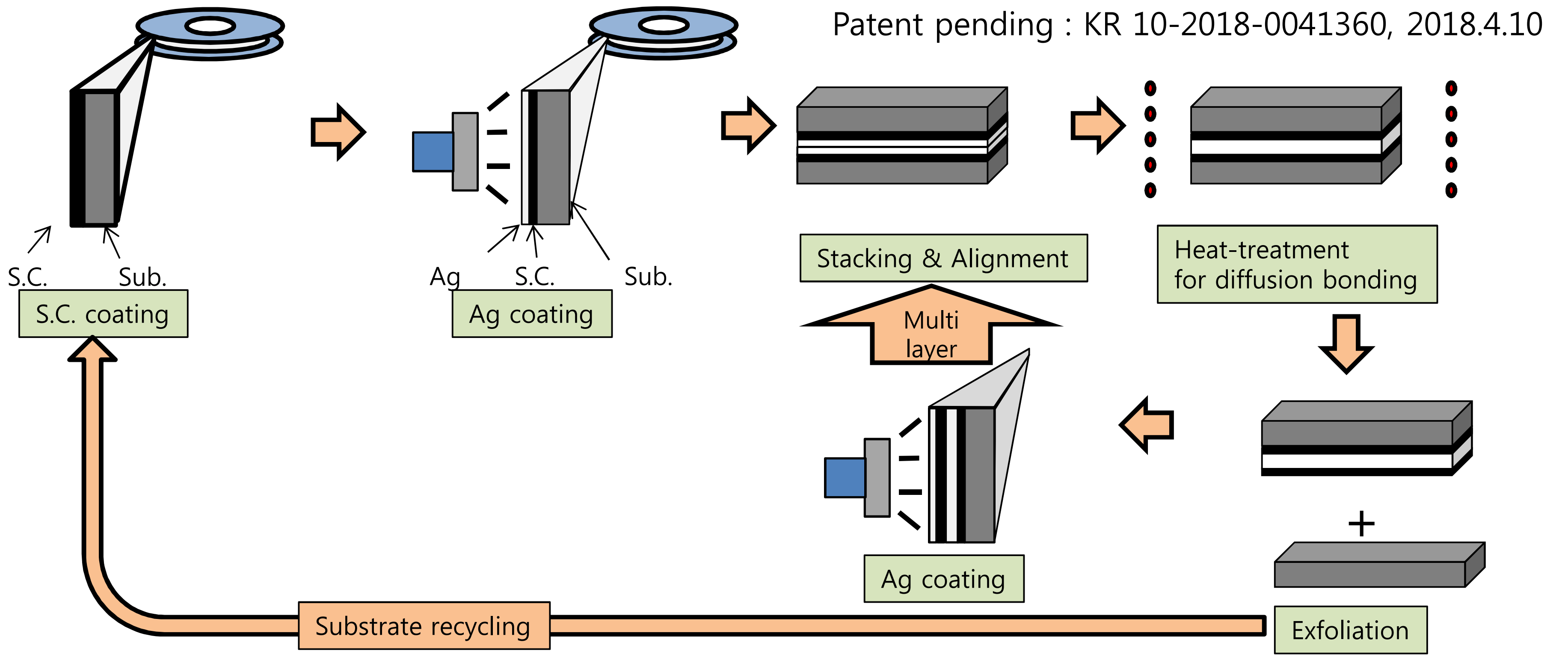
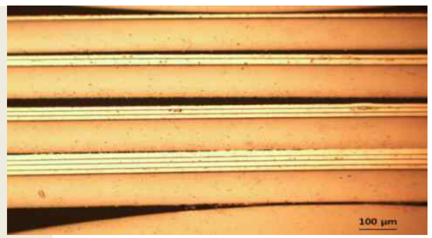
Newly invented method to make Multi-HTS conductor

Patent pending : KR 10-2018-0041360, 2018.4.10



Fabrication procedures of Multi HTS on One Substrate(MHOS) conductor

1. able to make higher Ic and Je HTS conductor
2. apply to LN2/SN2 cooled magnet (saving cooling cost to operate superconducting magnet) and high magnetic field magnet
3. realize large current transport conductor by bundling of MHOS conductor



