IEEE-CSC, ESAS and CSSJ SUPERCONDUCTIVITY NEWS FORUM (global edition), Issue No. 56, March, 2024. Invited presentation given at ISS 2023, Nov. 2023, Wellington, New Zealand

中國科學院 CHINESE ACADEMY OF SCIENCES

中国科学院电工研究所 Institute of Electrical Engineering Chinese Academy of Sciences

High performance iron-based superconducting wires: fabrication and properties

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Outline

1 Background on iron-based superconductors (IBS)

2 Development of high J_c PIT 122 IBS wires

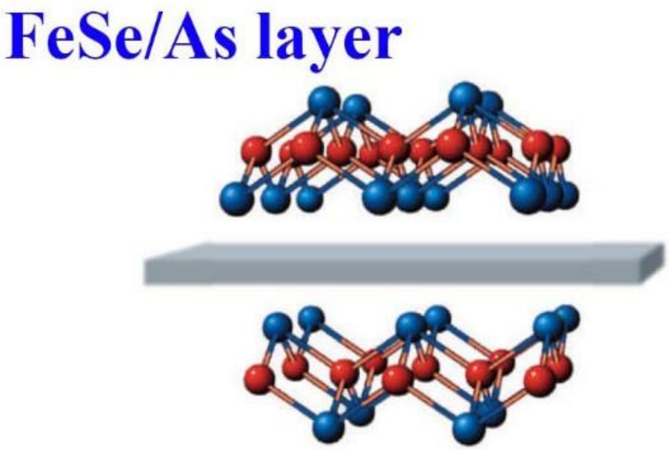
3 Application property of the IBS wires

4 Recent advances in long-length wires, joints, pancake & racetrack coils, cables

5 Conclusions and outlook

Iron-Based Superconductors (IBS)

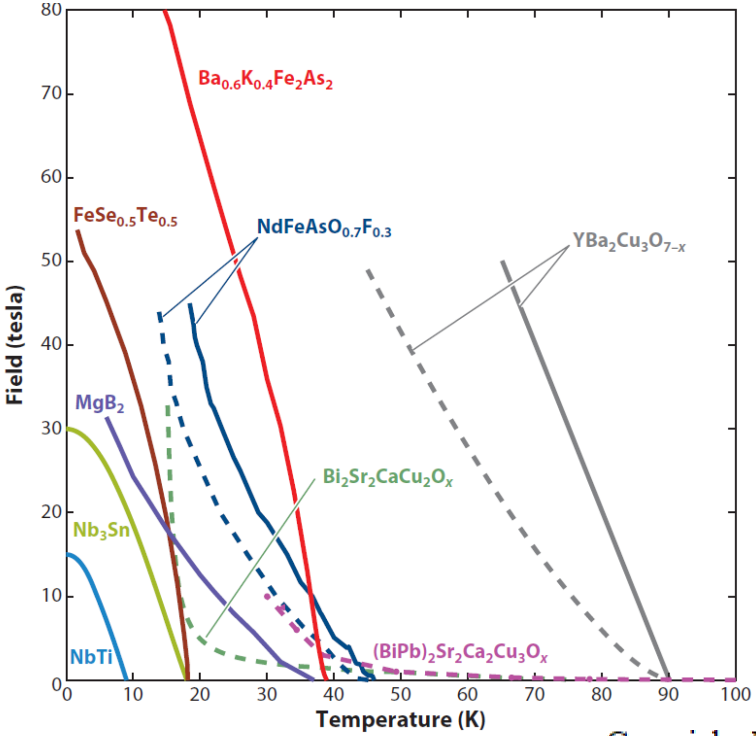
Prof. Hideo Hosono 2008



Varieties of Iron-based superconductors (IBS)

High performance:

- High T_c~**55 K**
- High ***H*$_{c2}$~100 T**, H_{irr} very close to H_{c2}
- Small anisotropy, γ<2
- High ***J*$_c$~6 MA/cm^2** & J_c-depairing~**160 MA/cm^2**



Gurevich, *Nature Mater.* 10 (2011) 255

At 20 K, the H_{c2} can be >70 T where IBS outperform both MgB_2 and Bi-2223.

	Bi-system	YBCO	IBS 122	MgB$_2$
γ	50-90	5-7	1-2	2
ξ_{ab}	2.3	2.1	2.4	8
Gi	1	10^{-2}	10^{-4}	10^{-5}

IBS are considered as “Cheap conductor for high fields”

IOP Publishing Superconductor Science and Technology

Supercond. Sci. Technol. 32 (2019) 070501 (3pp) https://doi.org/10.1088/1361-6668/ab1fc9

Viewpoint

CrossMark

Constructing high field magnets is a real tour de force

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This is a viewpoint on the letter by Dongliang Wang *et al* (2019 *Supercond. Sci. Technol.* 32 04LT01).

Following the discovery of superconductivity in 1911, Heike Kamerlingh Onnes foresaw the generation of strong magnetic fields as its possible application. He designed a 10 T electromagnet made of lead–tin wire, citing only the difficulty in obtaining ‘relatively modest financial support’ for his laboratory in Leiden. However, he soon found [1] that superconductivity disappears in the presence of a magnetic field above a critical value H_c, or a current density above a critical limit, J_c. For all known superconductors of the time, these critical values were low, making fabrication of strong magnets impossible.

It took half a century, and the investigation of thousands of different superconducting metals, compounds, and alloys [2], until the useful superconductors Nb_3Sn [3] and NbTi [4], with a high H_c and J_c, were found. Within a short time, kilometer lengths of Nb_3Sn wire were fabricated and the first 6 T ‘supermagnet’ was tested the same year. During the following decades, these low temperature superconductors (LTS) entered their industrial phase. NbTi magnets are the most widely used, taking ~80% of the market, while NbTi + Nb_3Sn magnets are used where fields above 10 T are needed. The record magnetic field generated by LTS is 23.5 T [5].

Meanwhile, a microscopic theory of superconductivity (Bardeen–Cooper–Schriffer) in 1957 [6] made it possible to understand the phenomenon of LTS, however, this new theory had only a minor impact on the search for new superconducting materials.

After the discovery of high-temperature superconductors (HTS) in 1986 [7], it took around 30 years to construct prototypes of 32 T [8], and more [9], only partially HTS magnets. Despite intensive efforts by the HTS community, high-temperature superconductivity still lacks a widely accepted microscopic model.

At present, long superconducting wires are only produced from six superconductors: NbTi, Nb_3Sb, MgB_2, Bi2223, Bi2212 and REBCO. Only wires of Nb compounds are used industrially, with intensive work on Nb_3Sn optimization still under way. The other materials are still considered in the research and development phase.

Thus, the discovery of a new class of iron based superconductors (IBS) in 2008 [10] opened the doors to a new perspective for microscopic models. Intensive studies show that IBS phenomenology and superconducting parameters bridge the gap between conventional superconductors and cuprates and may be helpful in explaining the latter. From a practical point of view, IBS are ideal candidates for applications. Indeed, some of them have quite a high critical current density, even in strong magnetic fields, and a low superconducting anisotropy. Moreover, the cost of IBS wire can be four to five times lower than that of Nb_3Sn, making it more expensive than NbTi, but with much higher critical parameters than Nb_3Sn. Attempts to make a superconducting wire started immediately, using either the powder-in-tube (PIT) [11–13] or coated conductor [14, 15] methods.

--Jan Jaroszynski, ***Supercond. Sci. Technol.*** 32 (2019) 070501

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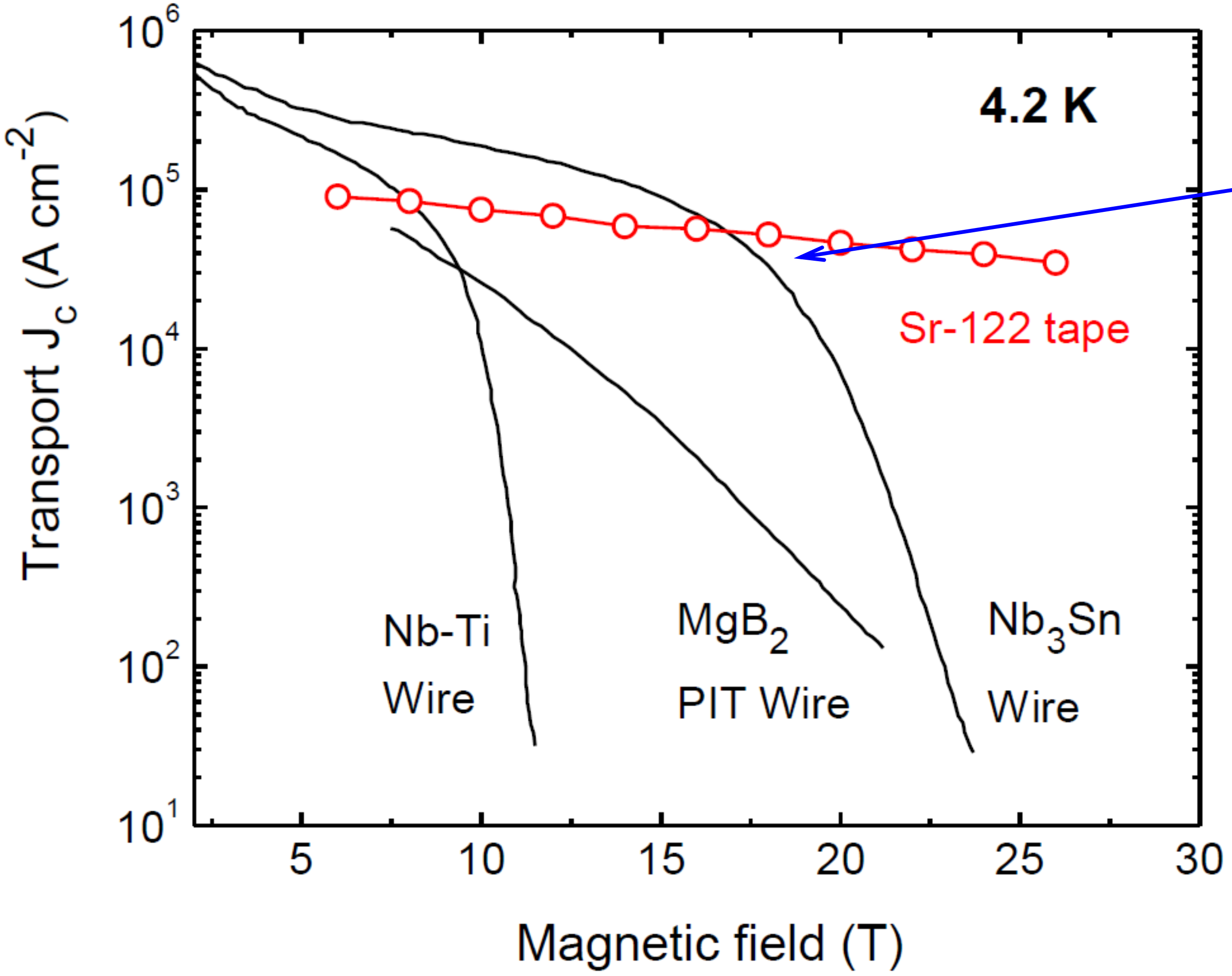
High J_c of IBS wires: Very weak field dependence in high field region



122 IBS wire:
Large J_c, at B > 20T

J_c shows very weak field dependence in high fields

I_c data of Sr-122 tape,
measured in 2013 at HFLSM, Sendai

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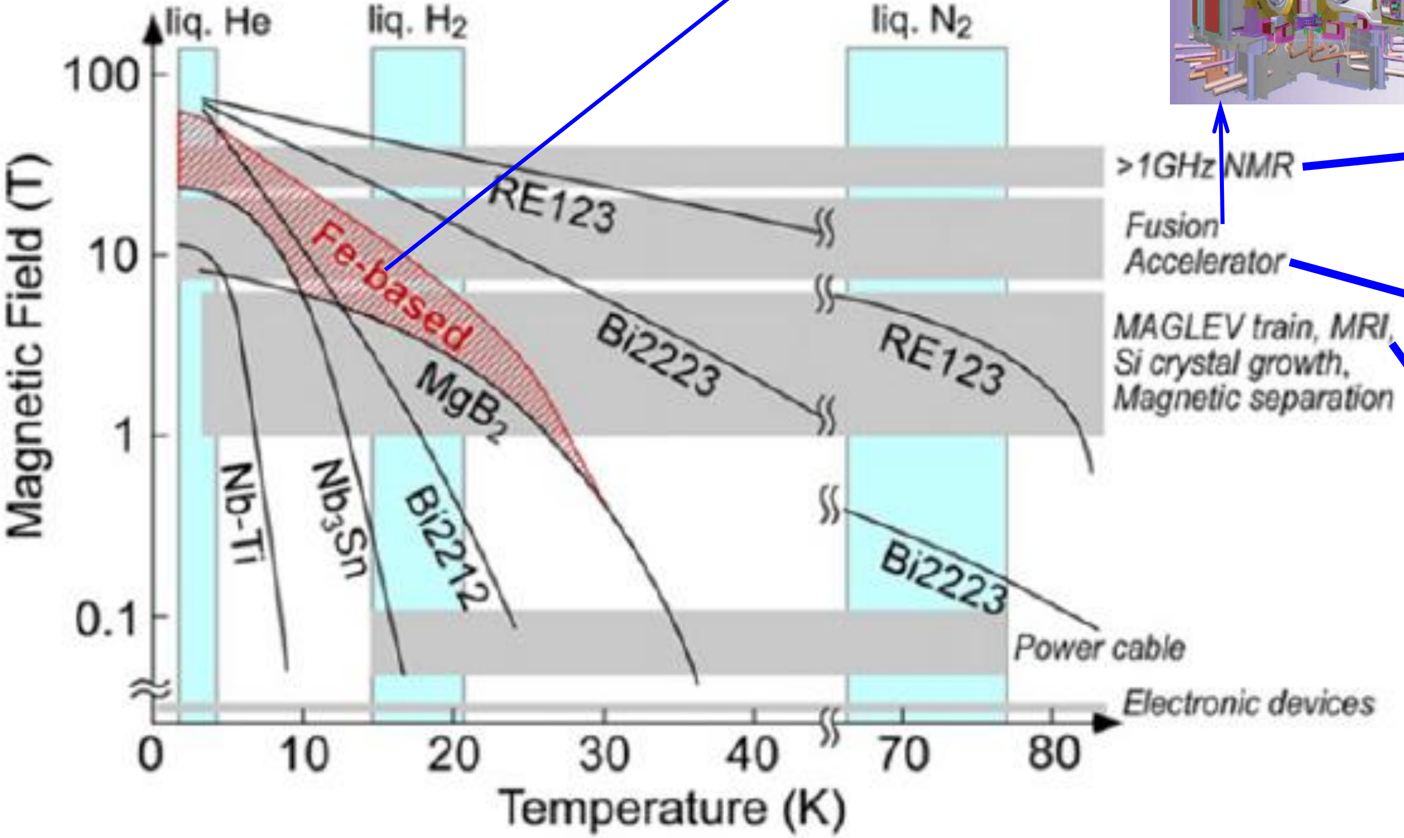
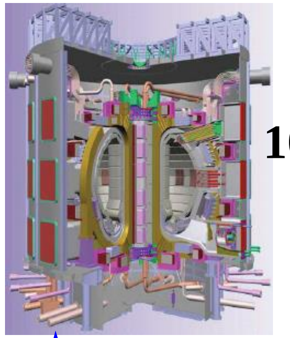
IBS have potential for high-field applications

Working Temp: 4.2 K – 30 K



J. Shimoyama, ***SuST*** 27 (2014) 044002



ITER
10 m, 15 T (4.2 K)

>1GHz **NMR**
>23.5 T

Accelerator (20 T)

MRI
(14 T)

Development of high-performance conductors is essential

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What makes a good superconducting wire?

Characteristics:

Superconductors

Intrinsic

- Low anisotropy
- High J_c, H_{c2}
- Chemically stable

Conductor design

Extrinsic

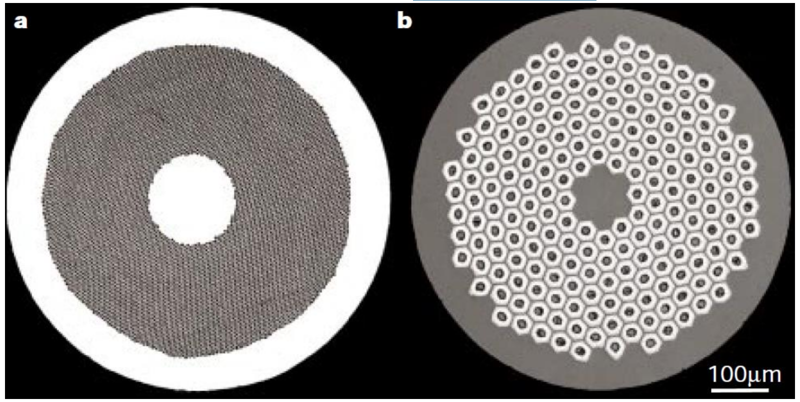
- Low AC loss (Multifilament)
- Thermal stability (Thermal quench)
- Good mechanical strength (Lorentz force)
- Scalable production (powders & wires)
- Small aspect ratio: round wire
- Low cost——Conundrum for HTSC

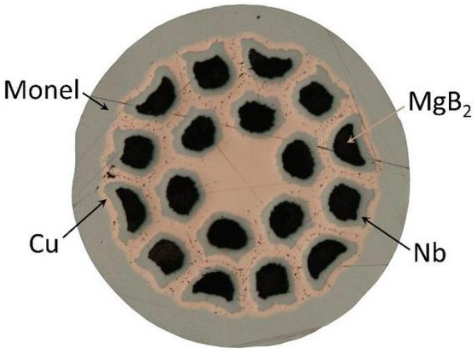
Commercial superconducting wires and tapes

