High performance $Ba_{0.6}K_{0.4}Fe_2As_2$ superconducting tapes at high magnetic field and high temperature with hot-pressing process

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2. **Prof. Hiroaki Kumakura, National Institute for Material Science, Japan**

Outline

- **Background of iron-based superconductor**
- **The influence of tape thickness on the properties of silver sheathed $Sr_{1-x}K_xFe_2As_2$ tapes**
- **Ultra high transport current in high textured iron-based superconducting tapes**
- **Summary**

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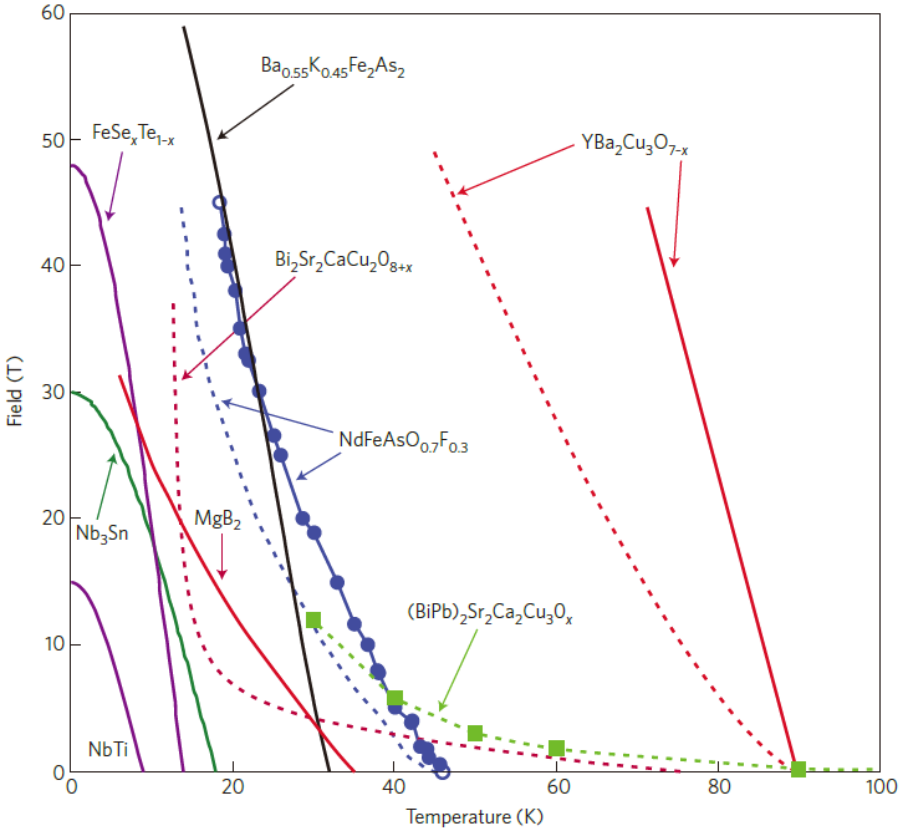
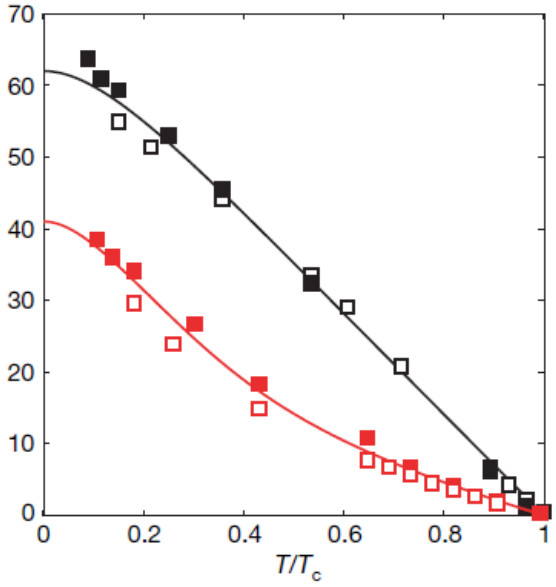
Very high upper critical fields



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



Hunte et al., ***Nature*** 453, 903 (2008)