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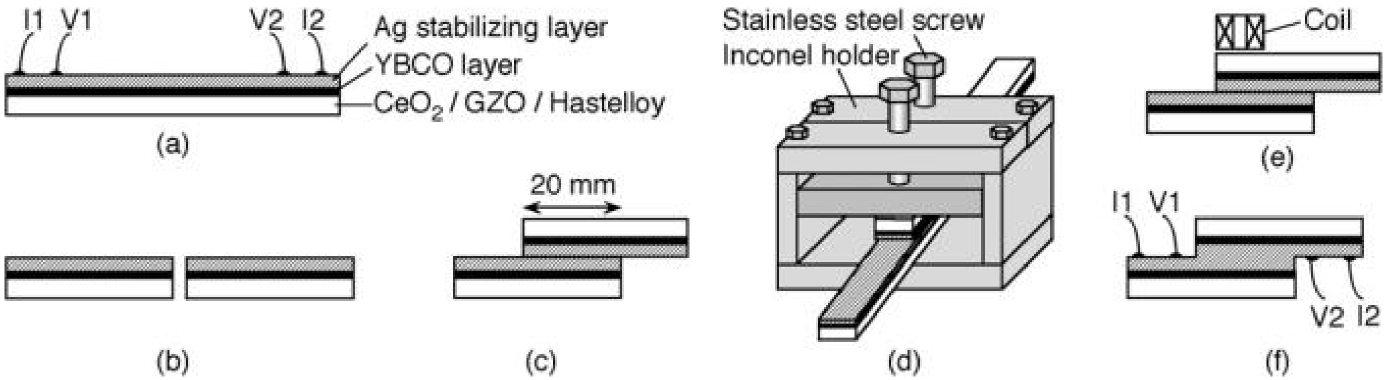
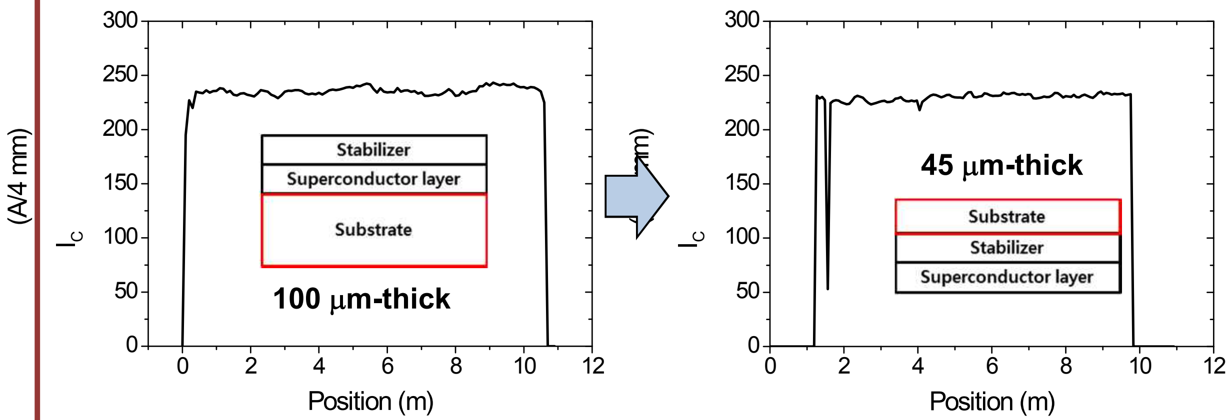
Basic techniques to make MHOS Conductor

1. Ag diffusion bonding : J. Kato et al. / Physica C 463–465 (2007) 747–750

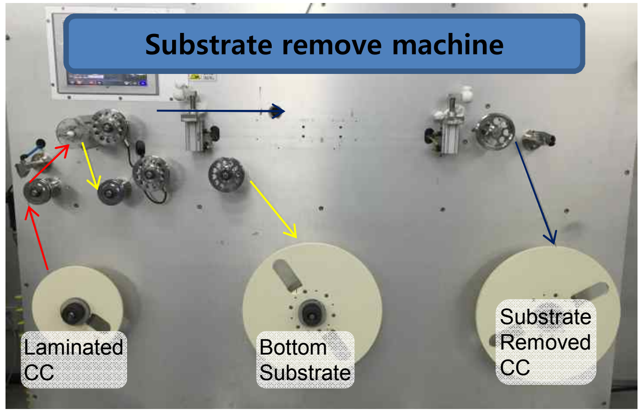


➔ Need to develop Long wire diffusion bonding technology

2. Continuous exfoliation technique



Continuous Ic measurement



SUNAM Ref. ISS2017

➔ Need to develop crack free exfoliation technology

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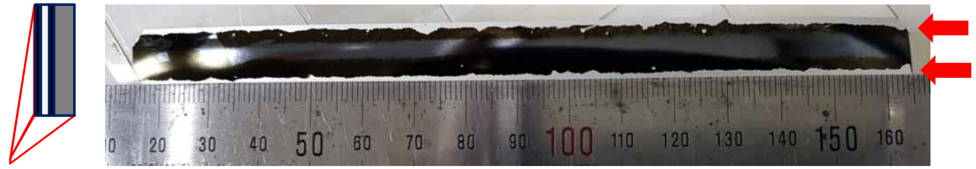
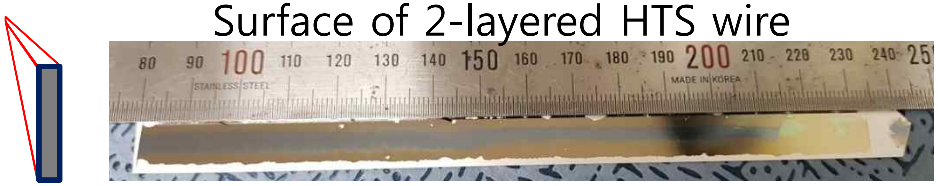
Fabrication of 2-MHOS conductor (2018.9.)