NbTi

Nb_3Sn

MgB_2

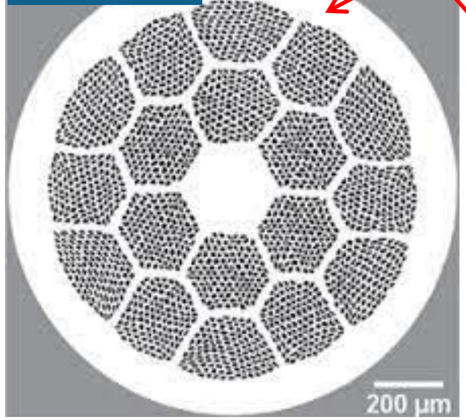




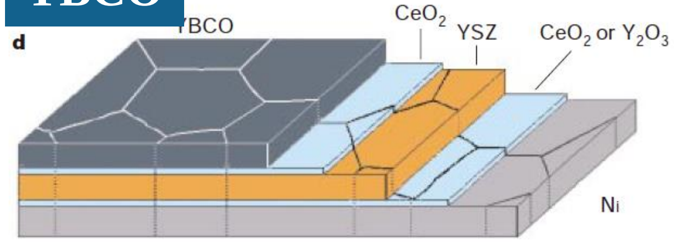
Bi2212

Ag

Bi2223



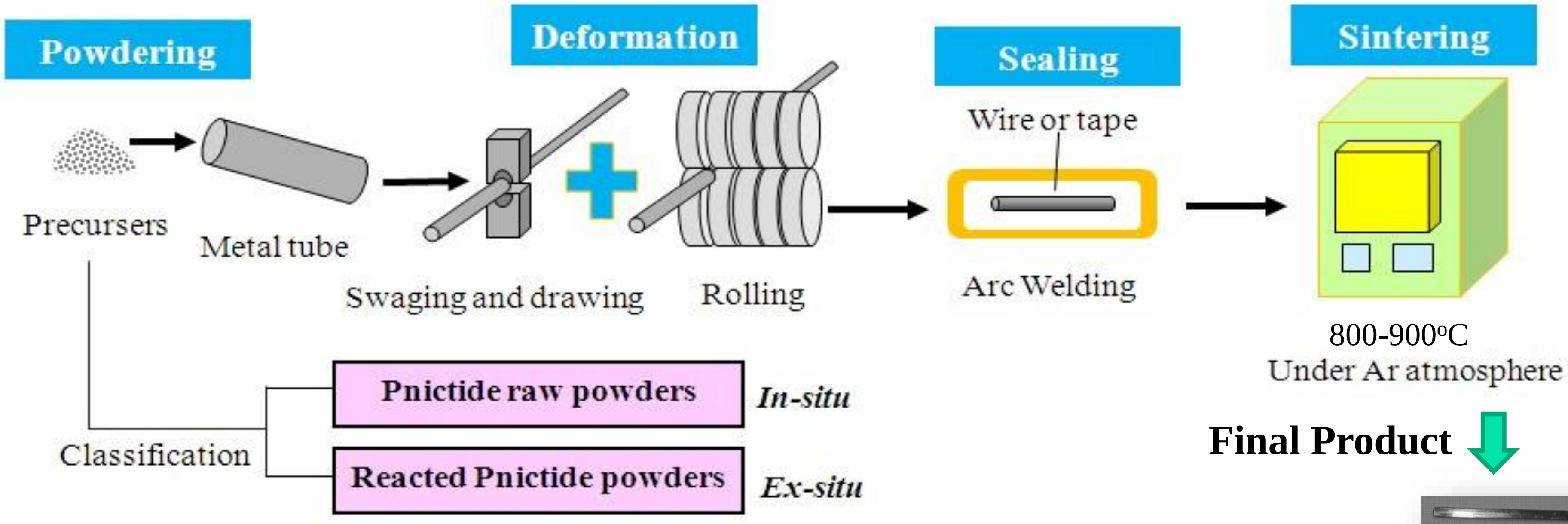
YBCO

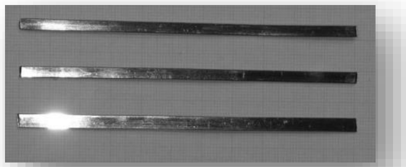


Fabrication process for IBS wires and tapes

(*Powder-in-tube method*)

—Low cost, simple deformation process



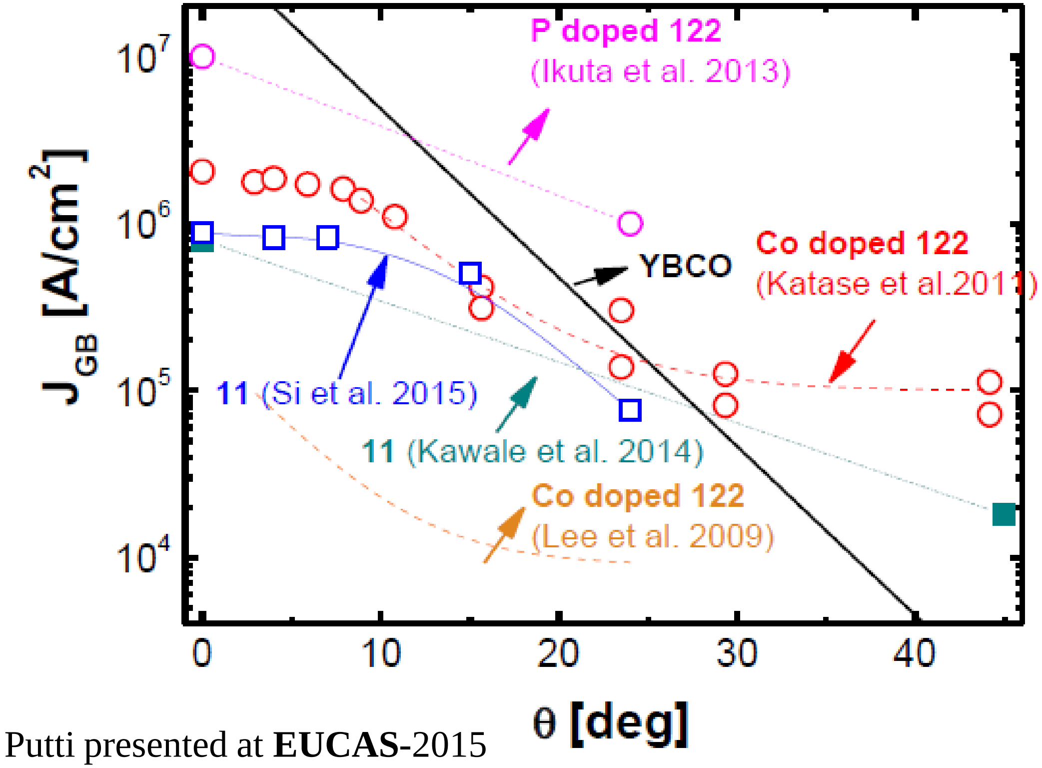


122 PIT wires are expected to be much cheaper than BSCCO conductors:

1. Many types of sheaths of Ag, Cu, Fe, and Ag-based composites (Ag/Fe, Ag/Cu, Ag/stainless steel) can be employed.

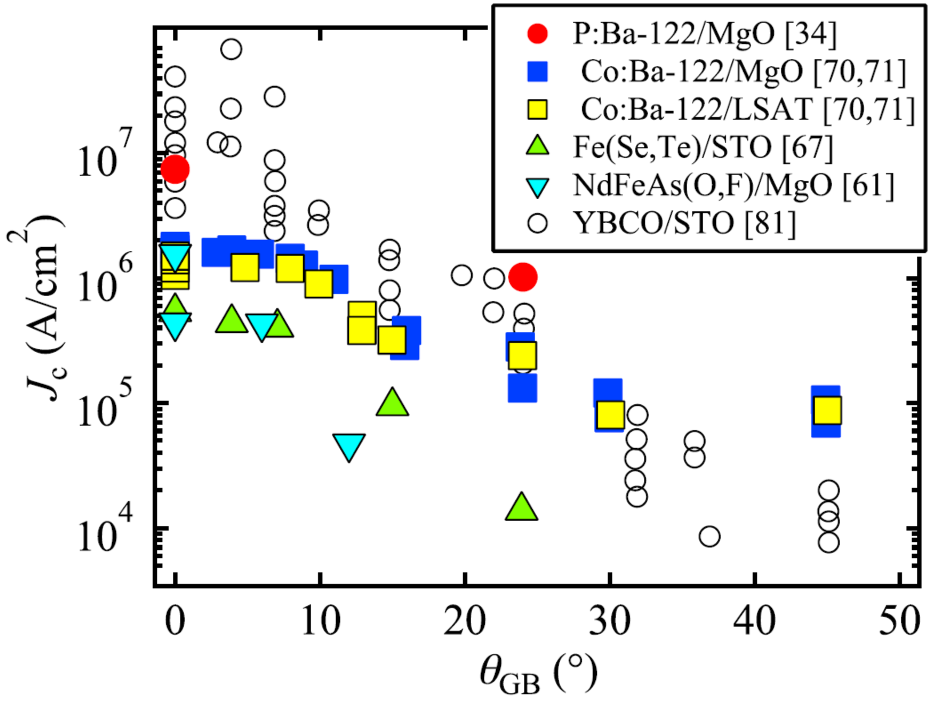
2. For BSCCO, Ag is the only material that is inert to the BSCCO superconductor and permeable to oxygen at the annealing temperature.

Misorientation dependence of J_c : GBs are less detrimental to current flow



M. Putti presented at **EUCAS**-2015

θ_{GB} dependence of inter-grain J_c for various IBS bicrystals



Iida et al., ***Appl Phys Rev*** 5 (2018) 031304

YBCO $\theta_c \approx 3°$ *vs* 122 IBS $\theta_c \approx 9°$ (The critical angle of GBs)

- **Misorientation angle of IBS grains < 9° usually do not impede the J_c flow**
- **Highly textured templates are not necessary: *PIT and low-cost CCs are possible***

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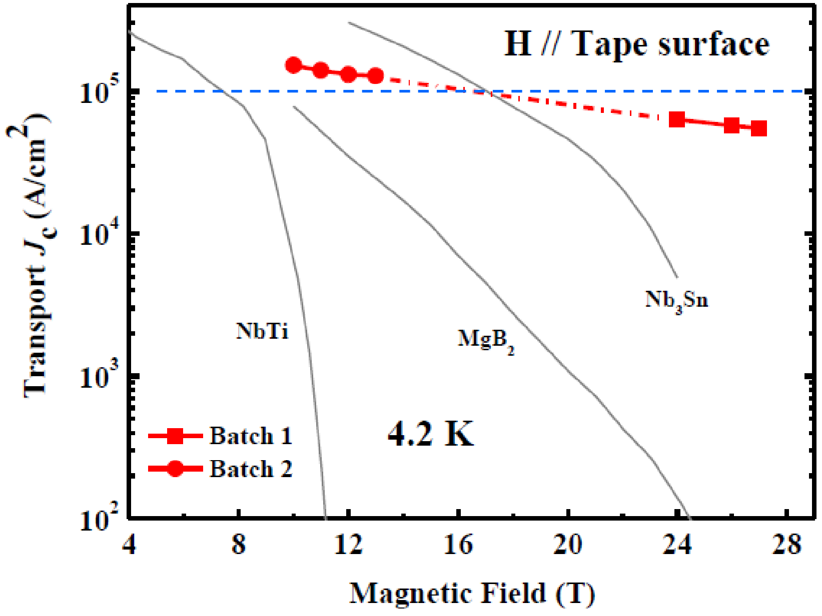
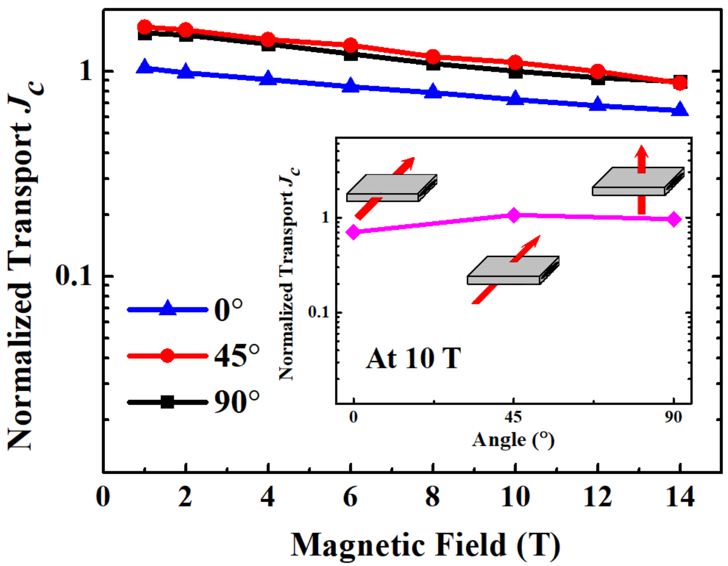
Powder-In-Tube 122 tapes: High J_c

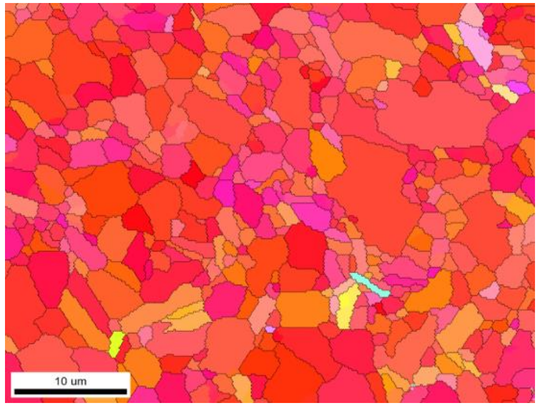
High J_c values were achieved in hot pressed (HP) Ba122/Ag tapes

Huang et al., *SuST* 31 (2018) 015017

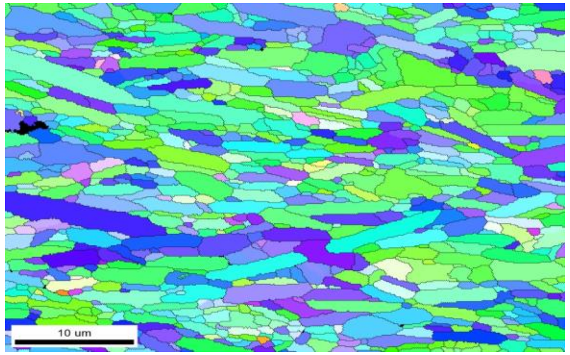




EBSD



The grains are aligned along the c-axis, most of the misorientation angles are 5-20



No apparent in-plane texture was found

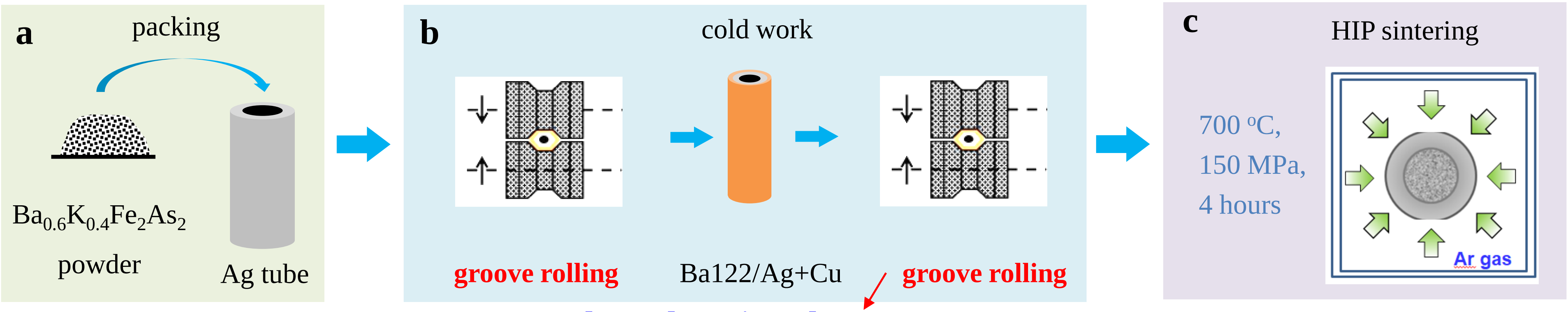
At 4.2 K, 10 T: J_c ~ 1.5×10^5 A/cm^2, I_c=437 A, γ = 1.37

18 T: J_c ~ 10^5 A/cm^2

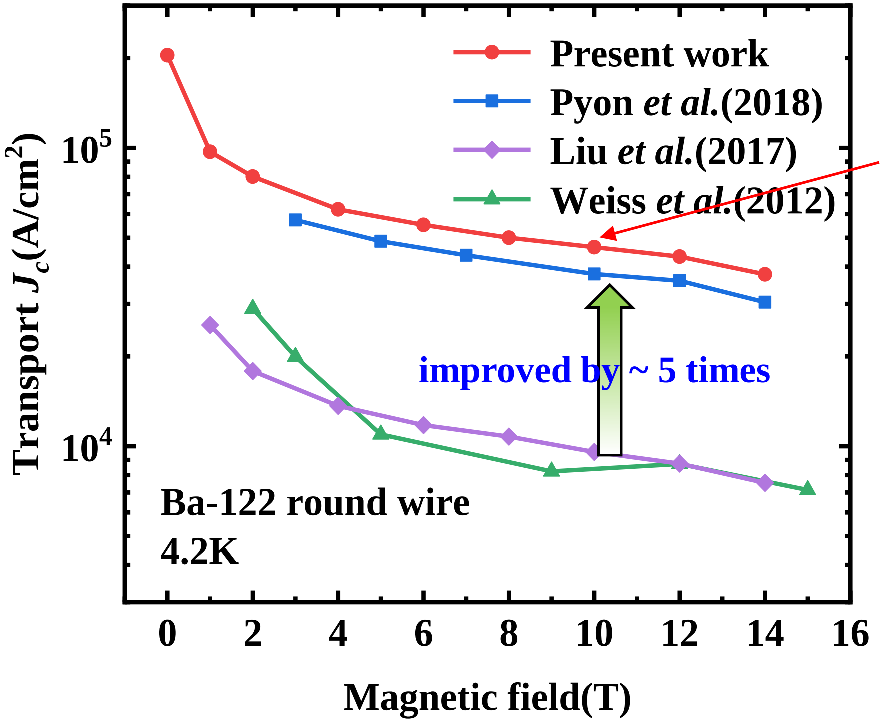
27 T: J_c ~ 5.5×10^4 A/cm^2

Latest: Record J_c of HP Ba122 tape= 1.81×10^5 A/cm^2 at 4.2 K, 10 T

High-J_c Ba-122 HIP wires improved by GR+HIP



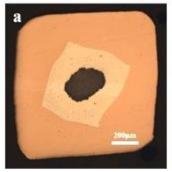
by enhancing the texture



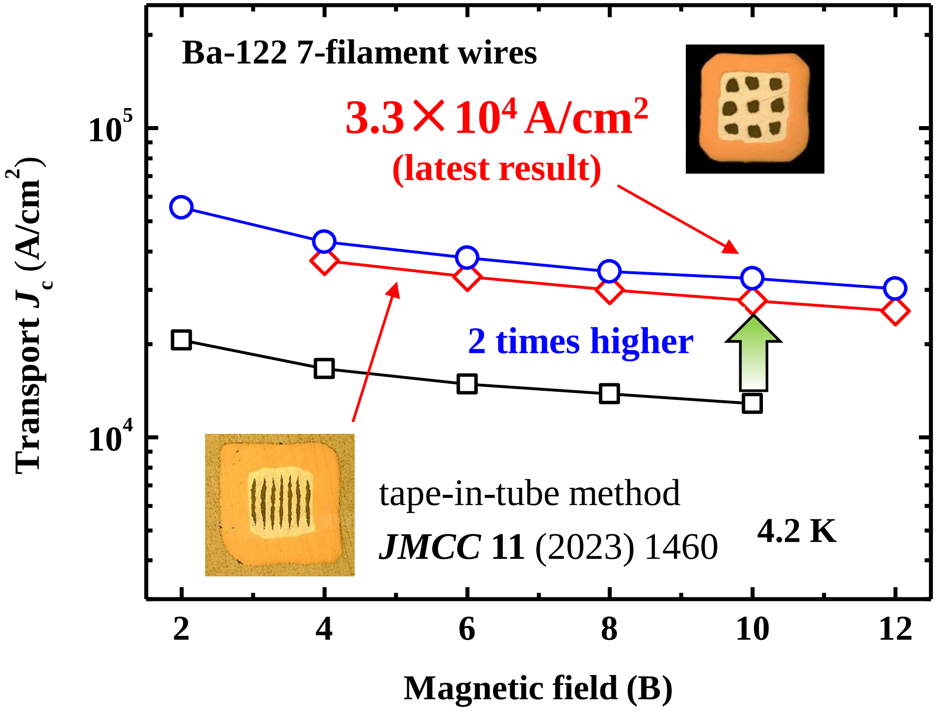
mono-core wires

4.7×10^4 A/cm²

(4.2 K, 10 T)