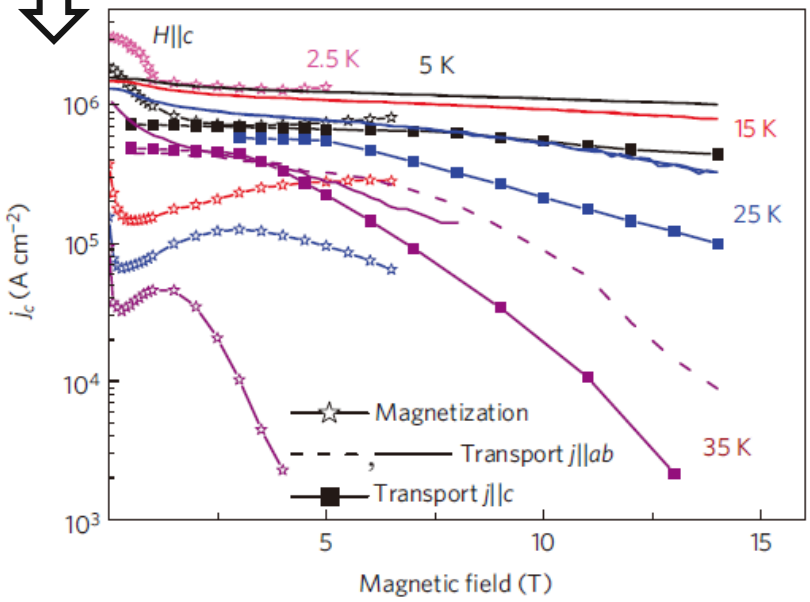
At 20 K, the B_{c2} can reached 50 T, suggesting a very encouraging application in high field magnets.

High critical current densities and low anisotropy

The anisotropy (γ) of the pnictides is relatively small.

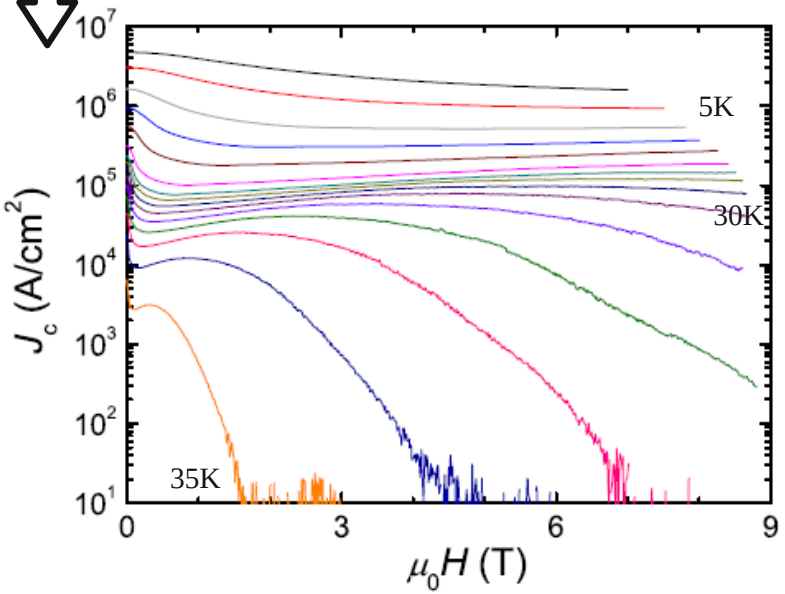
The single crystal of both the 1111 and 122 type pnictides show high J_c values

	J_c@5K/0T	$J_{c//a}$/ $J_{c//c}$
1111	~3×10^6 A/cm^2	2.5
122	~3×10^6 A/cm^2	2
11	~10^6 A/cm^2	



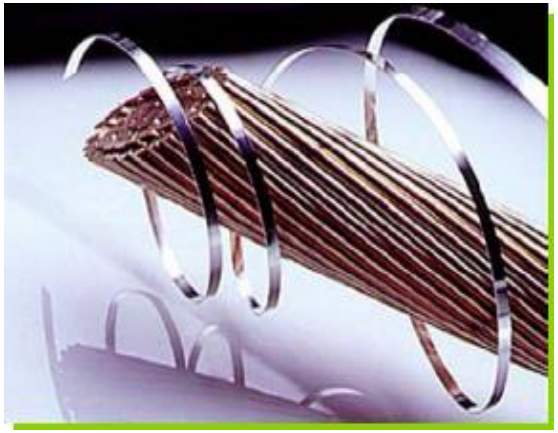
Moll et al., ***Nature Mater.*** 9, 628 (2010)

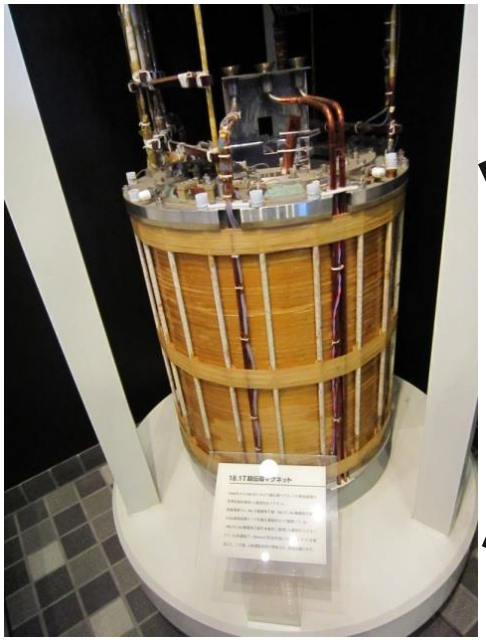
$Ba_{0.6}K_{0.4}Fe_2As_2$



Yang, et al, ***APL*** 93 142506 (2008)