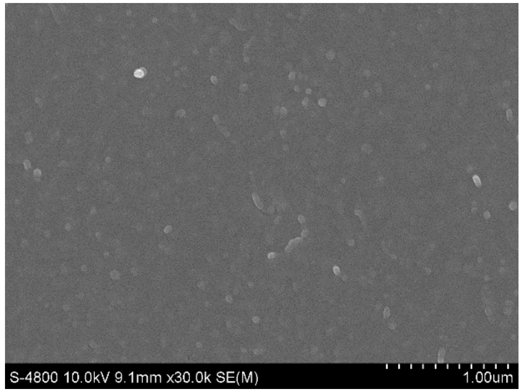


Not bonded region

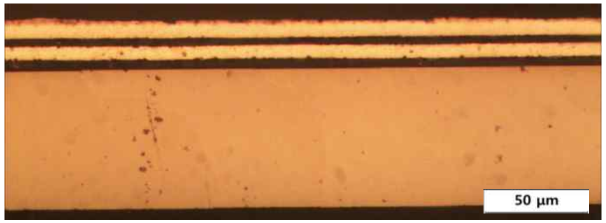
Surface of 2-layered HTS wire



metal substrate after de-lamination

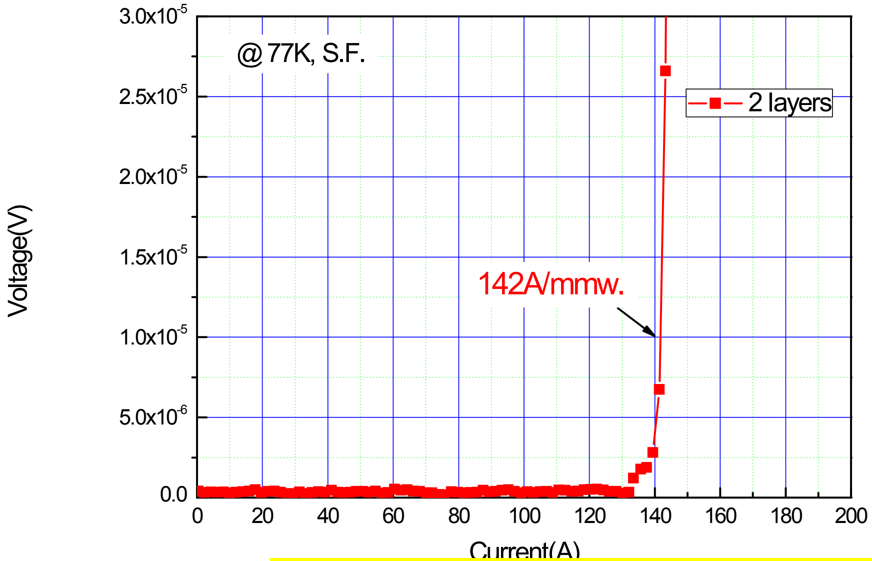


Surface of superconducting layer after de-lamination



Cross-section of 2-MHOS conductor

Ag coated 2-layered HTS wire (10cm long) (Laser patterning (1mmw.) for Ic measurement)



Ic = 142A/mmw.,
Je = 0.095MA/cm^2 , 0.15mmt.

Whole superconducting layer was not exfoliated.
➔ Only narrow width wire can be made.

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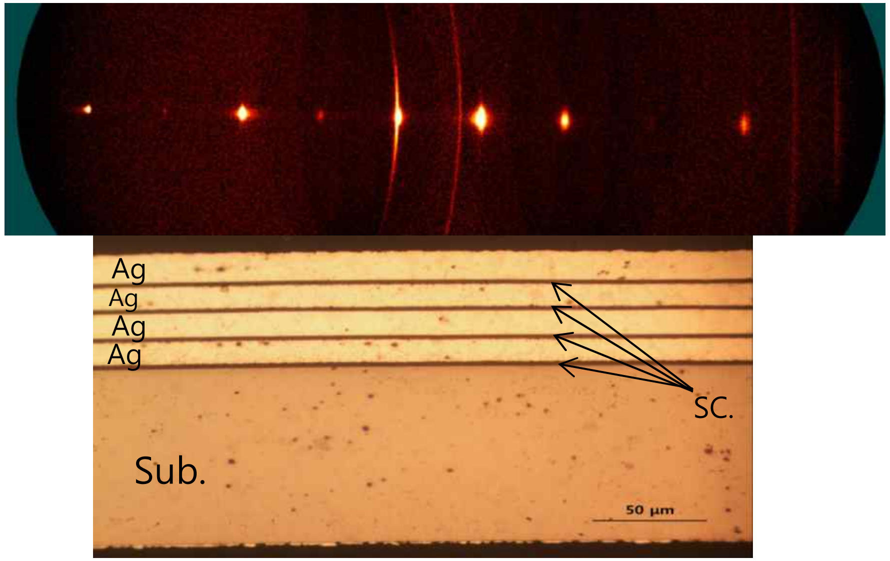
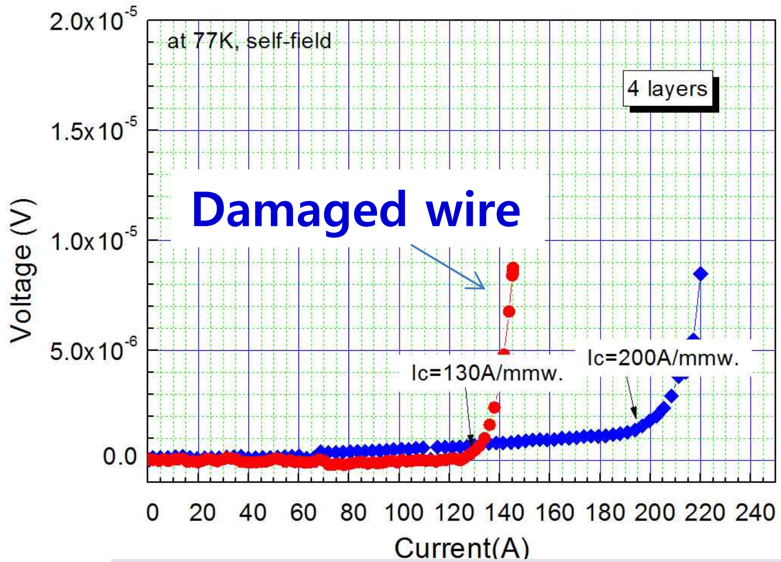
Fabrication of 4-MHOS conductor(2018. 9.)