Cu/Ag sheath



SuST 34 (2021) 094001, *Physica C* 585 (2021) 1353870

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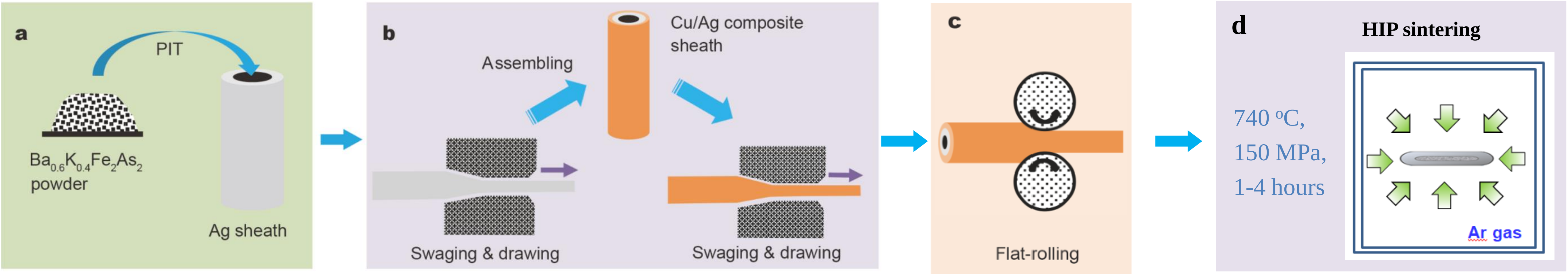
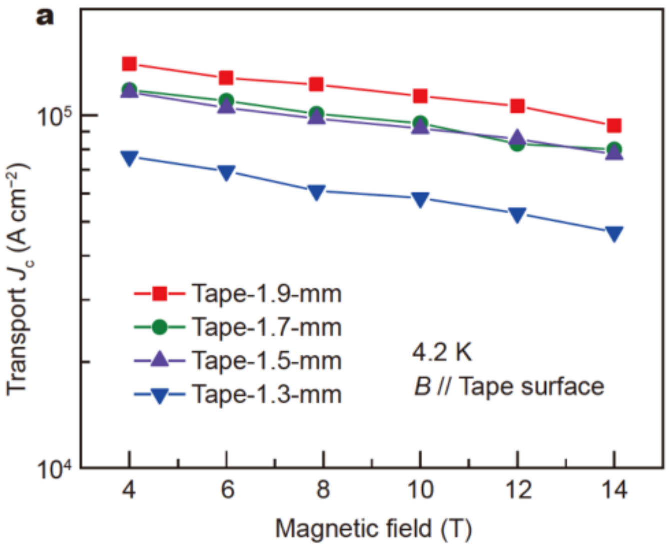
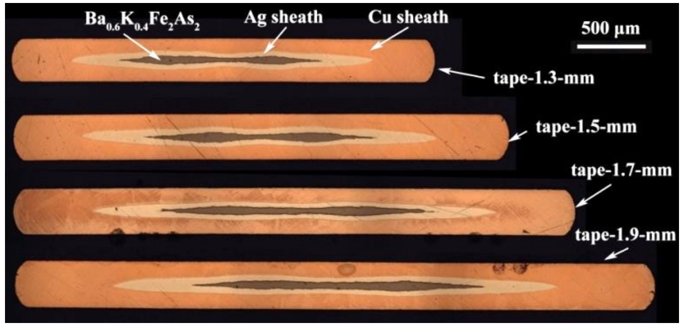
Cu/Ag sheathed Ba-122 tapes with practical level J_c







well textured grains

high core density

high transport J_c

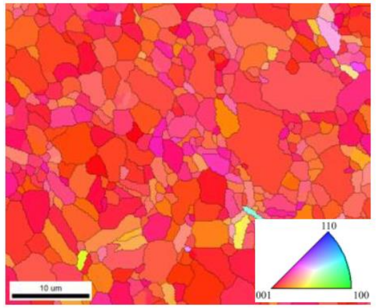
J_c (4.2 K, 10 T) = 1.1×10^5 A/cm^2

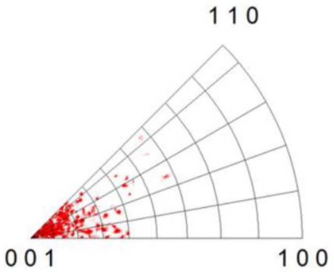
- J_c exceeding 10^5 A/cm^2 for the first time for Cu/Ag sheathed tapes
- A scalable and cost-effective fabrication route!

Liu et al., ***Sci. China Mater***. 64 (2021) 2503

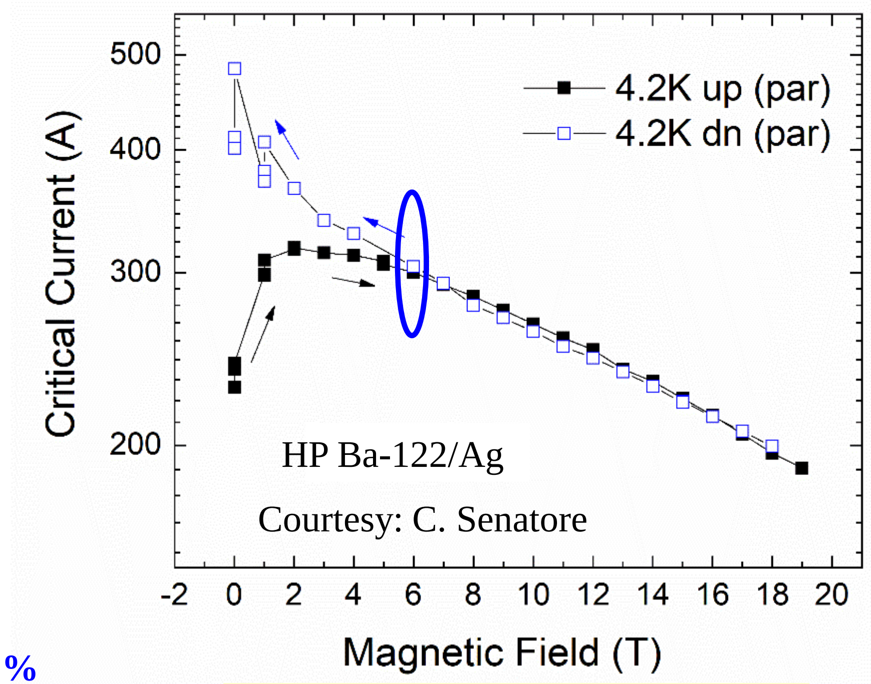
Comparison of hysteresis loops for HP and HIP 122 tapes

Hot Pressing





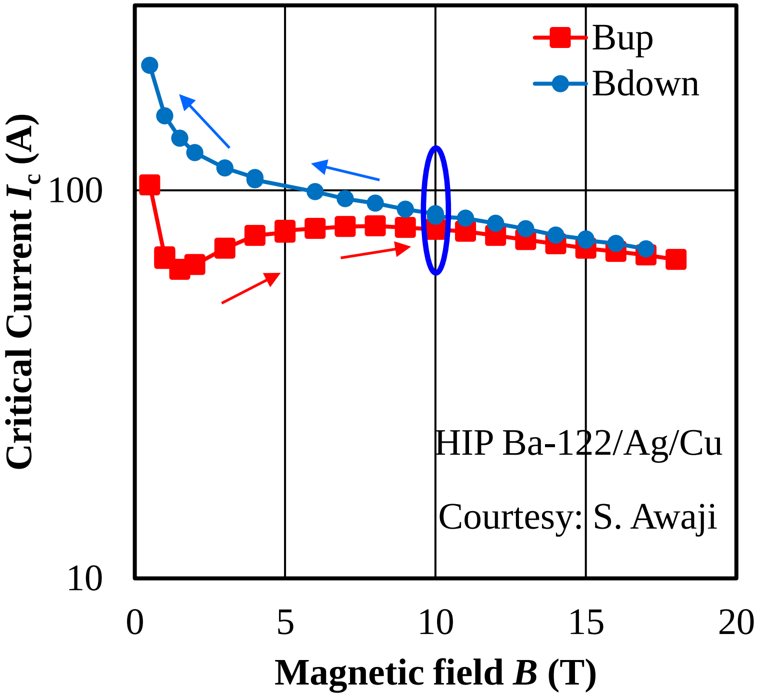
Fraction with θ<10º:~42 %

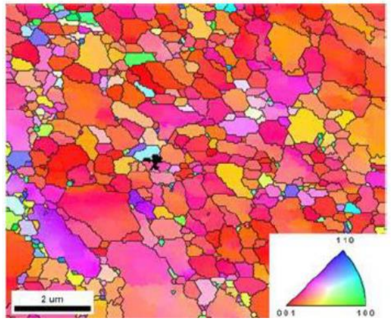


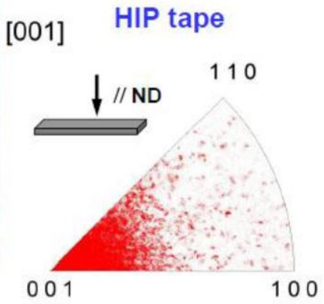
Bonura et al., ***SuST*** 33 (2020) 095008

J_c=1.8×10^5 A/cm^2 (10 T)

Hot Isostatic Pressing







Fraction with θ<10º:~10 %

J_c=1.1×10^5 A/cm^2 (10 T)

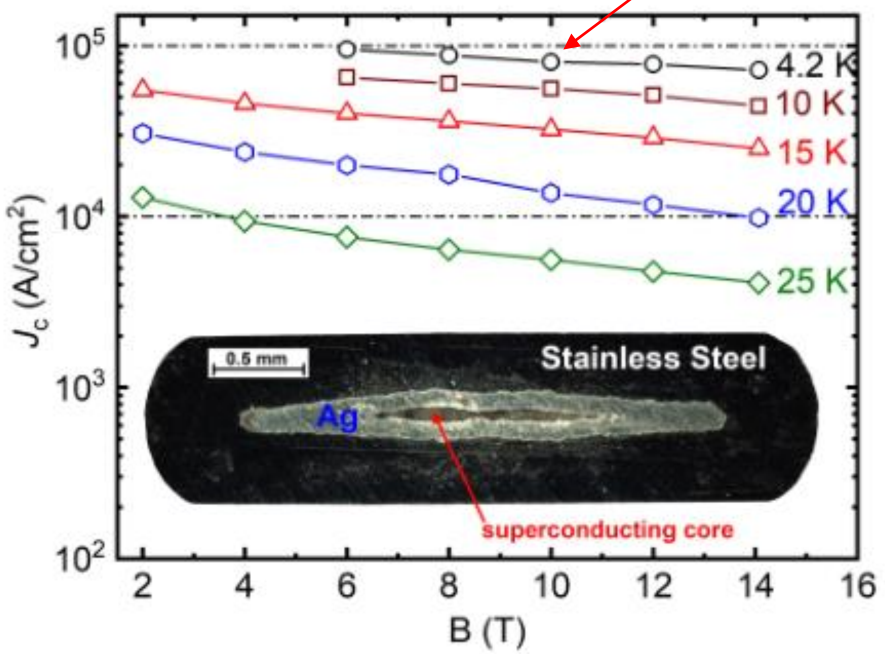
HP Temperature (880°C)
Grain size: ~3 μm
Lotgering orientation factor F: 0.87
Hv: ~140

Much room for the J_c improvement

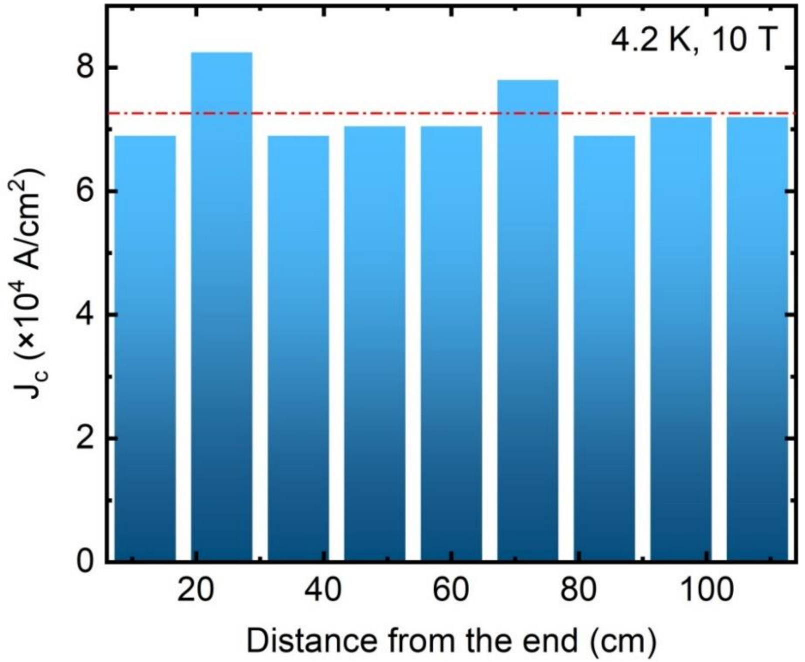
HIP Temperature (740 °C)
Grain size: ~0.5 μm
Lotgering orientation factor F: 0.46
Hv: >230

Powder-In-Tube 122 tapes: High J_c & high strength

High J_c values were achieved in Stainless Steel (SS)/Ag/Ba122 tapes, due to higher core density (Hv~230), the J_c is 8×10^4 A/cm^2 at 4.2 K and 10 T .



J_c distribution of 1.08 m SS/Ag/Ba-122 tape



High n value:

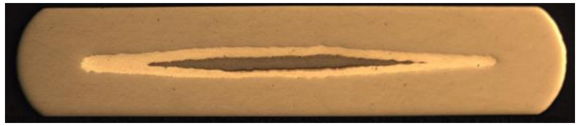
@10 K, 10 T, *n*~47

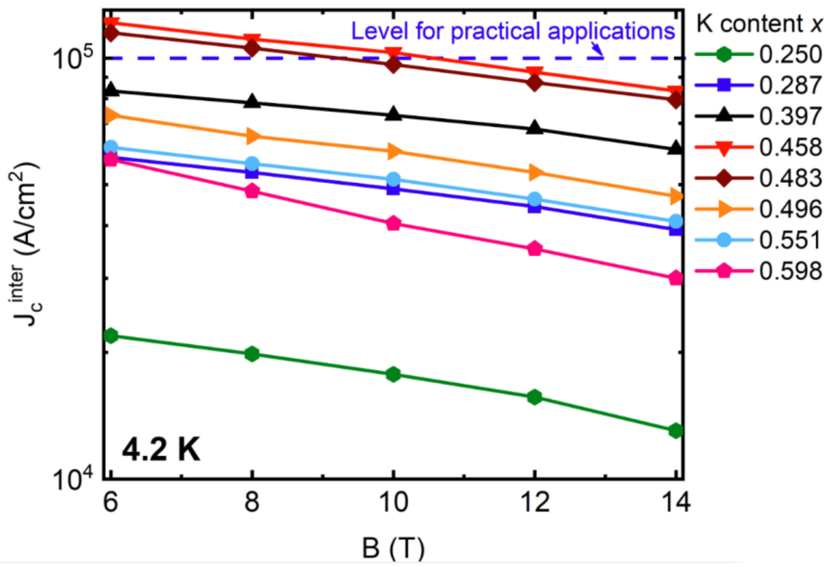
◆ **1.08 m long SS/Ag/Ba122 tape shows good J_c uniformity, the lowest J_c is over 7×10^4 A/cm^2.**

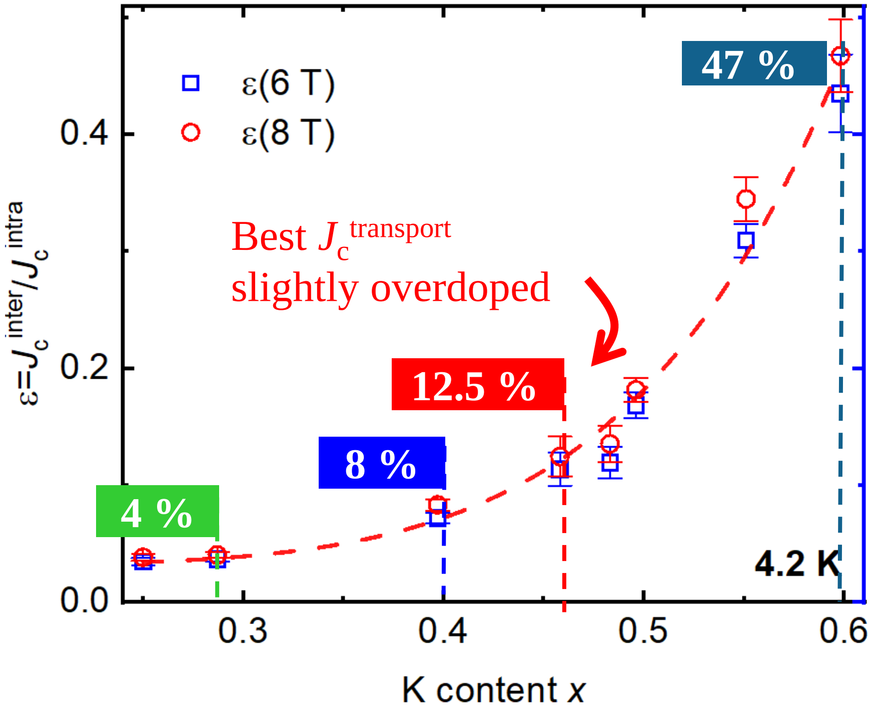
Dong et al., ***IEEE TAS*** 29 (2019) 7300504

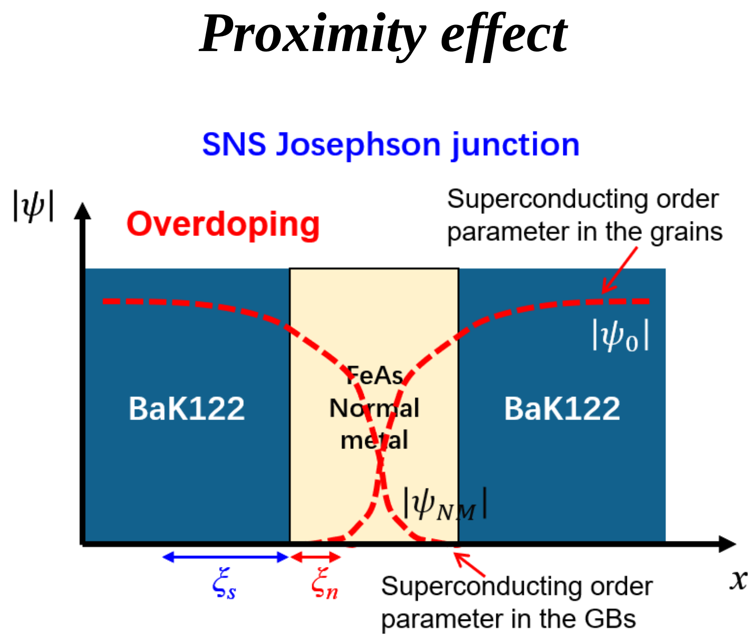
Critical current density of SS/Ag composite tapes

Stainless steel/Ag/$Ba_{1-x}K_xFe_2As_2$ tapes were made with a wide doping range ($0.25 \leq x \leq 0.6$)









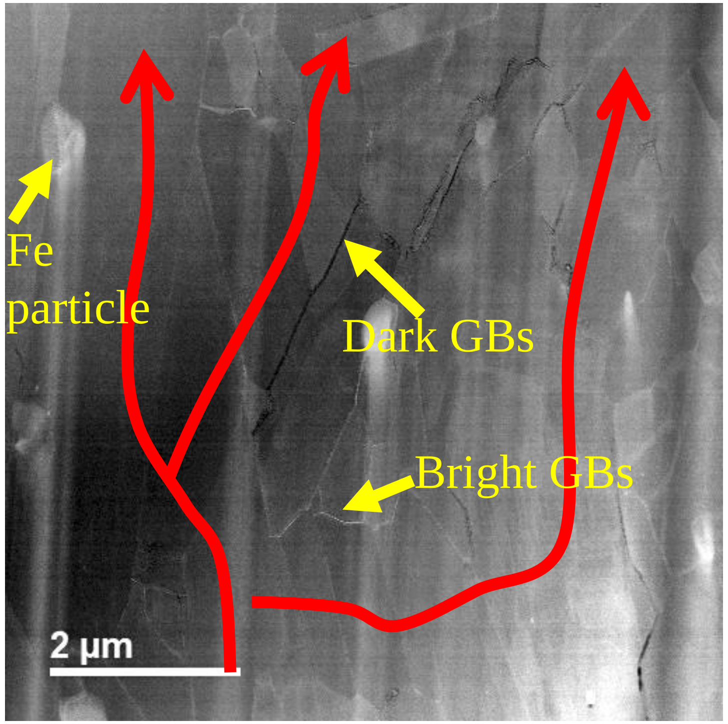
- The highest J_c^{trans} **>0.1 MA/cm^2** at x=0.458 @ 4.2 K, 10 T
- Grain boundary transparency parameter **$\varepsilon = J_c^{inter}/J_c^{intra}$ continuously increases with doping**
- ***Grain boundaries are contaminated by FeAs***, doping enhances proximity effect and inter-grain J_c.

Cheng et al., ***Mater. Today Phys.*** 28 (2022) 100848

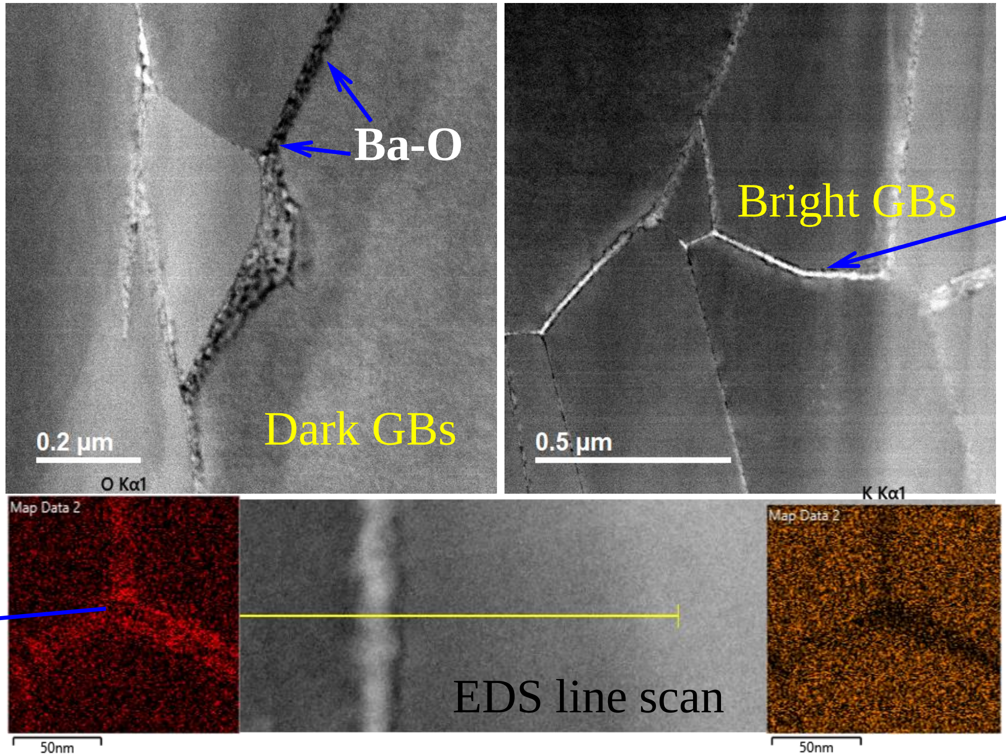
Bright field STEM for HP Ba-122 tapes: Second phases at GB

-- analyzed by Prof. Larbalestier group at FSU

HAADF



Many clear GBs in HP-122 tape



◆ **The state-of-art high J_c tapes still contain many contaminated GBs which disconnect the Ba122 grains. The J_c can be largely improved if we can eliminate these secondary phases.**

Kametani et al., *Appl. Phys. Express* 17 (2024) 013004

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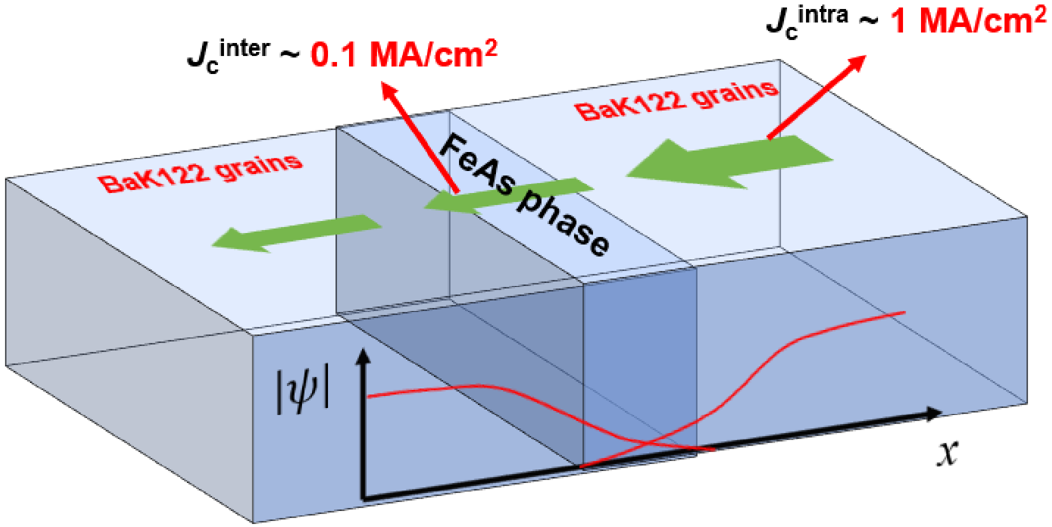
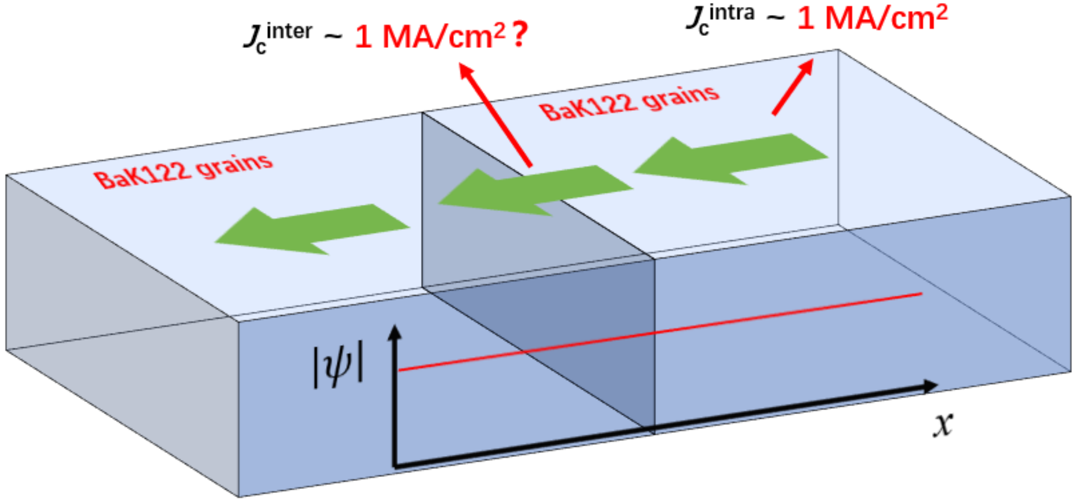
NEXT STEP for iron-based PIT wires?

Dirty grain boundaries



Clean grain boundaries

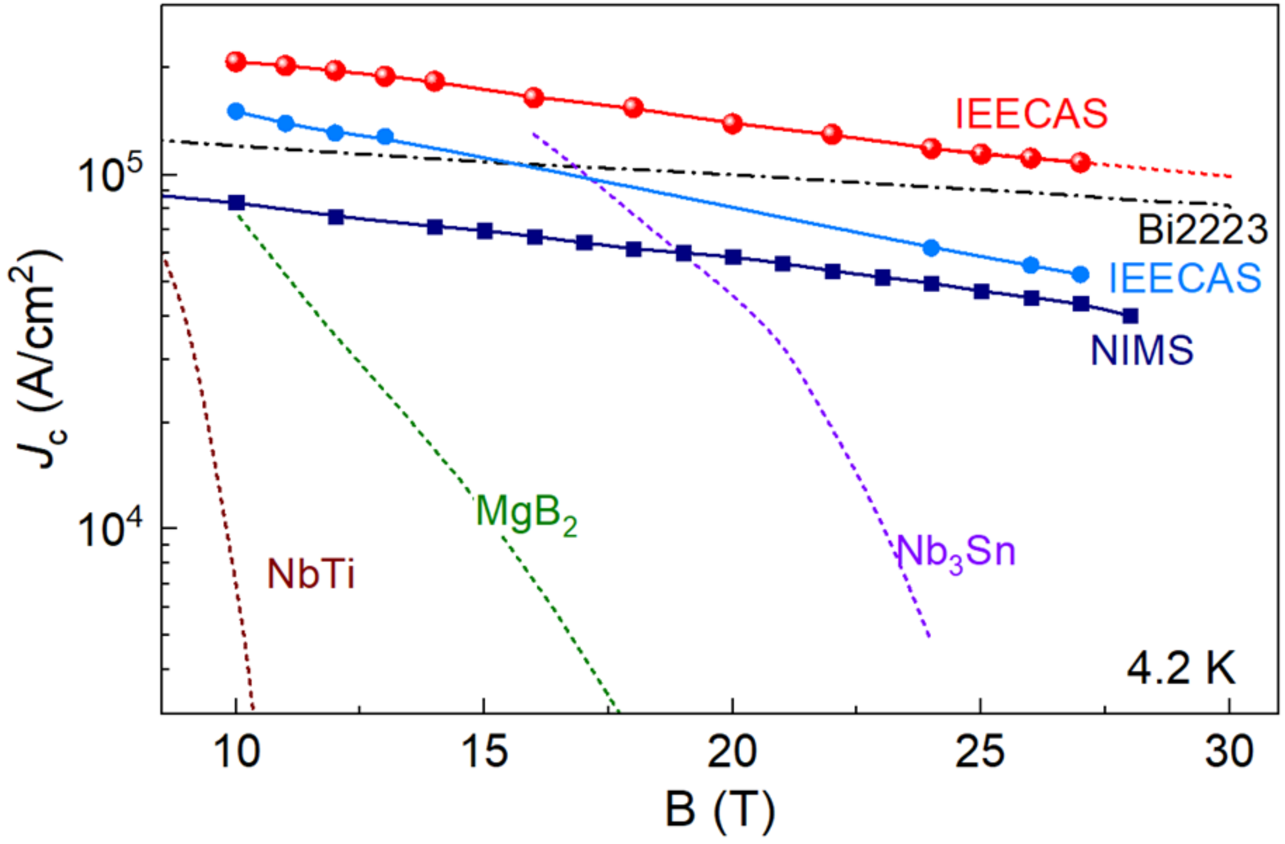


- Most GBs are contaminated by FeAs, largely limiting intergrain current transport
  - **Slightly overdoping is a good way to enhance J_c^{trans}**
- Clean GBs without FeAs phase is always the best choice!
  - **ε~100%** may be achieved in the **GBs without FeAs** (misorientation angle θ<9°)

But how to remove FeAs ?

New record high J_c in PIT SS/Ag Ba122 tapes

Special technique to remove FeAs wetting phase, details will be published soon.



No published data

New record !

- **High J_c @ 4.2 K :**
  - **J_c~2.2×10^5 A/cm^2 @ 10 T**
  - **J_c>10^5 A/cm^2 even @ 30 T**
- High mechanical strength
- Low material cost
- Easy fabrication process scalable to long length tapes

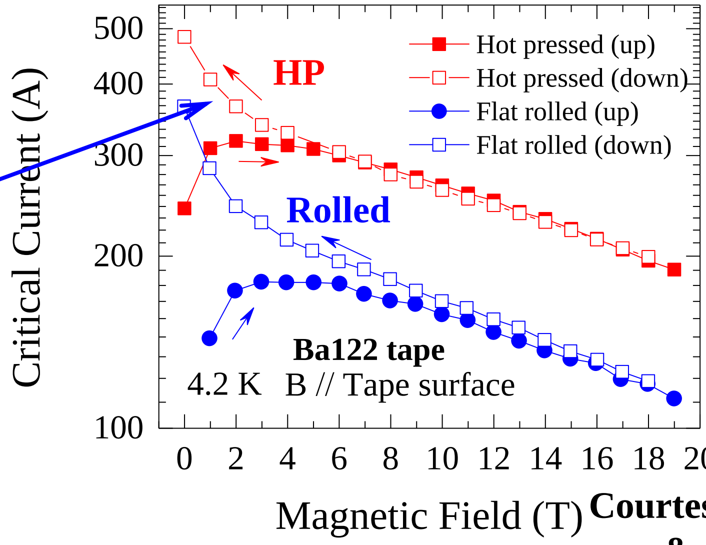
Very promising to be used in high field magnets!

Strategies to further improve J_c in 122 PIT wires

- **To further reduce secondary phases at GBs**

- **To improve the texture degree**

  especially increase the fraction of misorientation angle <9º.

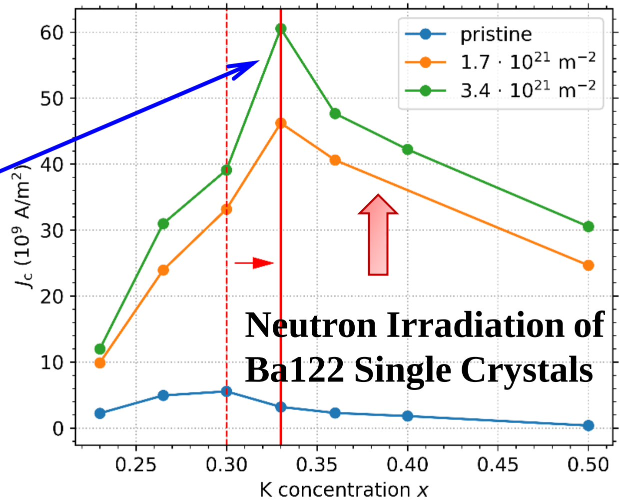


Courtesy: M. Bonura & C. Senatore

- **To further increase flux pinning force**

  (1) decrease grain size to make more GBs,

  (2) increase point pinning sites, *e.g.* irradiation or the introduction of nano-particle inclusion.



Courtesy: M. Eisterer

Outline

1 Background on iron-based superconductors (IBS)

2 Development of high J_c PIT 122 IBS wires

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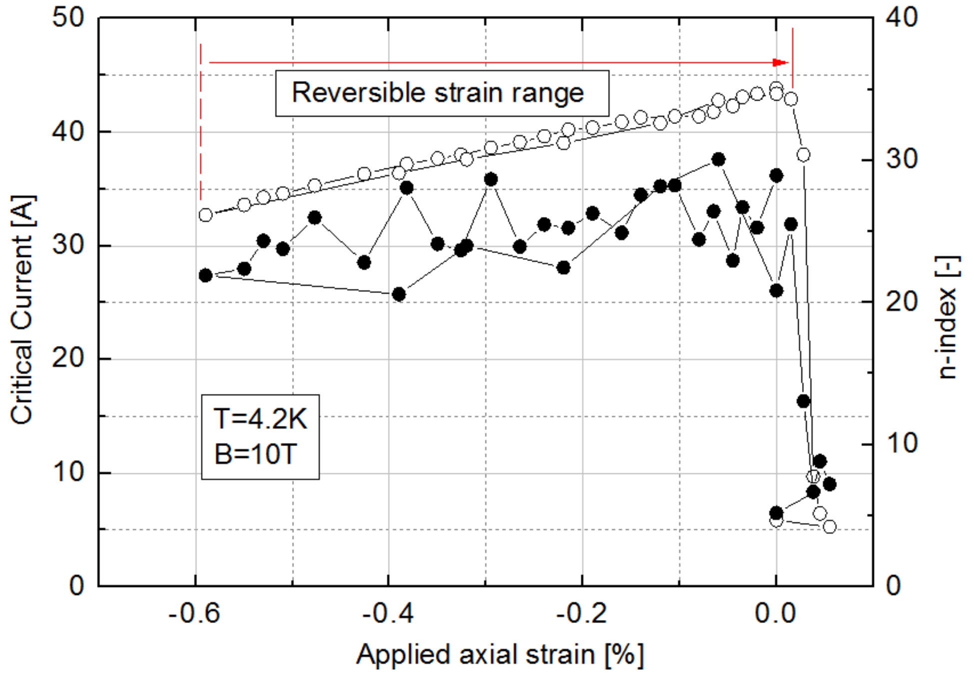
4 Recent advances in long-length wires, joints, pancake & racetrack coils, cables