Longitudinal cross-section of 4-Superconducting layered HTS wire



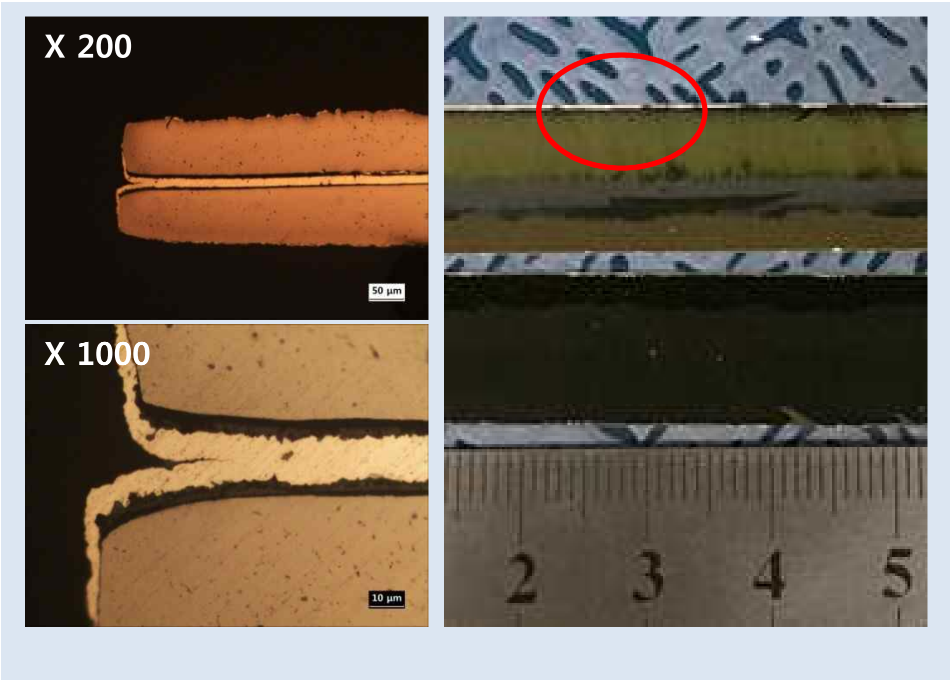
Ic = 2,000A/cm-w. , Je = 0.12MA/cm²
1mmw. X 0.17mmt. X 2cmL.

As-received CCs (A/mmw.)	Slit with 1mmw. (A/mmw.)	2-layer (A/mmw.)	Je (MA/cm²)	4-layer (A/mmw.)	Highest Je (MA/cm²)
73 (SuNAM, 880A/12mmw.)	72 (SuNAM)	142	0.095*	130, 200	**0.12***

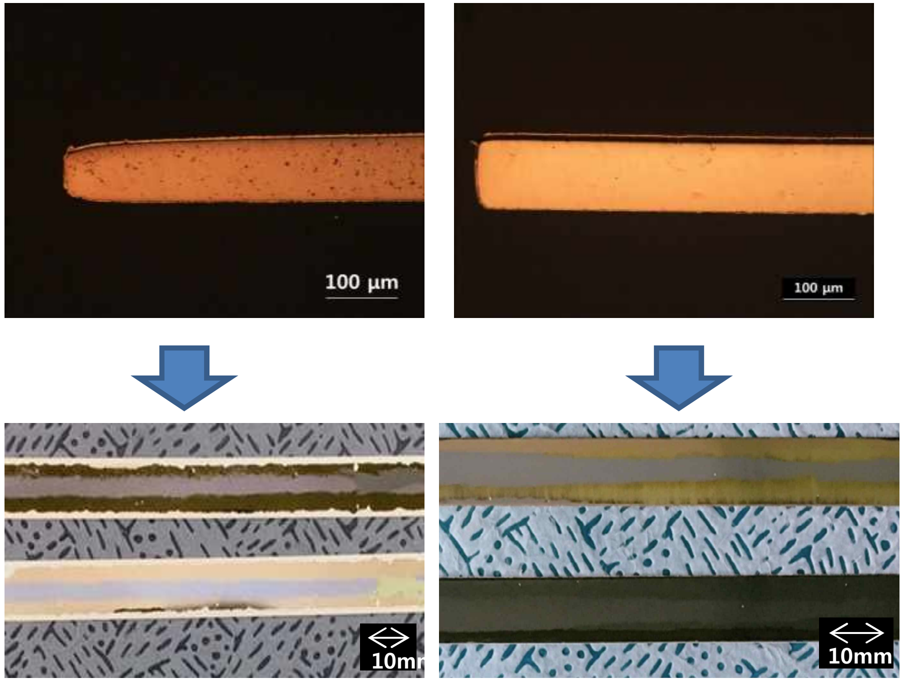
*Ag thickness is not optimized.
These wires have thick Ag layers to measure Ic without Cu.

This process was not stable to make 4-MHOS conductor.
➔ we could not make long 4-MHOS conductor without defect.

The influence of shape of substrate on diffusion bonding



Cross-section of diffusion bonded 2-MHOS conductor



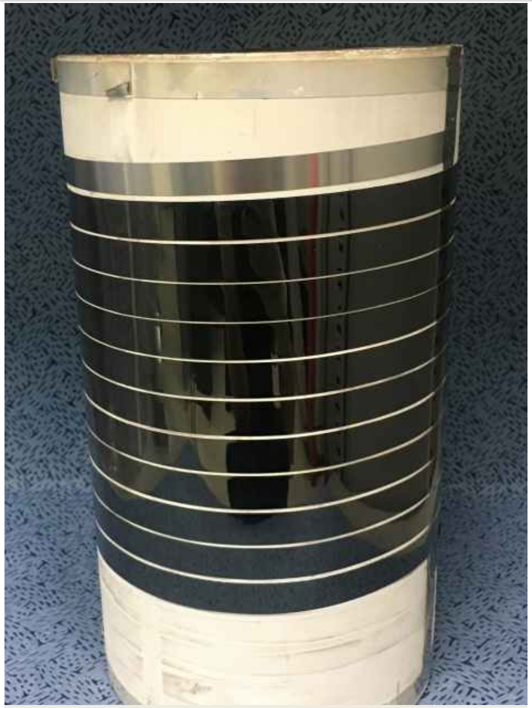
Relationship between shape of substrate and exfoliation property

Near rectangular cross-section of substrate shows good exfoliation property.
➔ Quality of raw metal strip and electro polishing technology are important to sustain rectangular cross-section.