5 Conclusions and outlook

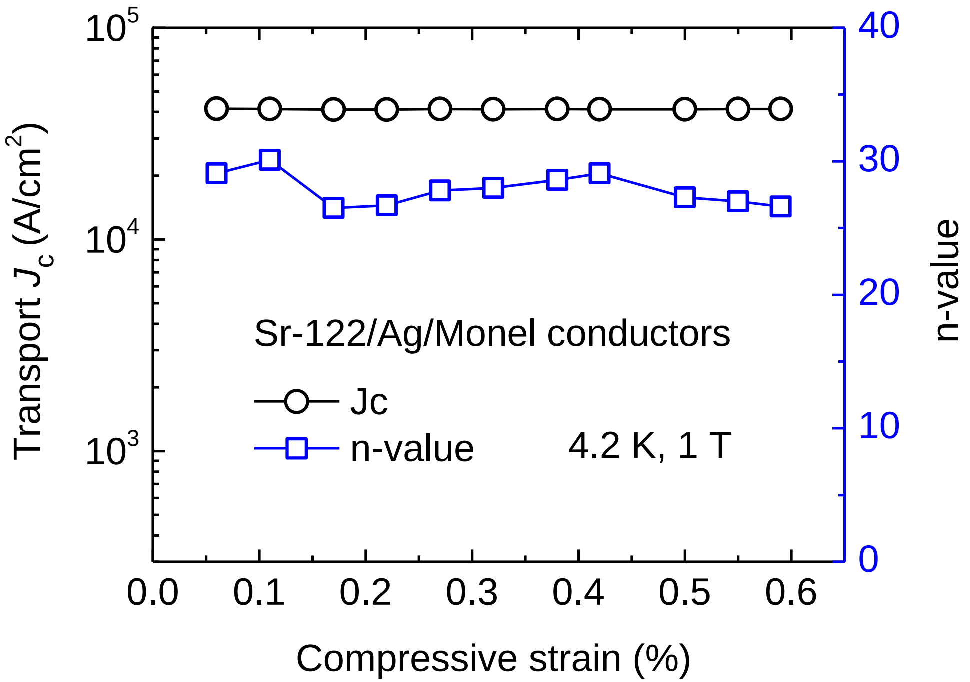
122 tapes – Strain properties

Sr-122/Ag tapes



Liu et al., *SuST* 30 (2017) 07LT01

7-filament Sr-122/Ag/Monel tapes



Yao et al. 2017 *SuST* 30 075010

Reversible critical currents under a large compressive strain of ε = –0.6%

Almost no J_c degradation under a large compressive strain of 0.6%

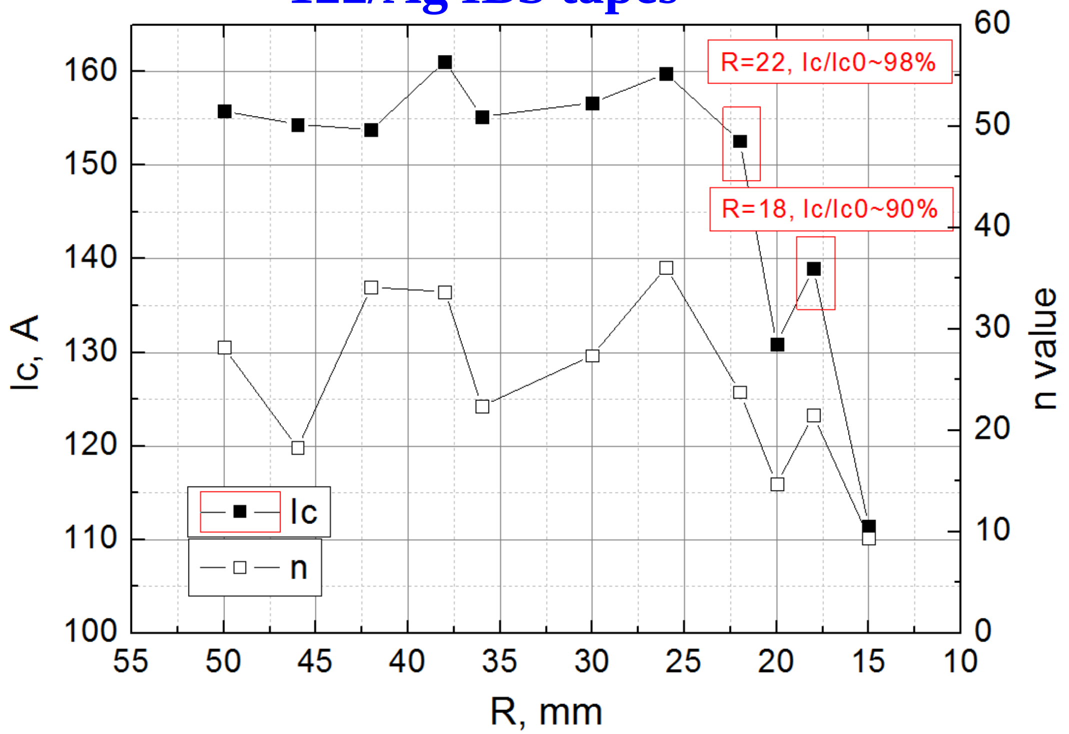
The I_c of 122 tapes exhibits less strain sensitivity than that of the Nb_3Sn, which is important for ITER application.

Straight ⇒ Bent ⇒ Straighten

Bending test of 122 IBS tapes

--Heated samples

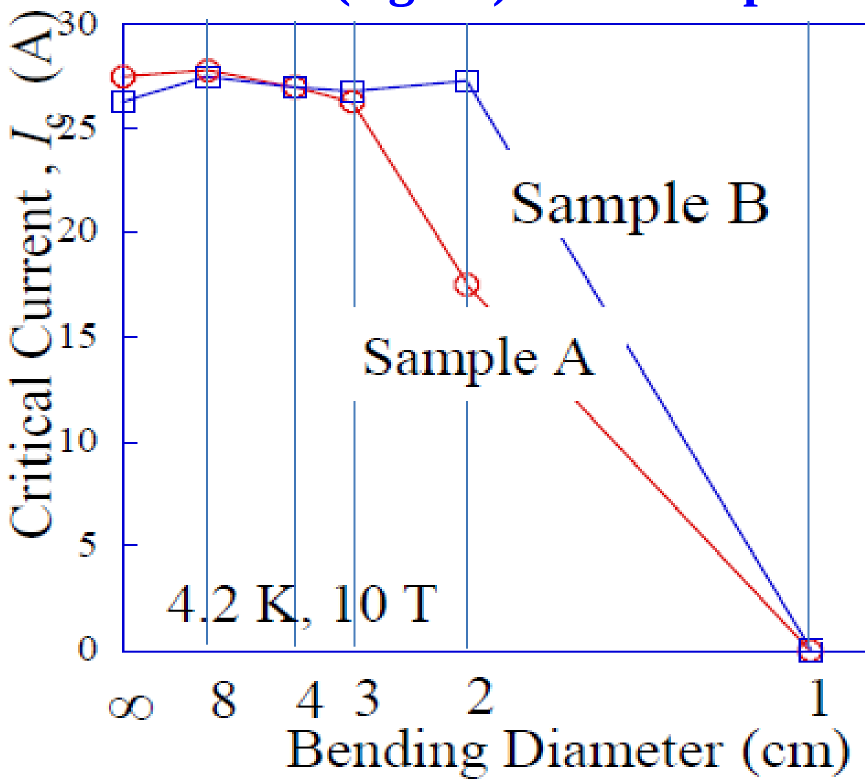
122/Ag IBS tapes



width ~ 4.5 mm, thickness = 0.3 mm

Cooperated with Prof. Huajun Liu in IPP-CAS

SUS/(Ag-Sn)/Ba-122 tapes

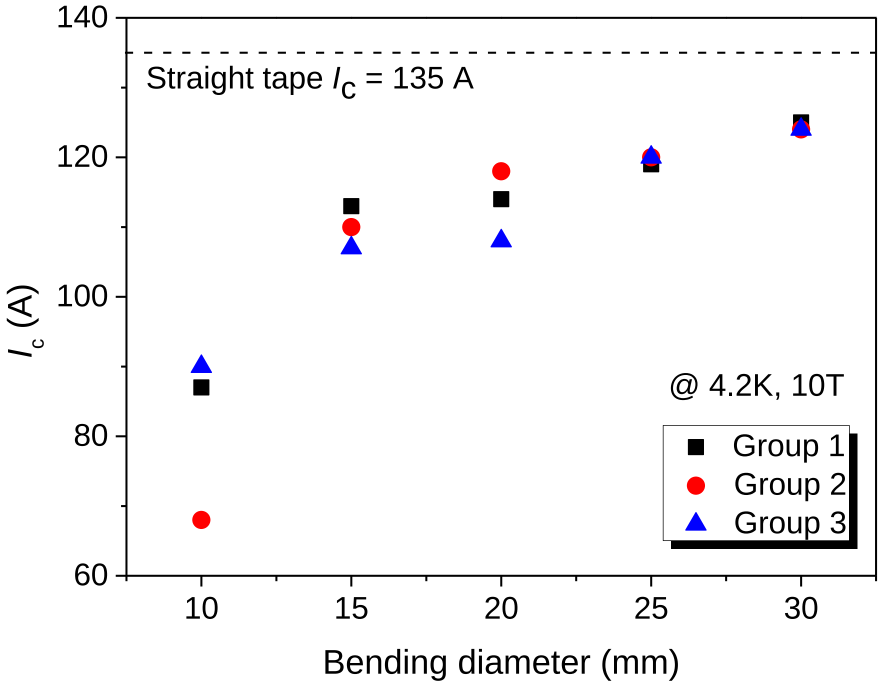


Courtesy of H. Kumakura

- **The critical bending diameter is 4.4 cm for Sr-122/Ag tapes in thickness of 0.3 mm.**
- **For high strength Ba-122 tapes, the bending diameter is even smaller, only of 2~3 cm.**

IEEE-CSC, ESAS and CSSJ SUPERCONDUCTIVITY NEWS FORUM (global edition), Issue No. 56, March, 2024. Invited presentation given at ISS 2023, Nov. 2023, Wellington, New Zealand

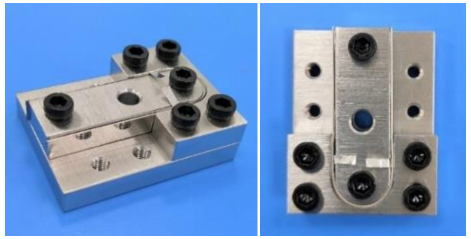
Bending diameter of 7-filament 122/Ag tapes

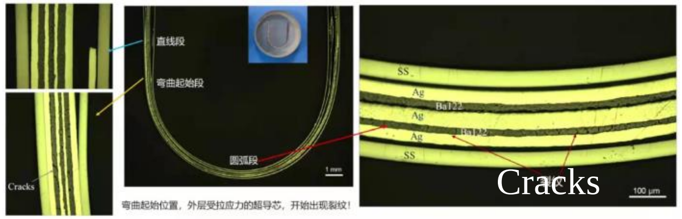


By courtesy of Prof. Q. Xu at IHEP-CAS

Ratio = I_c (bending) / I_c (pristine~135A)

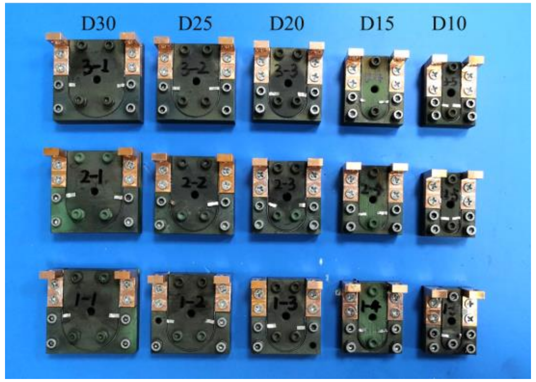
- ✓ **Good retention above Φ15 mm**
- ✓ **Rapid decrease of I_c in the D10 sample**





Cracks in the D10 sample

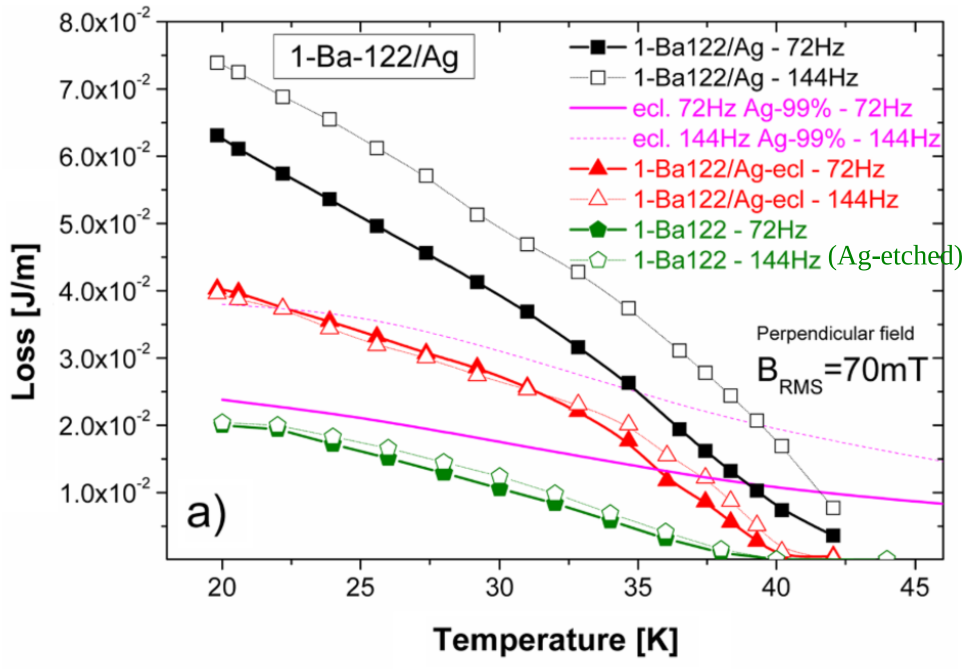
Ic@4.2K/10T	D10	D15	D20	D25	D30
Group 1	90	113	114	119	125
Group 2	70	110	118	120	124
Group 3	95	107	110	121	125
Average Ic (A)	85	110	114	120	125
Ratio (%)	63.0%	81.5%	84.4%	88.9%	92.6%



Li et al., ***IEEE TAS*** 32 (2022) 7300304

122/Ag tape – Magnetization AC loss

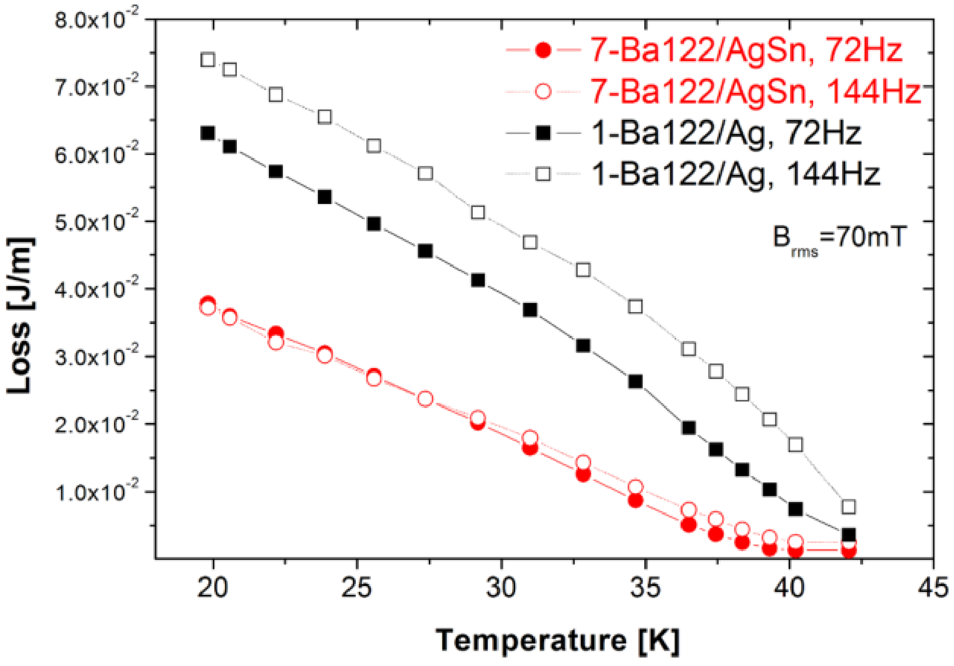
single-core tapes



$$Q_{\text{1-Ba122/Ag – ecl}} = Q_{\text{1-Ba122/Ag}} - Q_{\text{ecl Ag-99\%}}$$

Due to highly conductive Ag sheath, large eddy current losses (ecl) was observed for single-core tape

single-core tapes *vs* 7-core tapes

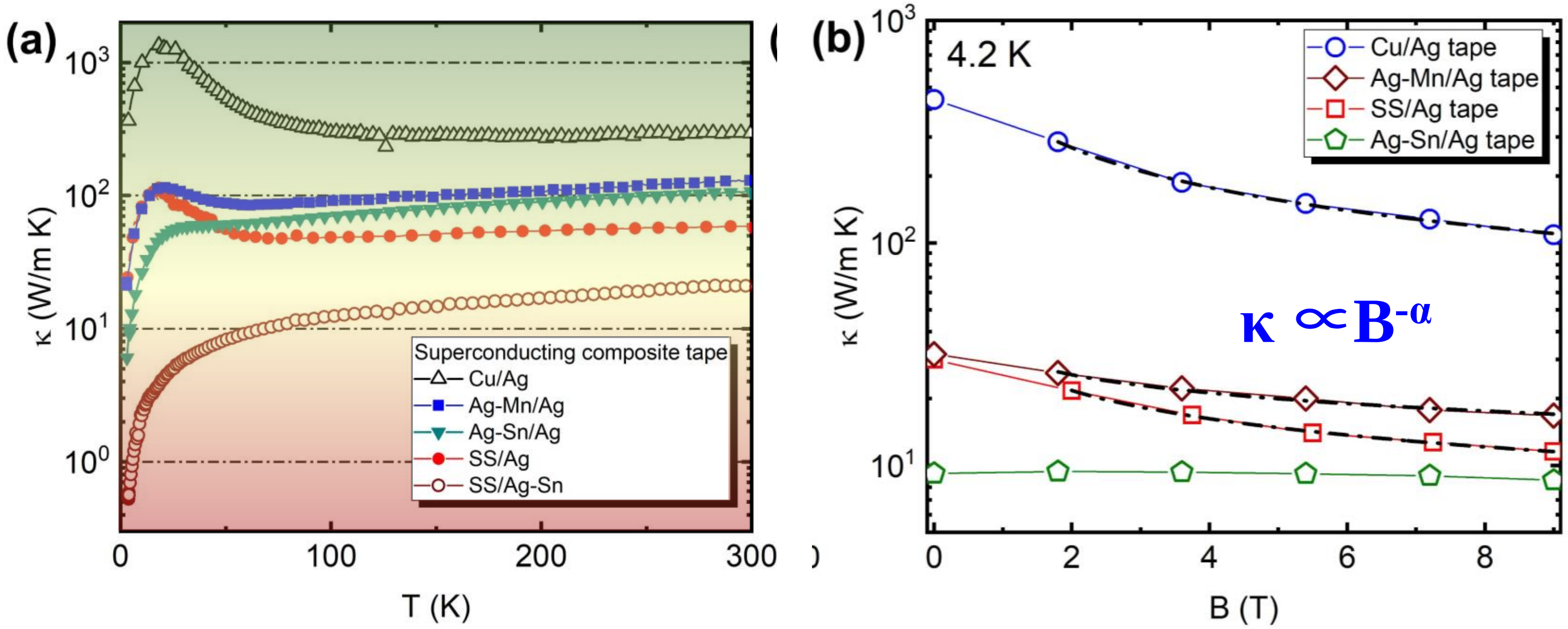


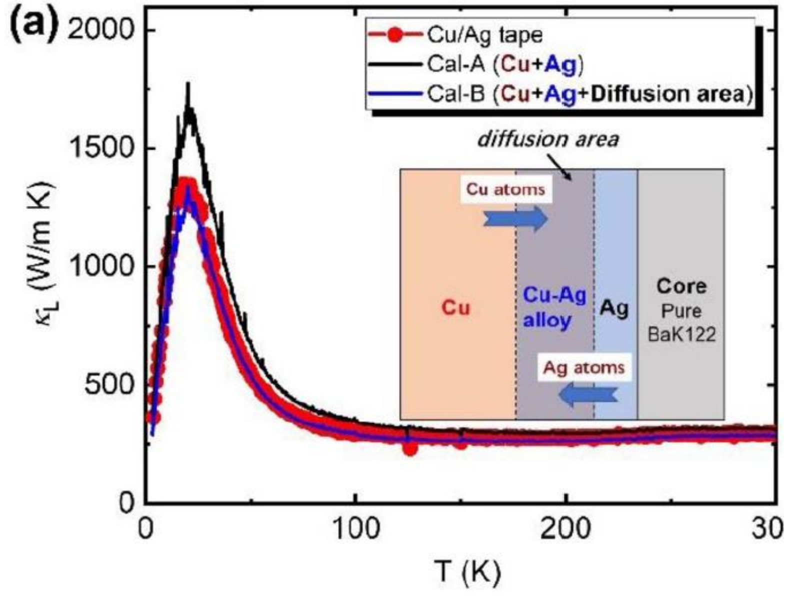
- **The AC loss for 7-core tapes reduced by ~50% at 20 K,**
- **due to the negligible eddy current losses by using more resistive AgSn alloy outer sheath.**

Kovac et al., ***Cryogenics*** 116 (2021) 103281

*The difference observed between the extracted Q_{ecl} (red lines) and those measured for etched Ag (green lines) could be attributed to different J_cs due to sample degradation

Thermal conductivity of composite Ba122 tapes





- ❑ **Thermal properties are dominated by the sheath materials**
- ❑ **The thermal conductivity ranges from 1 to 1000 W/m K by adjusting the sheath materials**

  @4.2 K： Cu/Ag: 400 W/m K at 0 T; >100 W/m K at 9 T--magnets

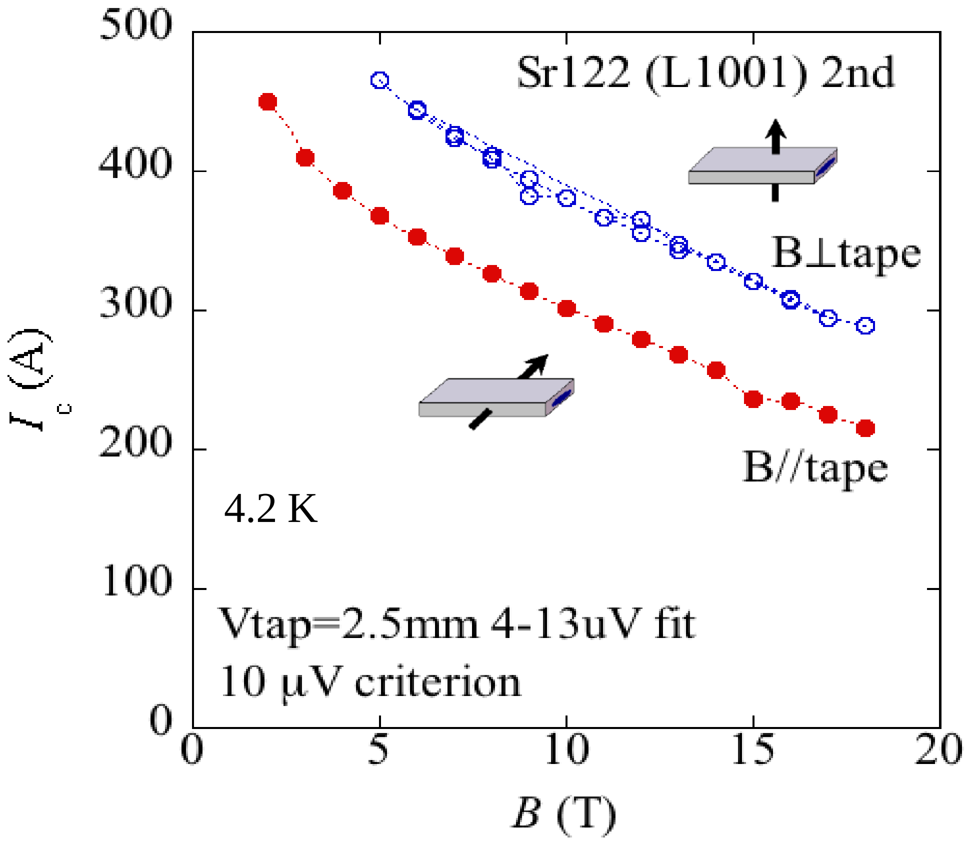
  SS/Ag: ~10 W/m K-- current leads

- ❑ **Atoms diffusion between different sheathes and superconducting cores**

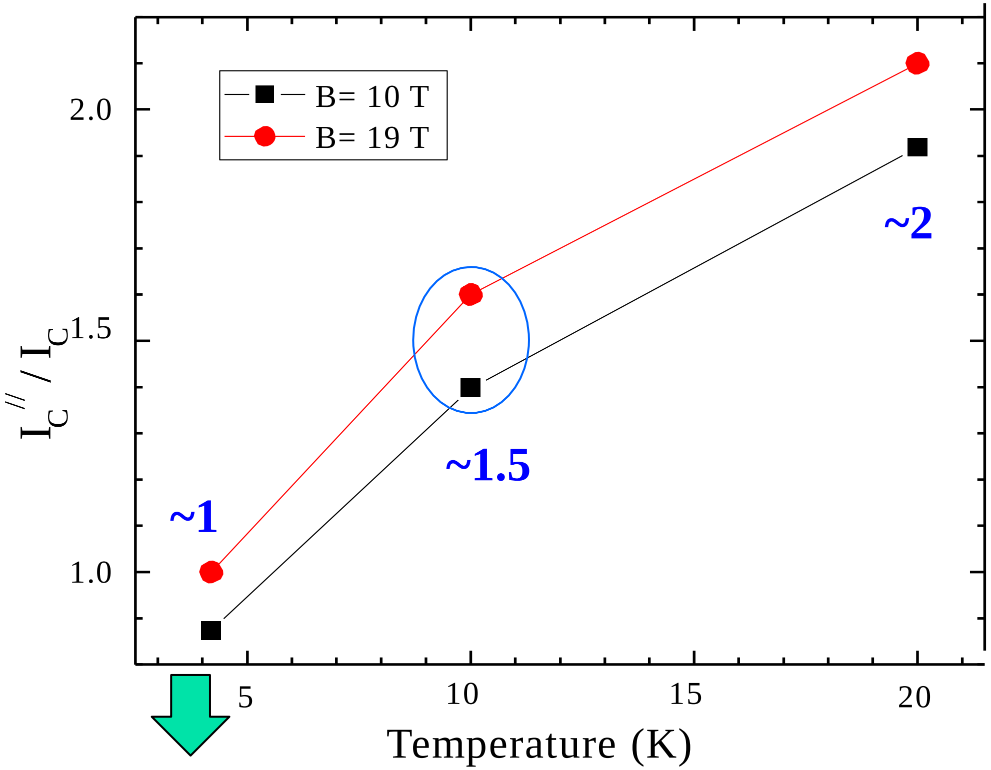
Supercond. Sci. Technol. 33, 075010 (2020)

J_c anisotropy of 122/Ag tapes

Awaji et al., ***SuST*** 30 (2017) 035018



Senatore et al., ***SuST*** 33 (2020) 095008

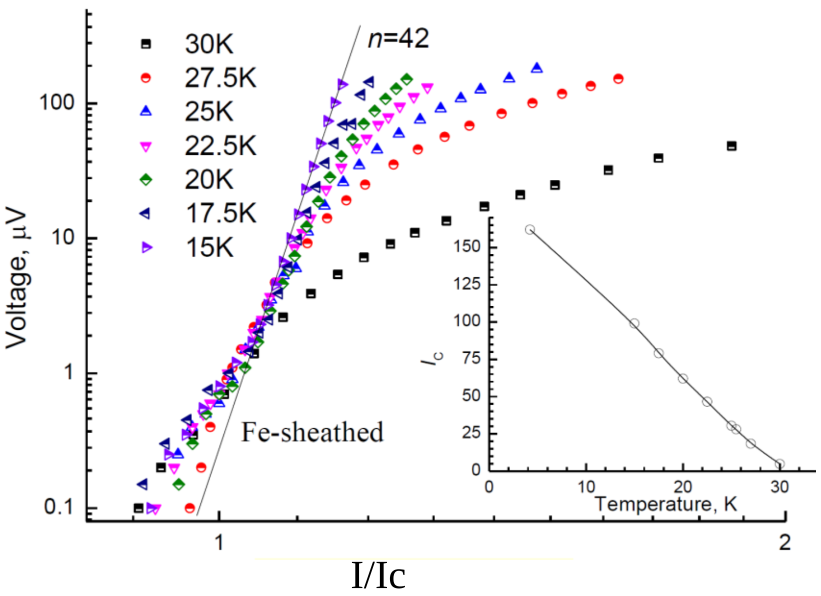


$I_{c//} < I_c$ only at low temperature and fields

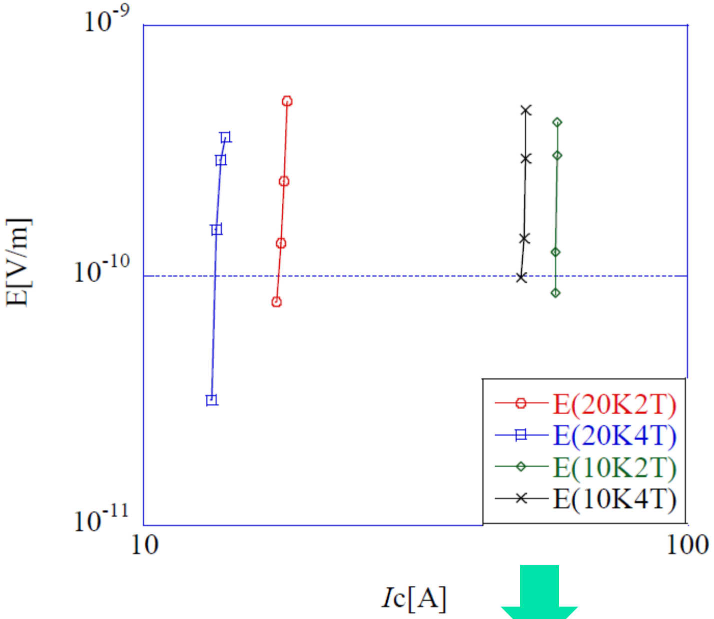
- **The I_c in applied magnetic fields is slightly higher in the perpendicular field ($I_c^{\perp}$) than in the parallel field ($I_c^{//}$).**
- **The anisotropy ratio ($\Gamma = I_c^{\perp}/I_c^{//}$) is quite low, less than 2, very good for applications.**

n value of 122 tapes

Measured by Prof. Yang
Univ. of Southampton, UK

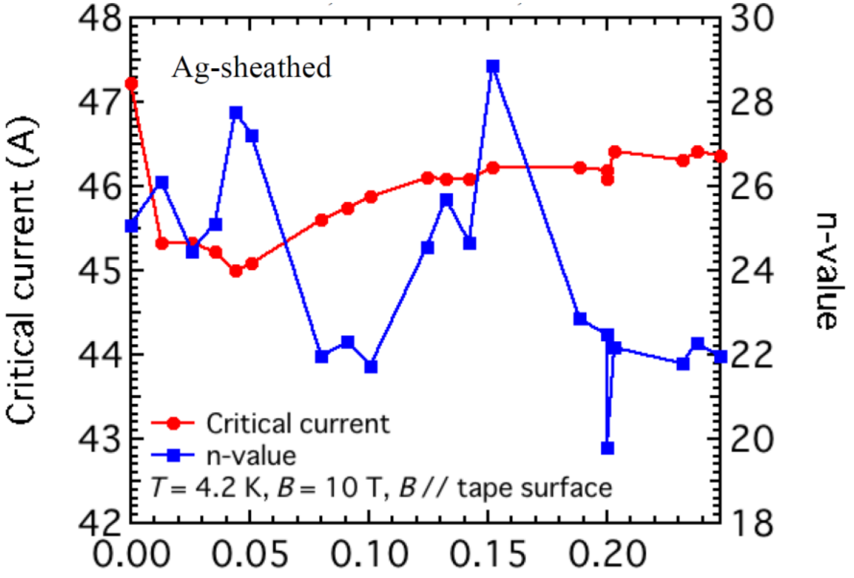


Measured by Prof. Kiss
Kyushu Univ., JP



Temperature & Field	n value
10 K & 2 T	143.4
10 K & 4 T	77.9
20 K & 2 T	43.9
20 K & 4 T	39.4

Measured by Dr. Oguro
HFLSM, Tohoku Univ., JP



At 20 K, the *n value* was over 30

At 4.2 K, 10 T, the *n value* was over 20

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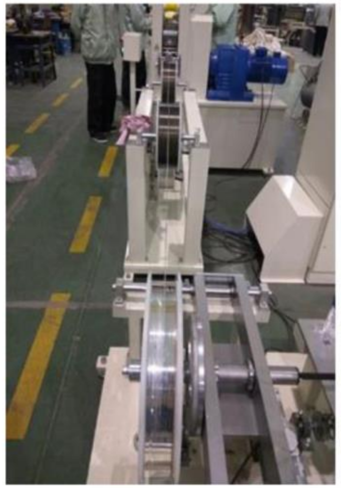
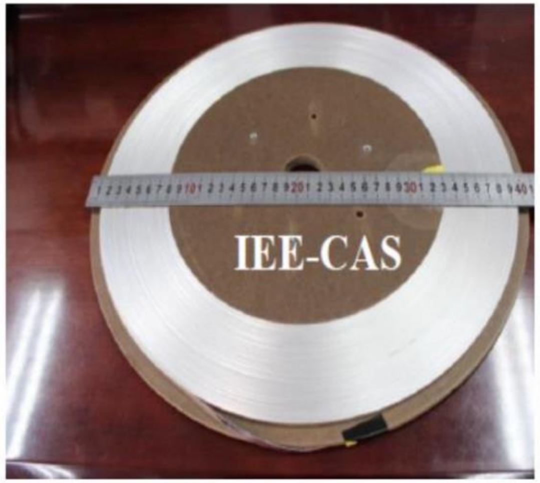
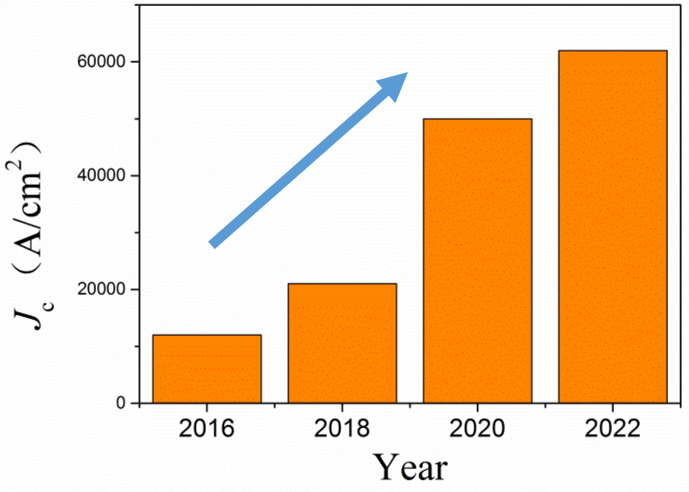
IEEE-CSC, ESAS and CSSJ SUPERCONDUCTIVITY NEWS FORUM (global edition), Issue No. 56, March, 2024. Invited presentation given at ISS 2023, Nov. 2023, Wellington, New Zealand

Powder-In-Tube 122 tapes: Long length

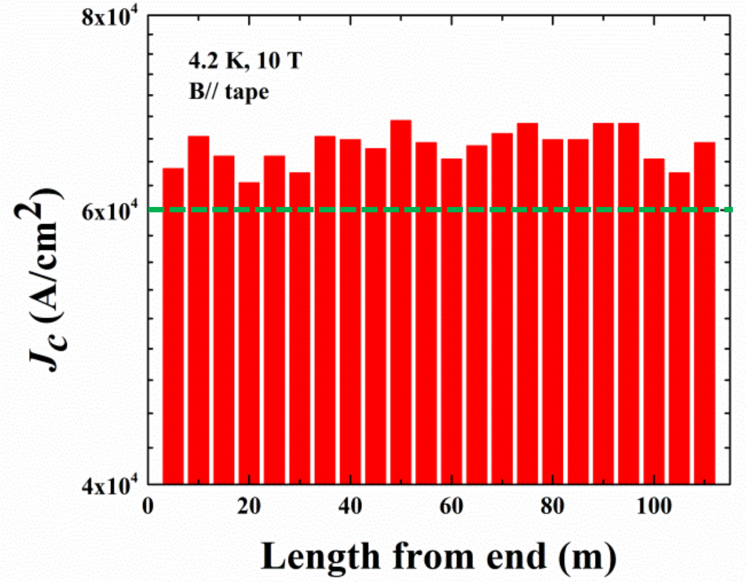
100 m long, 7-core Ba122 tapes are fabricated by rolling process, and the J_c is continuously improving.