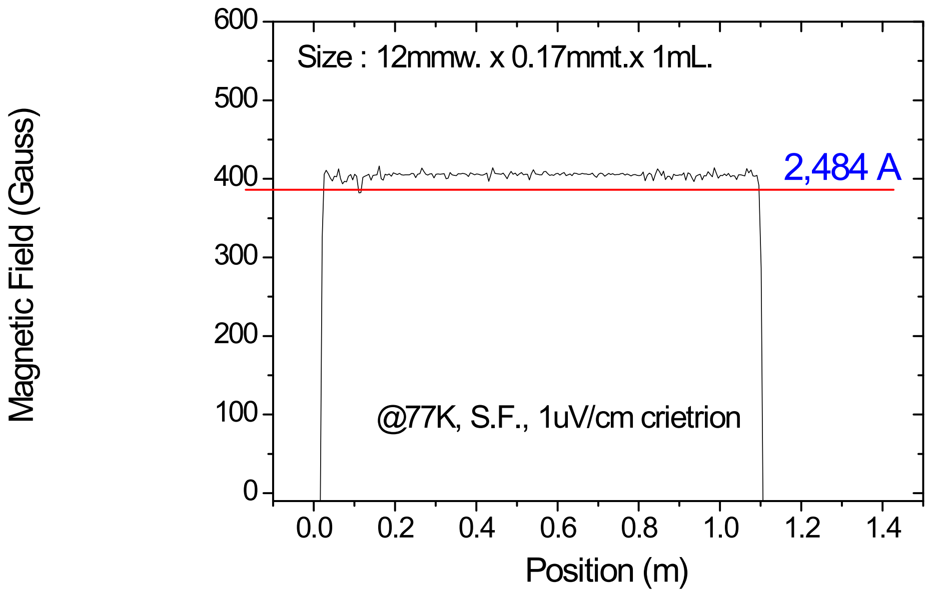
Discrepancy of alignment between two wires during diffusion bonding deteriorate exfoliation property of MHOS conductor.

Fabrication of 1m long 4-MHOS conductor (2019.08.)

New apparatus is applied to exfoliate superconducting layers from Ag diffusion bonded conductor.
➔Successfully exfoliate superconducting layers from the substrate without damages and good alignment



Exfoliated 1m long 4-MHOS conductor



Hall-Ic measurement (by SuNAM)

Je =2484/(12x0.17mm^2)=**1,217A**/mm^2
=**0.12MA**/cm^2

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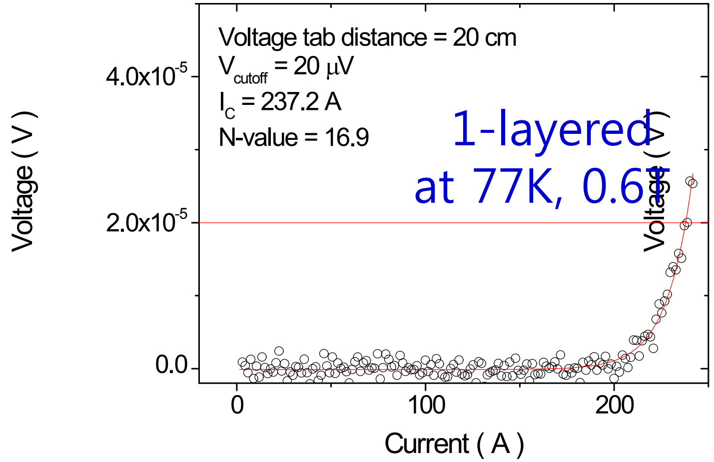
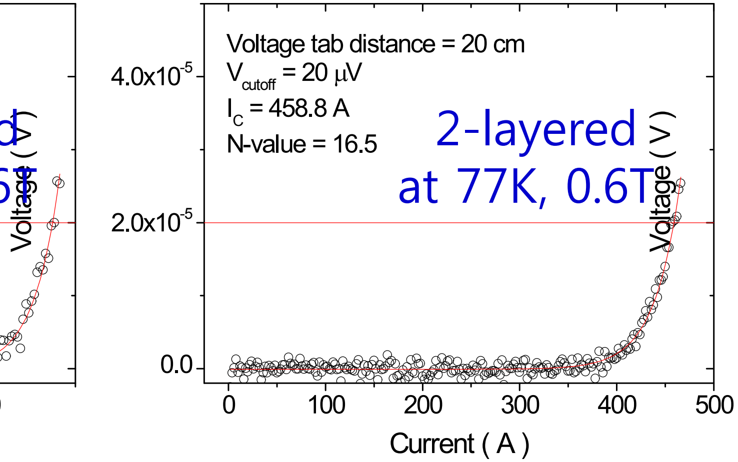
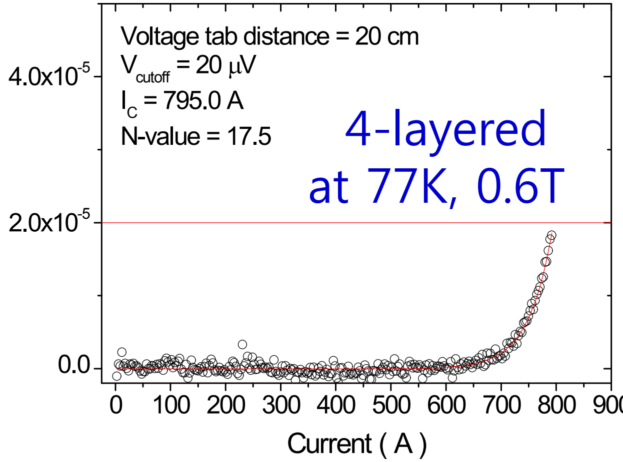
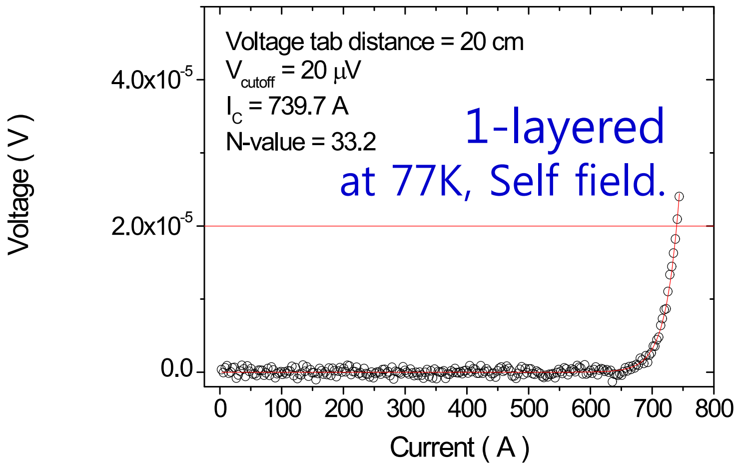
Critical current of MHOS conductors at 77K, 0.6T