@4.2 K, 10 T, transport J_c >60000 A/cm^2



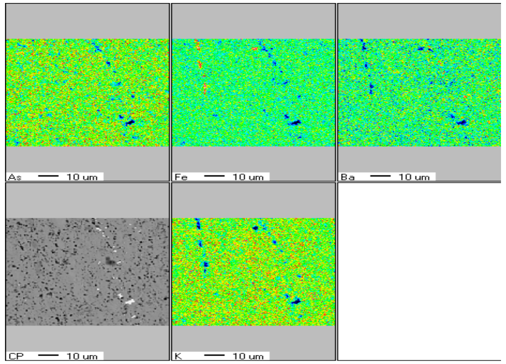
Recently, the J_c of long wires has been increased above 6×10^4 A/cm^2 @ 4.2 K, 10 T by optimizing fabrication process

Supported by the Strategic Priority Research Program of Chinese Academy of Sciences (Grant No. XDB25000000)

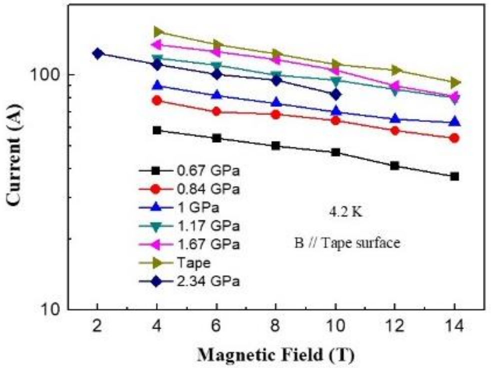
Powder-In-Tube 122 tapes: Superconducting joints

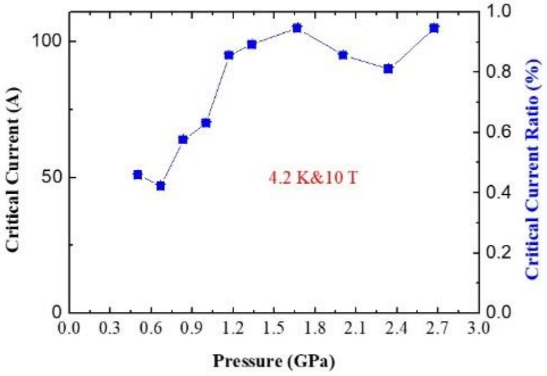
Cold pressing

High-quality IBS joint

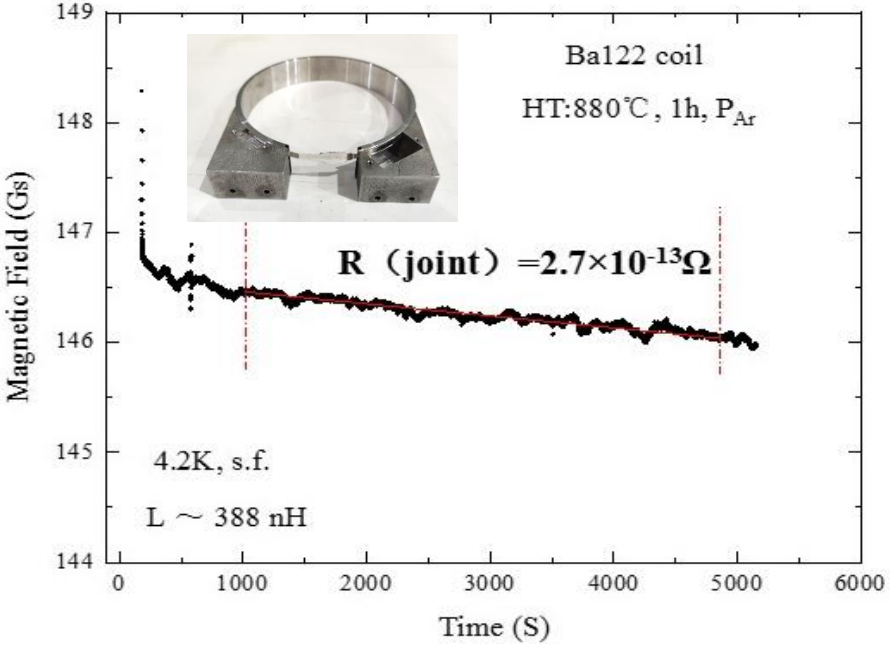


95 % @ 4.2 K, 10 T





for persistent current operation

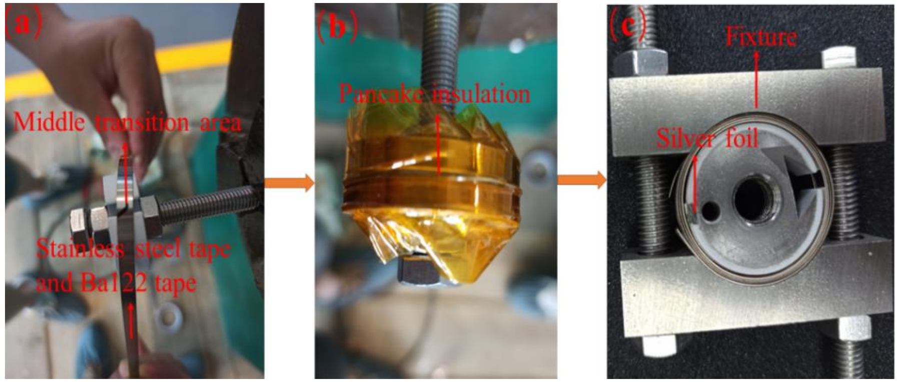


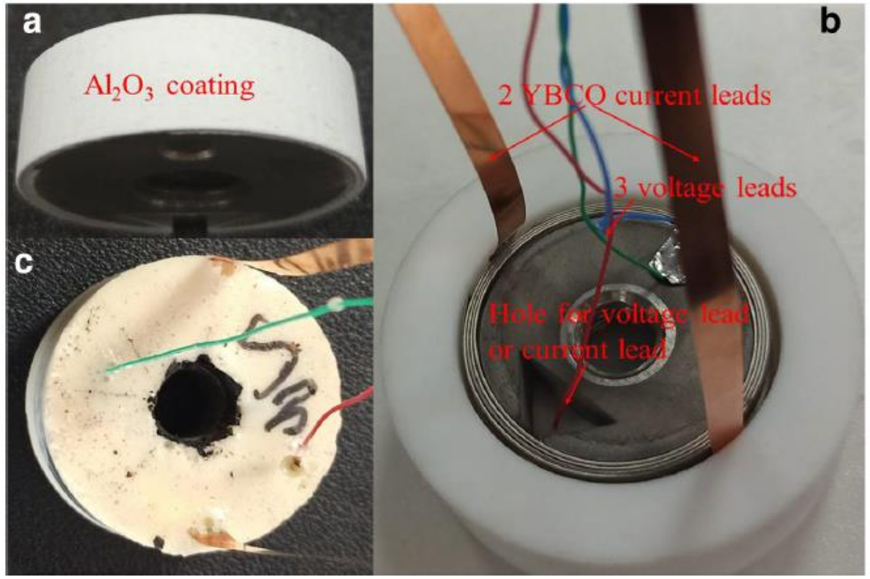
IBS closed-loop coil test

- **High-performance joints were developed for IBS tapes, with a high critical current ratio (CCR) of 95%.**
- **The IBS joint was tested in a closed-loop coil, showing a low resistance of 2.7×10^{-13} Ohm.**
- **Meet the application requirements in persistent mode MRI magnets.**

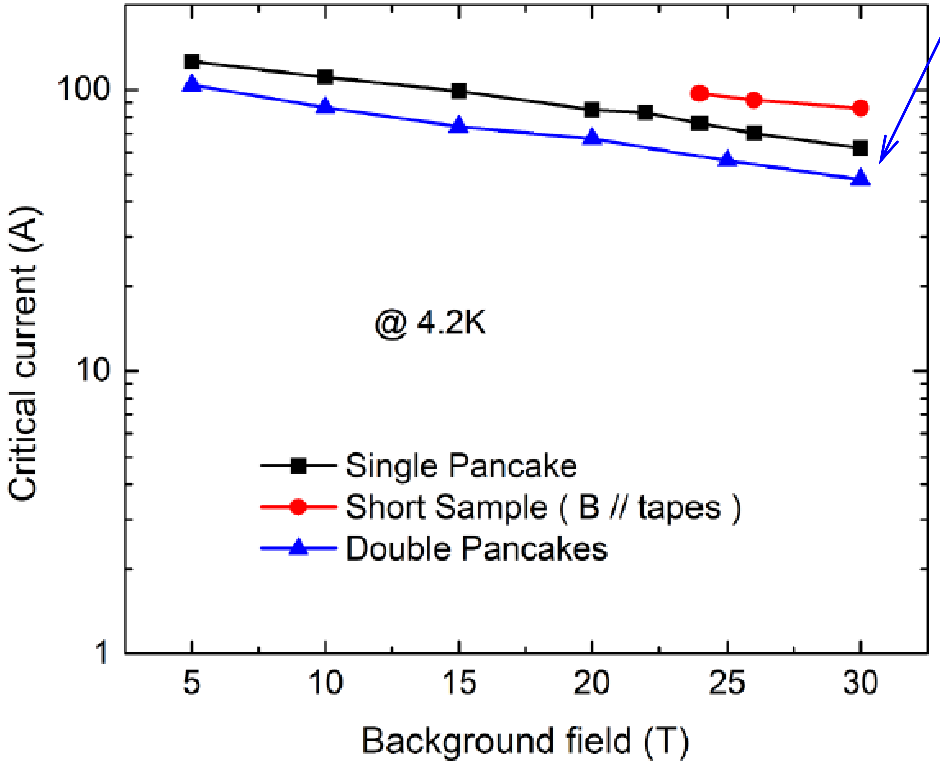
Zhu et al., ***SuST*** 35 (2022) 03LT01

Powder-In-Tube 122 tapes: Pancake coils





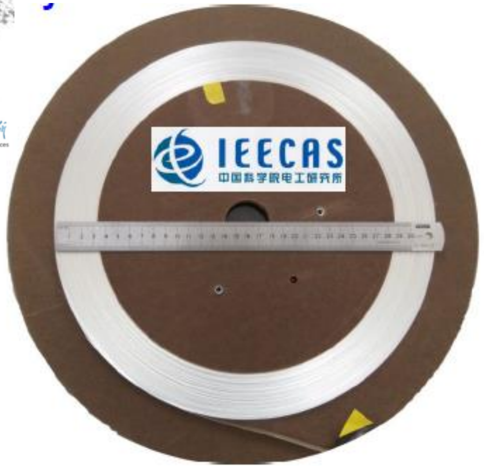
New IBS pancake coils have been made, measured up to very high fields reaching 62 A @ 4.2 K, 30 T

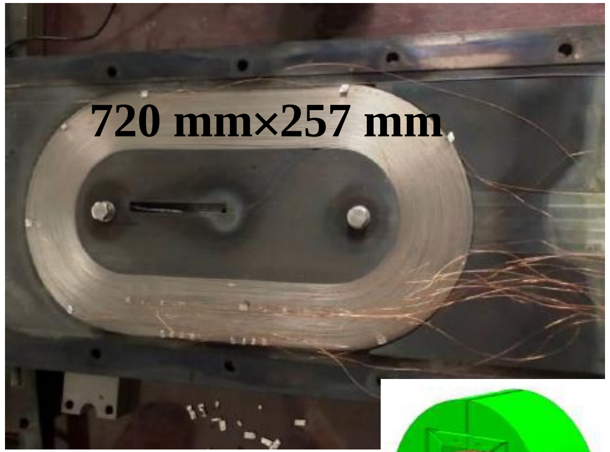


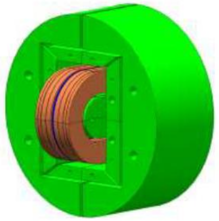
35 T water-cooled magnet (Hefei, China)

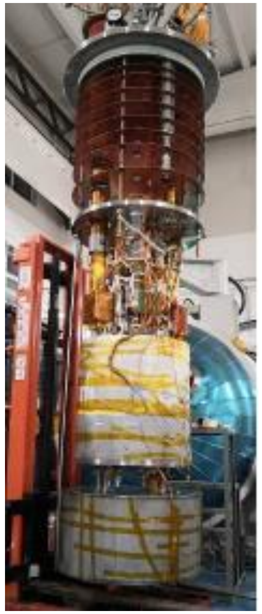
Qian et al., ***Physica C*** 580 (2021) 1353787

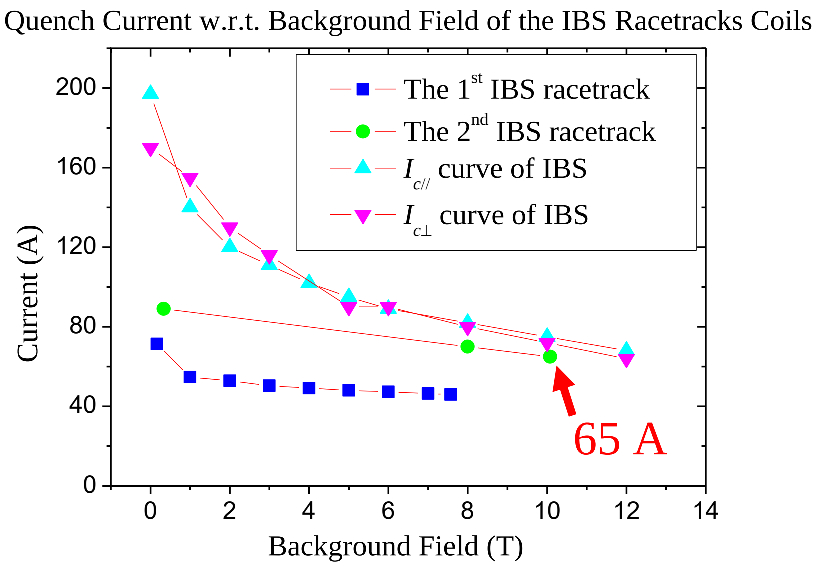
IBS Racetrack coils made using the 100 m long tapes











J_c(coil) = 87% J_c(short tape) @ 10 T

7-filaments IBS 100-m long tapes

Tapes' Parameters	Values (mm)
Thickness of IBS tape	0.33
Width of IBS tape	4.5
Non-SC/SC ratio	5

Parameters	Values (mm)
Thickness of coil winding	57.6
Width of coil	235.2
Width of coil winding	4.66
Length of straight part of coil	200
Thickness of SS tape	0.3
Turns	96
Bending radius	60

- ✓ Metal-as-insulation technique
- ✓ Wind & react > 800 °C
- ✓ I_c~65 A @ 4.2 K, 10 T

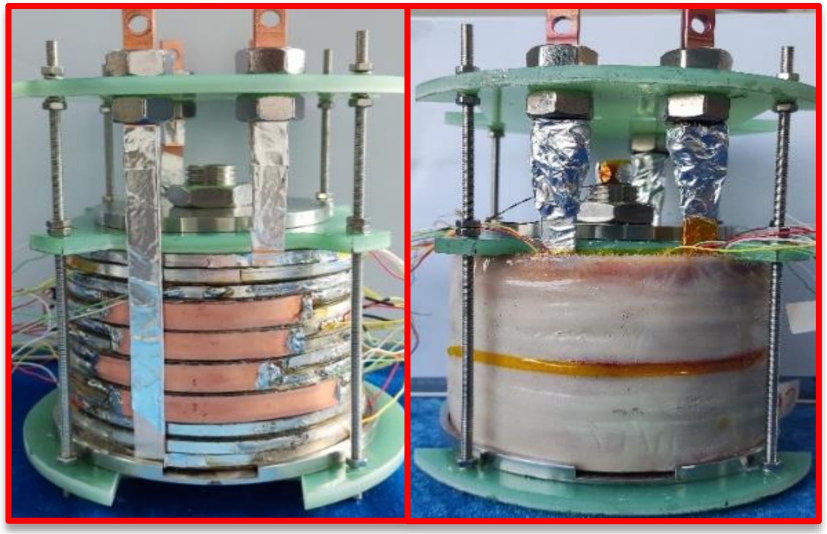
87 % of the short sample at 10T

Very promising for next generation accelerator!

Zhang et al., ***SuST*** 34 (2021) 035021

IEEE-CSC, ESAS and CSSJ SUPERCONDUCTIVITY NEWS FORUM (global edition), Issue No. 56, March, 2024. Invited presentation given at ISS 2023, Nov. 2023, Wellington, New Zealand

First Tesla class IBS coil for high field application



Tesla class IBS coil

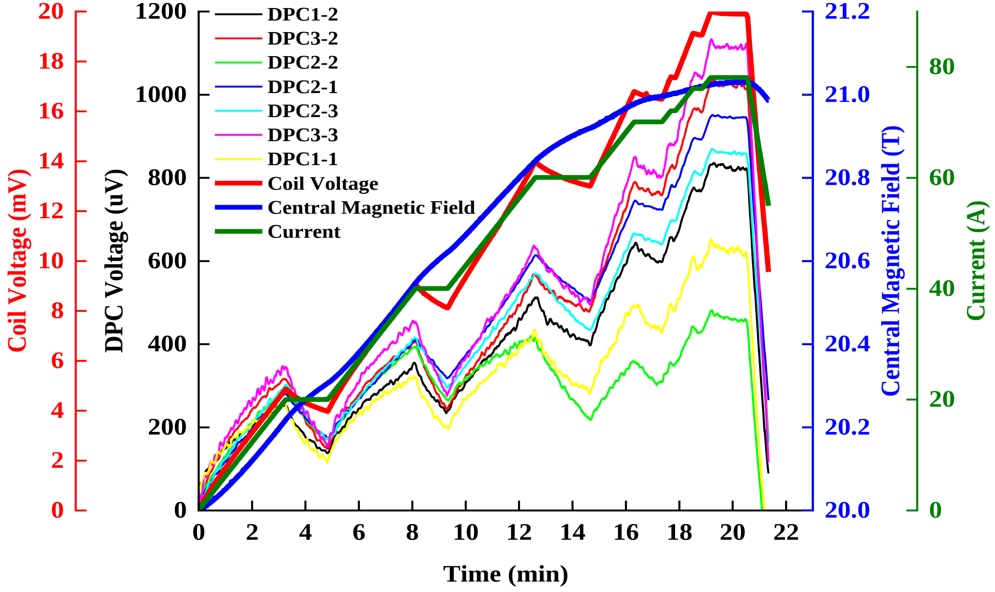
Courtesy of Prof. Wenge Chen

20 T background field

- ✓ Six double pancake coils
- ✓ Self field 1.03 T @ 4.2 K, 20 T

The poorest IBS double pancake coil still had a critical current of about 84 A at the background field of 20 T

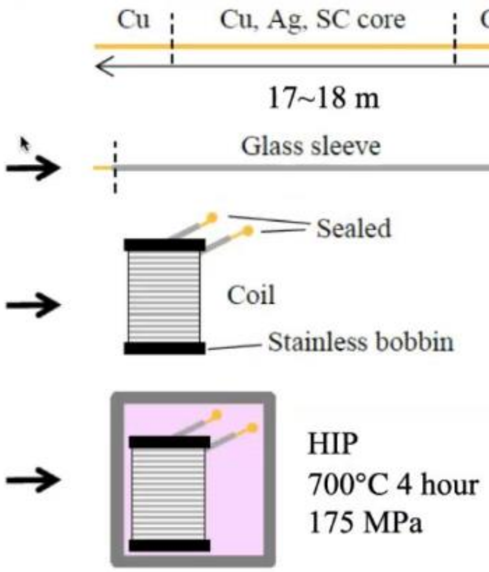
Outperformed all previously reported IBS coils



Ding et al., *SuST*, 36 (2023) 11LT01

IEEE-CSC, ESAS and CSSJ SUPERCONDUCTIVITY NEWS FORUM (global edition), Issue No. 56, March, 2024. Invited presentation given at ISS 2023, Nov. 2023, Wellington, New Zealand

Powder-In-Tube HIP 122 wires: Coils

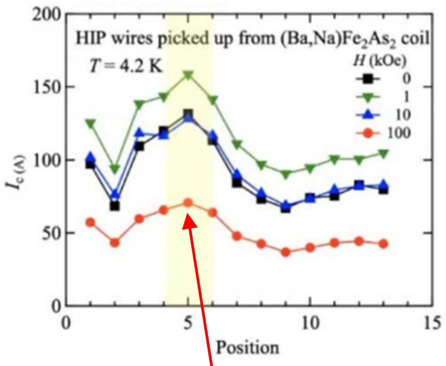


17~18 m mono- and 7-core Ba-122 wires

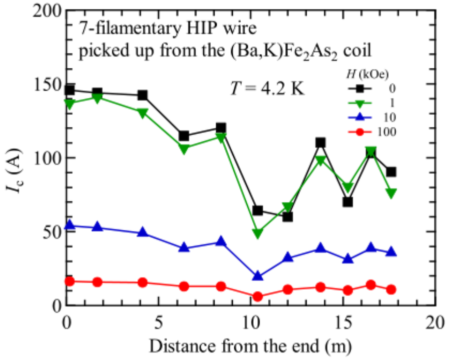
Wires covered by glass sleeve are wound on SS bobbins

HIP process is applied (Wind & React)

segments of mono-core wire

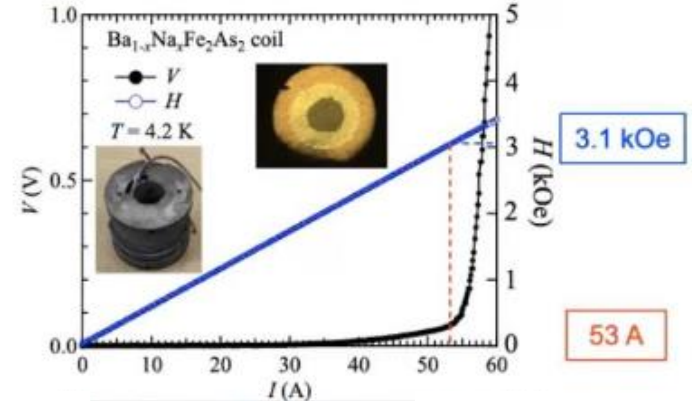


segments of 7-core wire

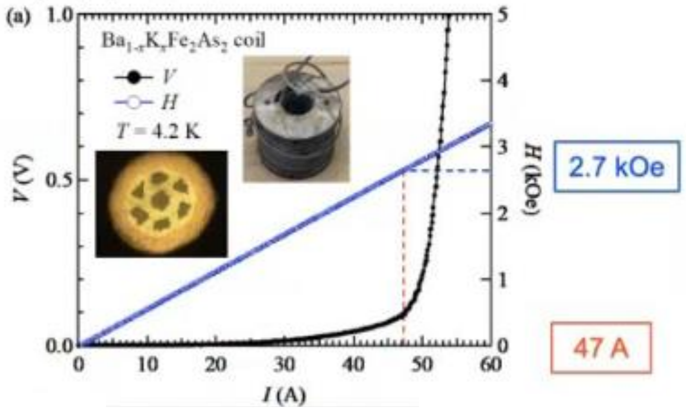


- A high J_c of 71 kA/cm^2 (I_c ~67 A) at 4.2 K, 10 T was measured in short segments picked up from the mono-core coil

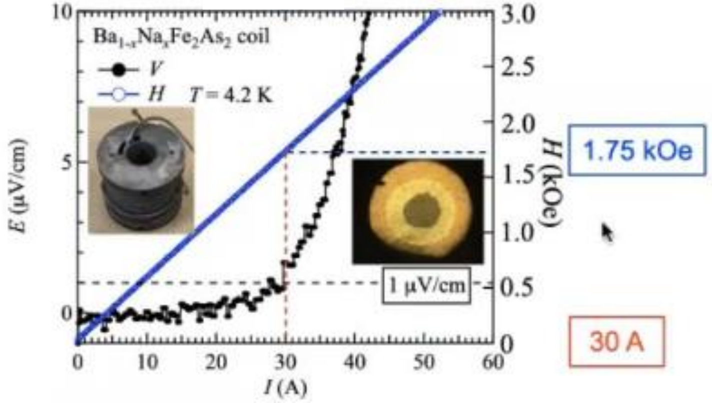
$(Ba,Na)Fe_2As_2$ coil with mono-core wire

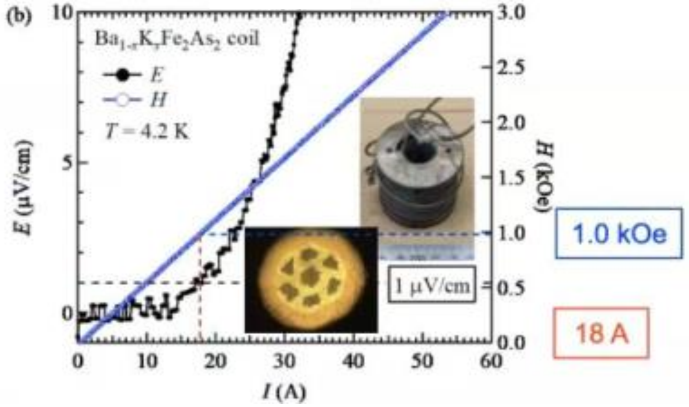


$(Ba,K)Fe_2As_2$ coil with 7-core wire



- **Rapid increase in dissipation starts above 53 and 47 A for mono- and 7-core wires**



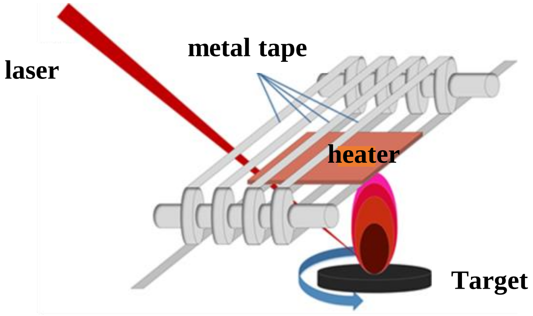


- **I_c of the whole coil wires are 30 and 18 A in self-field, corresponding H = 1.75 and 1.0 kOe for mono- and 7-core wires**

Pyon et al., ***SuST*** 26 (2023) 015009

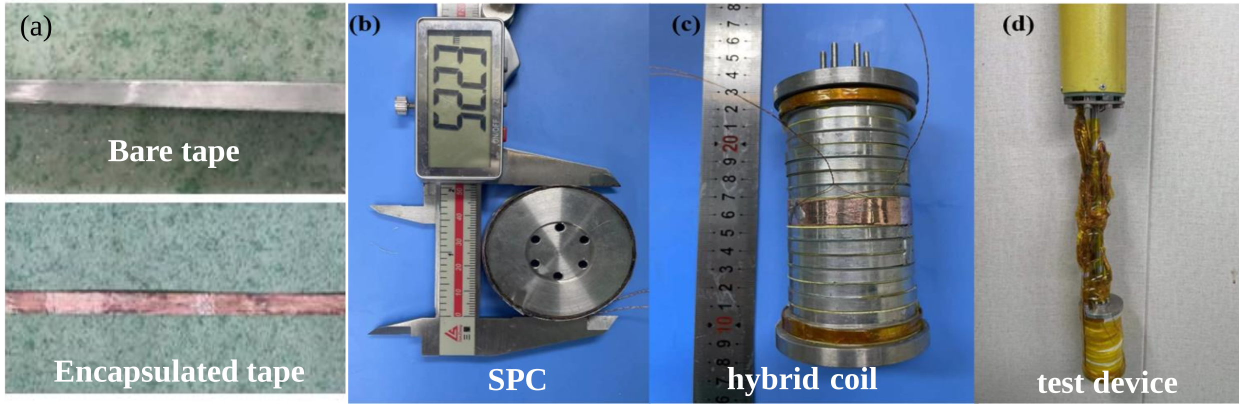
$FeSe_{0.5}Te_{0.5}$ coated conductor tape and coil

$FeSe_{0.5}Te_{0.5}$ single pancake coil (SPC) was fabricated and tested under magnetic field



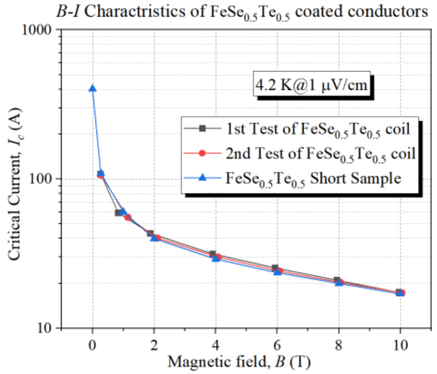
PLD

One-meter long



Parameter	Unit	Value
Bare tape width	mm	10
Bare tape thickness	mm	0.1
Encapsulated tape width	mm	10.5
Encapsulated tape thickness	mm	0.15
I_c @ 4.2 K, 0 T (encapsulated tape)	A	402.4
I_c @ 4.2 K, 10 T (encapsulated tape)	A	17

Parameters	YBCO coil	$FeSe_{0.5}Te_{0.5}$ coil
Coil type	DPC	SPC
Tape width (mm)	4.8	10.5
Tape thickness (mm)	0.185	0.15
Tape length (mm)	4026	560
Inner diameter (mm)	45	51.04
Outer diameter (mm)	50.18	52.23
Turn	14	3.5
Coil number	8	1
Coil height (mm)	45.5 × 2	10.5



- One-meter $FeSe_{0.5}Te_{0.5}$ coated conductor tapes can be fabricated via PLD
- The transport critical current of the SPC was 108 A at self-field and 17 A at 10 T, which is as same as the tape.

Wei et al., ***SuST*** 36 (2023) 04LT01

High Field Model Dipole Magnet: HTS Cable R&D

Courtesy of Prof. Qingjin Xu

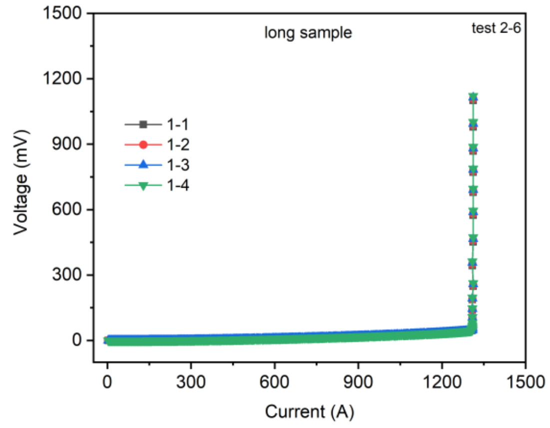
Cable design

Schematic illustration of the transposed cable and the fabrication steps

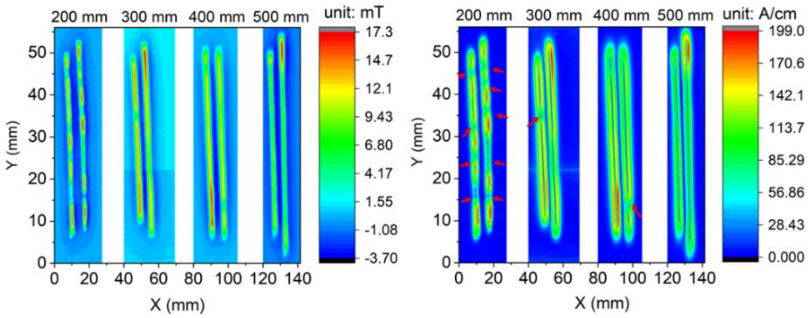
The advantages of the designed cable:

- High current-carrying compacity
- Low dynamic loss
- High mechanical stability

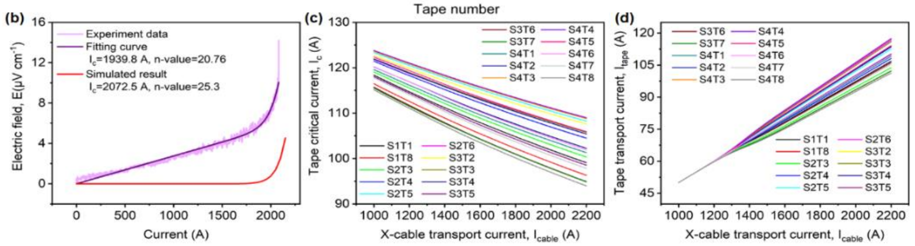
IBS transposed cable reached 1.3 kA



REBCO transposed cable reached 2 kA



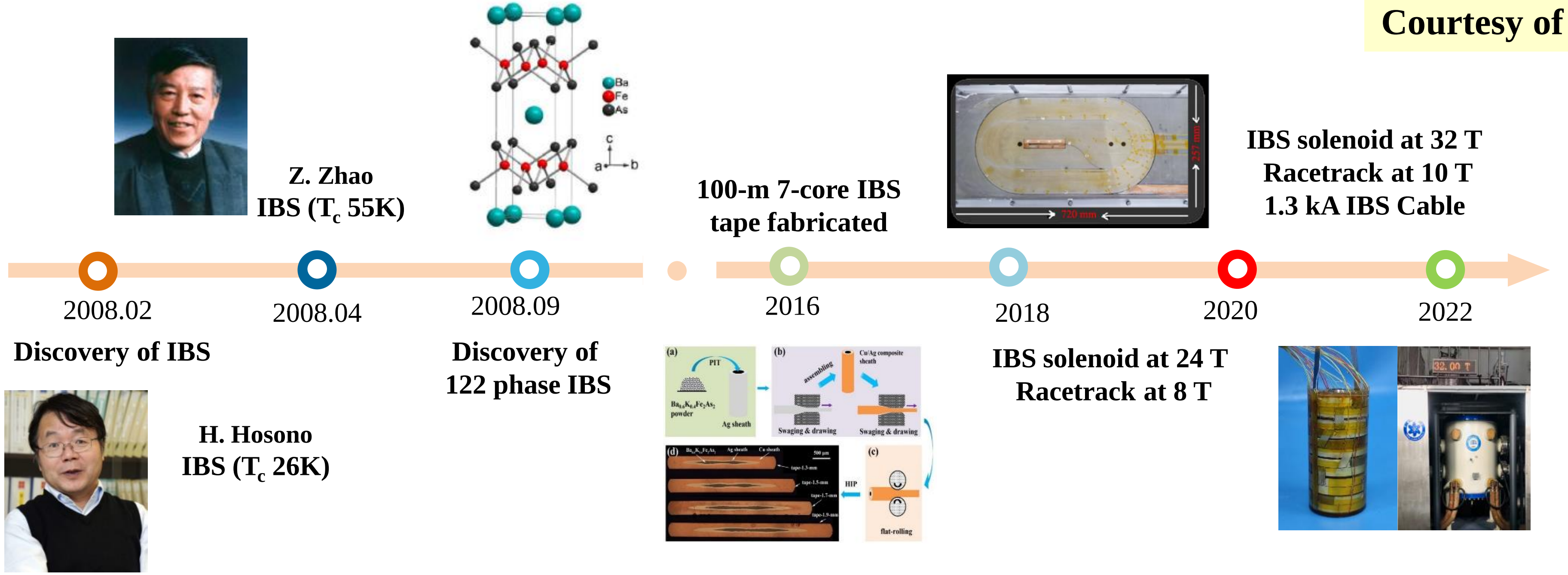
J. Wang et al, *Superconductivity* 3 (2022) 100019



IEEE-CSC, ESAS and CSSJ SUPERCONDUCTIVITY NEWS FORUM (global edition), Issue No. 56, March, 2024. Invited presentation given at ISS 2023, Nov. 2023, Wellington, New Zealand

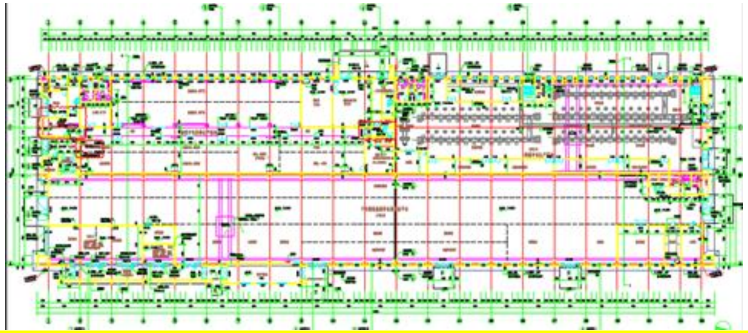
IBS Technology: Status and Outlook

Courtesy of Prof. Qingjin Xu



- The **engineering current density** of the long-length IBS still needs a significant improvement, to reach the similar level as ReBCO or Bi-2212 conductors.
- The **materials of stabilizer** should be shifted to copper or any other low-cost metals to realize the low cost of IBS.
- **Structure and fabrication methods** of IBS and corresponding coils should be further optimized to minimize the J_c degradation at high field and high stress.
- Many other issues like detailed magnetic and mechanical properties study of IBS, quench detection and protection of the IBS coils/magnets and etc.

Platform for kilometer-scale IBS wire



Plant layout, ~3000 square meters

Currently, a platform for the preparation of kilometer-scale long IBS wire is constructing in China.

Equipment in place

Wire drawing machine

Tape rolling machine

HIP furnace

Projects on IBS & Financial support

CAS funded "Science and Technology Frontier Research for the Next Generation Superconducting Magnet Applications" within the Strategic Priority Research Program of CAS

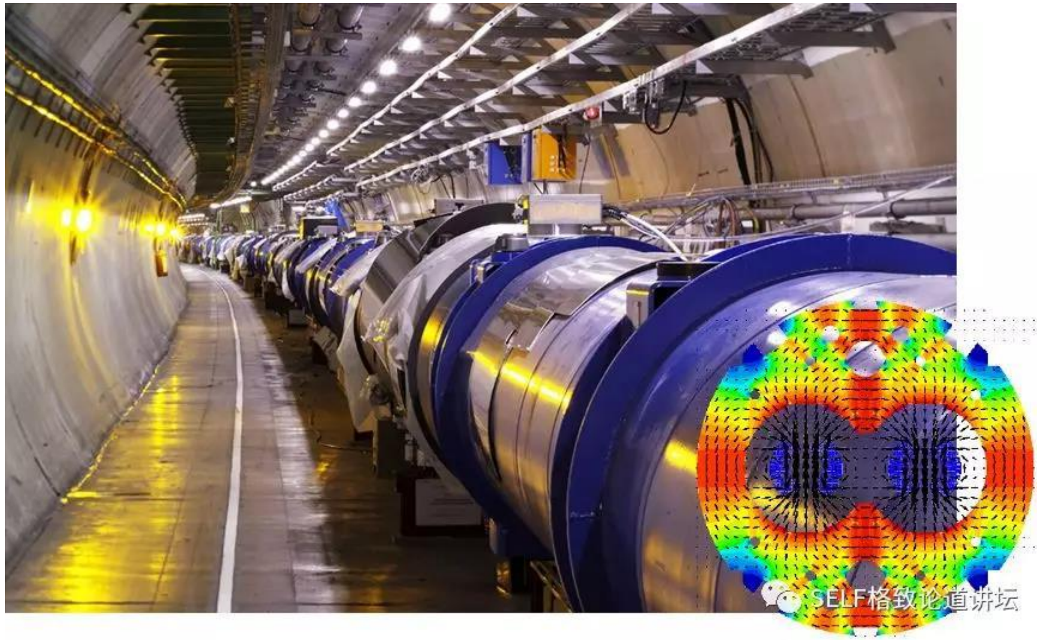
MoST funded "Next Generation High-field Magnet Technology Based on Iron-based Superconductor" within the National Key R&D Program of China

NSFC funded "High-performance Fe-based Superconducting Materials for High Magnetic Field Applications" within Major International (Regional) Joint Research Project

Conclusions

- ✓ **Currently, iron-based wires and tapes are in the rapid development stage of research and development.**
- ✓ **Transport J_c of 122-type IBS wires has been significantly improved, and has surpassed the practical level at 4.2 K & 10 T with a maximum of 2.2×10^5 A/cm^2.**
- ✓ **Transport J_c of 100-m-class Ba-122 IBS tapes was further improved to > 6×10^4 A/cm^2 at 10 T & 4.2 K.**
- ✓ **Highlights some remarkable advances of IBS relevant to practical applications, including superconducting joints, cable, the first IBS inserted coils and racetrack coils.**
- ✓ **We believe that Fe-based wires are very promising for applications in high magnetic fields, e.g. >20 T at 4.2 K or >10 T at 20-30 K.**

Thank you for your attention!



From a movie： Avatar