1. Ic of as-received wire at 77K, 0.6T shows about 32% of Ico at 77K, S.F..
2. Ic of MHOS conductors are not proportional to the number of superconducting layers.
   ➔ 100%(1layer)➔ 97%(2-MHOS)➔ 87%(4-MHOS)

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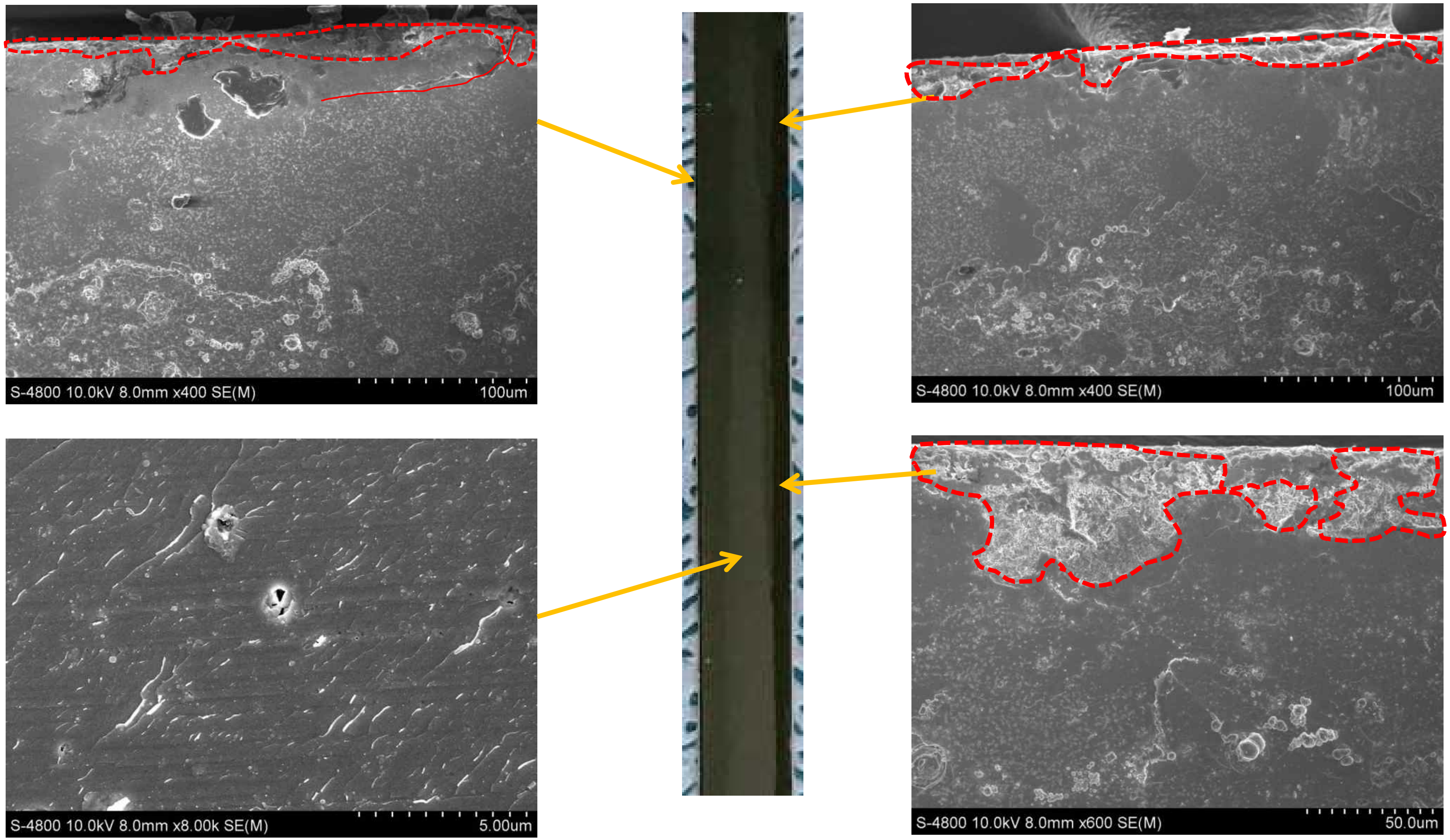
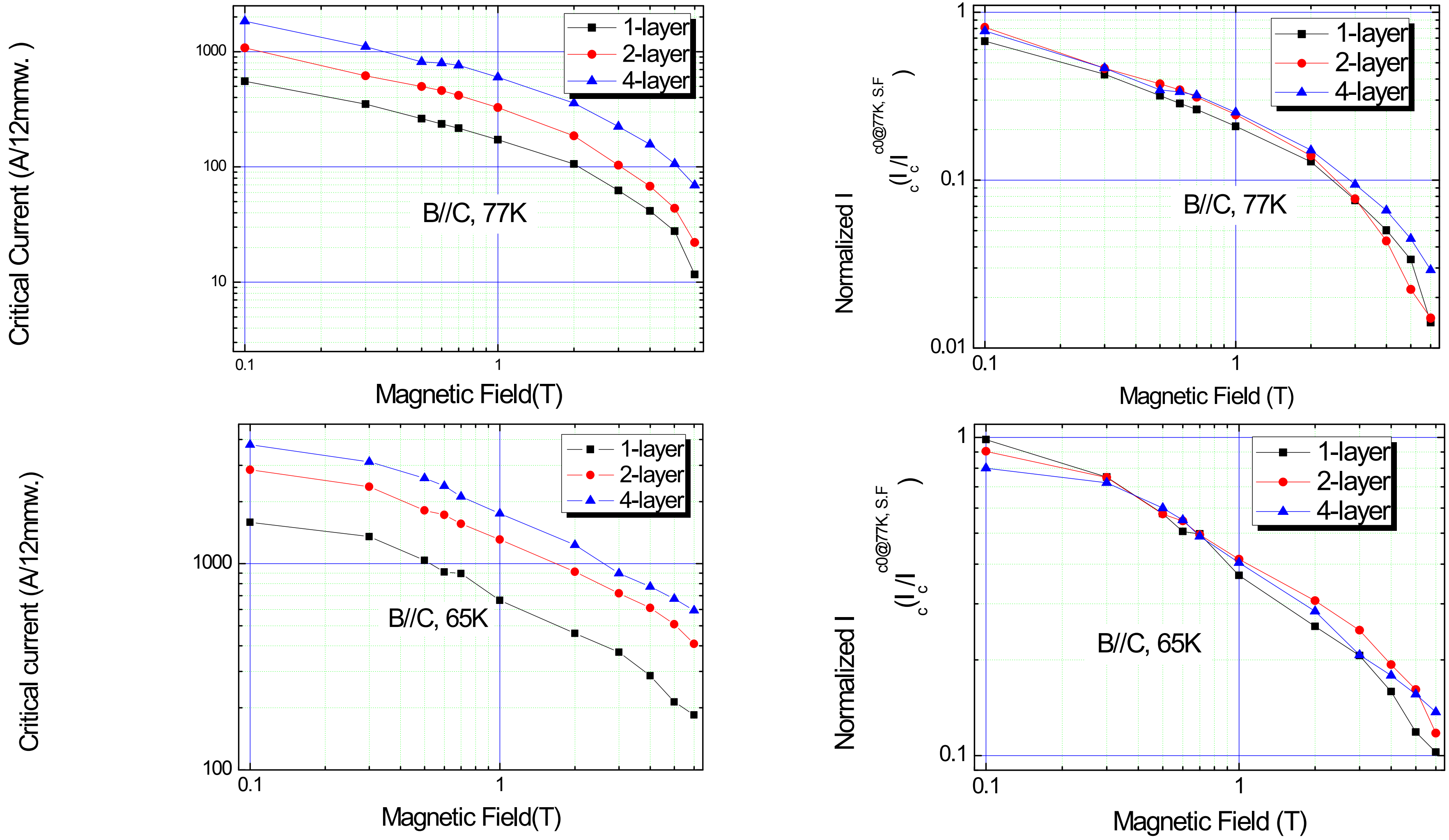
Defects of edge of MHOS conductor



Some of superconductors are cracked off at the edge of the superconducting layer.

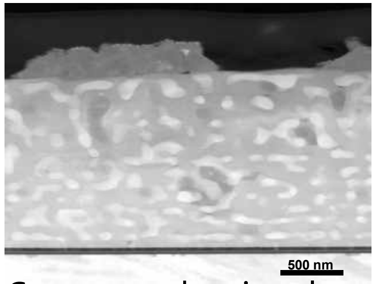
But, large crack or crack propagation along the width direction were not detected at the surface of superconducting layer of MHOS conductor.

Magnetic field property of MHOS conductors at LN2

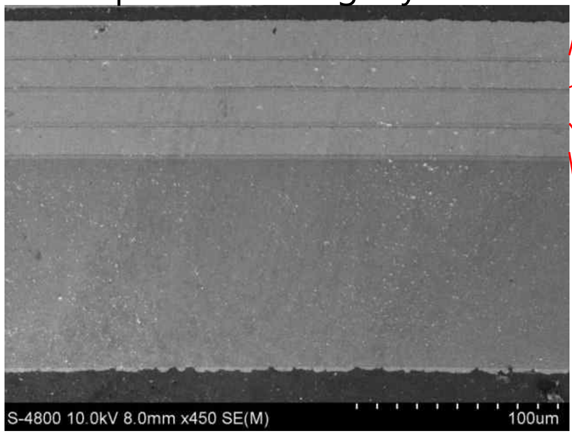


- Critical currents of MHOS conductors are increased by the number of superconducting layers under magnetic field from 0 to 6 Tesla.
- Normalized Ic-B properties of MHOS conductors show nearly same values.
- Tailored MHOS conductor can be made to meet the demanded Ic under special B & T by controlling the number of superconducting layers.

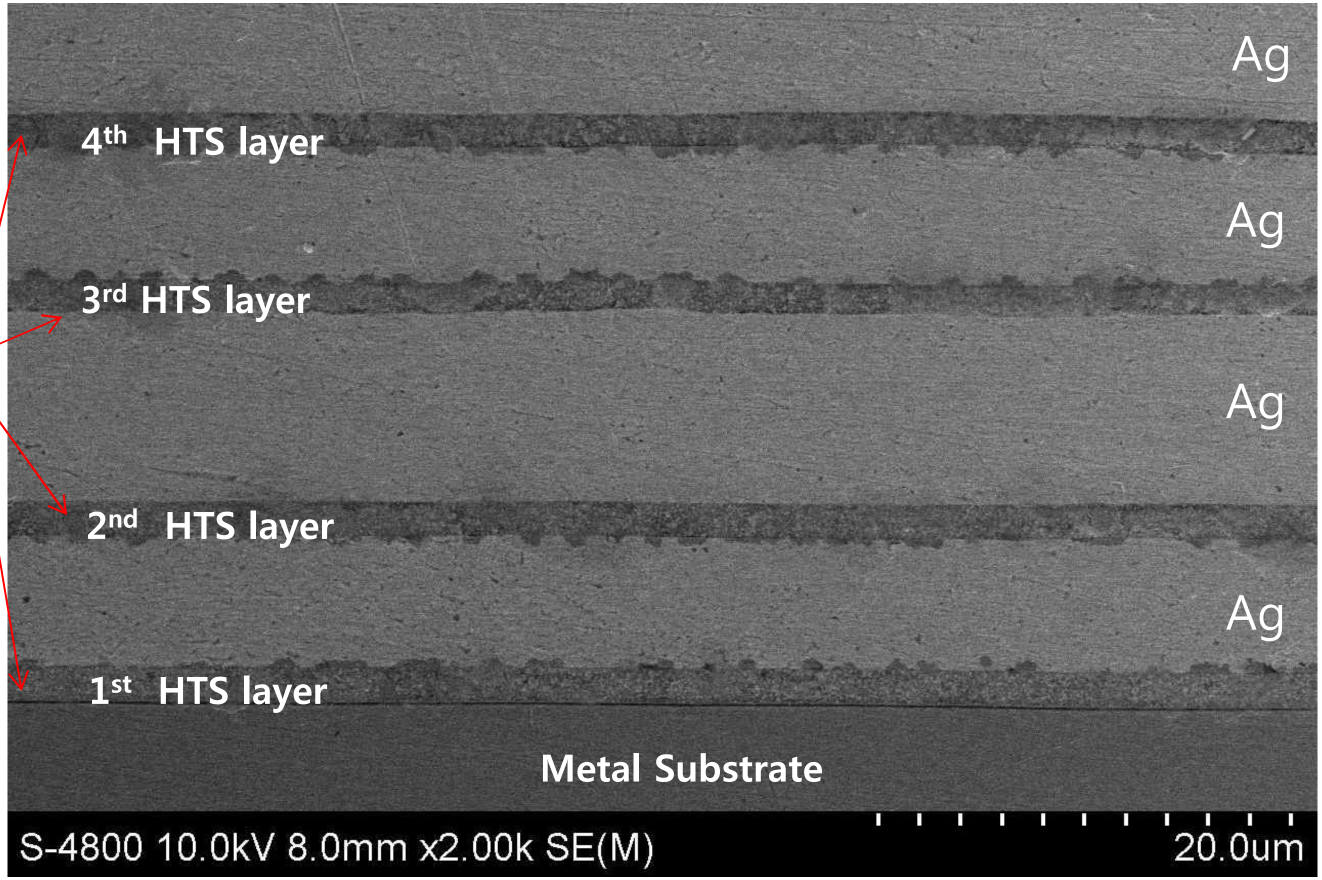
Cross-section analysis of 4-MHOS conductor



Superconducting layer



4-layered HTS wire



1. Interface between Ag layers was removed by Ag diffusion bonding treatment.
2. Superconducting layers shows flat and clean without cracks and defects.
3. The thickness of Ag layers is not optimized, if Ag layers become thinner by optimization, Je will be improved over 0.12MA/cm ^{2} @77K,S.F..

Conclusions

1. **1 m long 4-MHOS(Multi HTS on One Substrate) conductor has been successfully fabricated by improved fabrication process.**
2. **MHOS conductor consists of multi biaxial textured superconducting layers without any epitaxial grown buffer layer or solder layer between superconducting layers.**
3. **1m long 4-MHOS conductor shows higher engineering critical current density(Je = 0.12MA/cm^2) and critical current(2,484A/12mmw.)**

Future works

1. Evaluate mechanical and high magnetic field property of MHOS conductor
2. Fabricate 6~10 layered MHOS conductor for higher Je
3. Optimize thickness of Ag layer between superconducting layers
4. Develop new machine to fabricate MHOS conductor automatically
5. Fabricate long MHOS conductor over 100m long to make magnet operated at 63~77K.

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Thank you for your attention

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