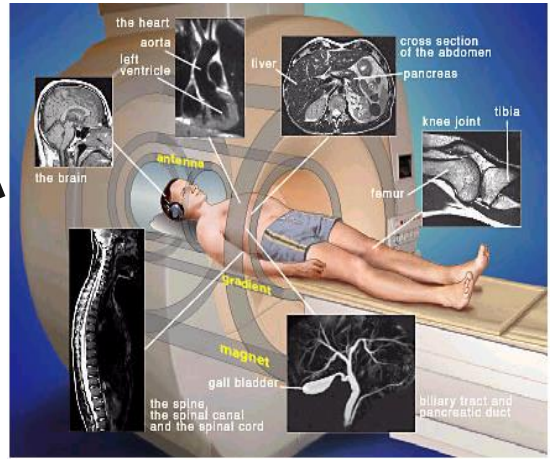
Potential for high-field applications





NMR

MRI



Wires and tapes are the foundation for large scale application
Development of high-performance wire conductors is essential

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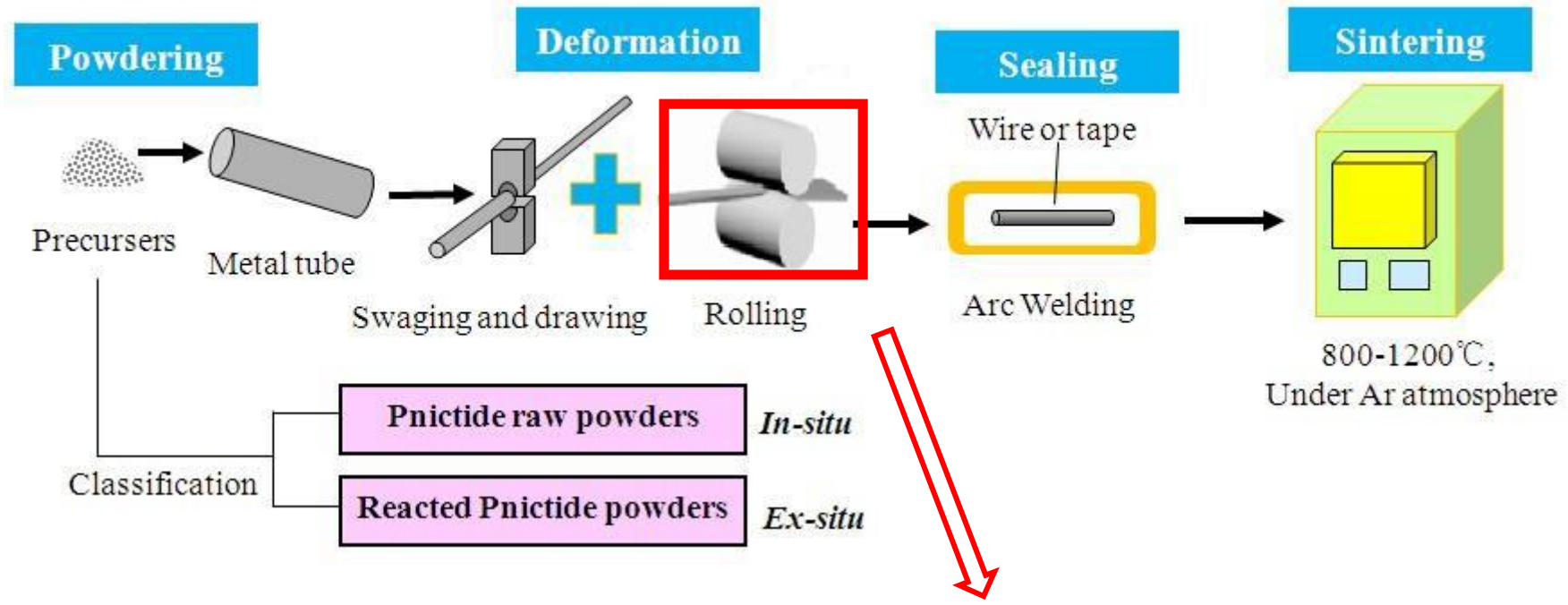
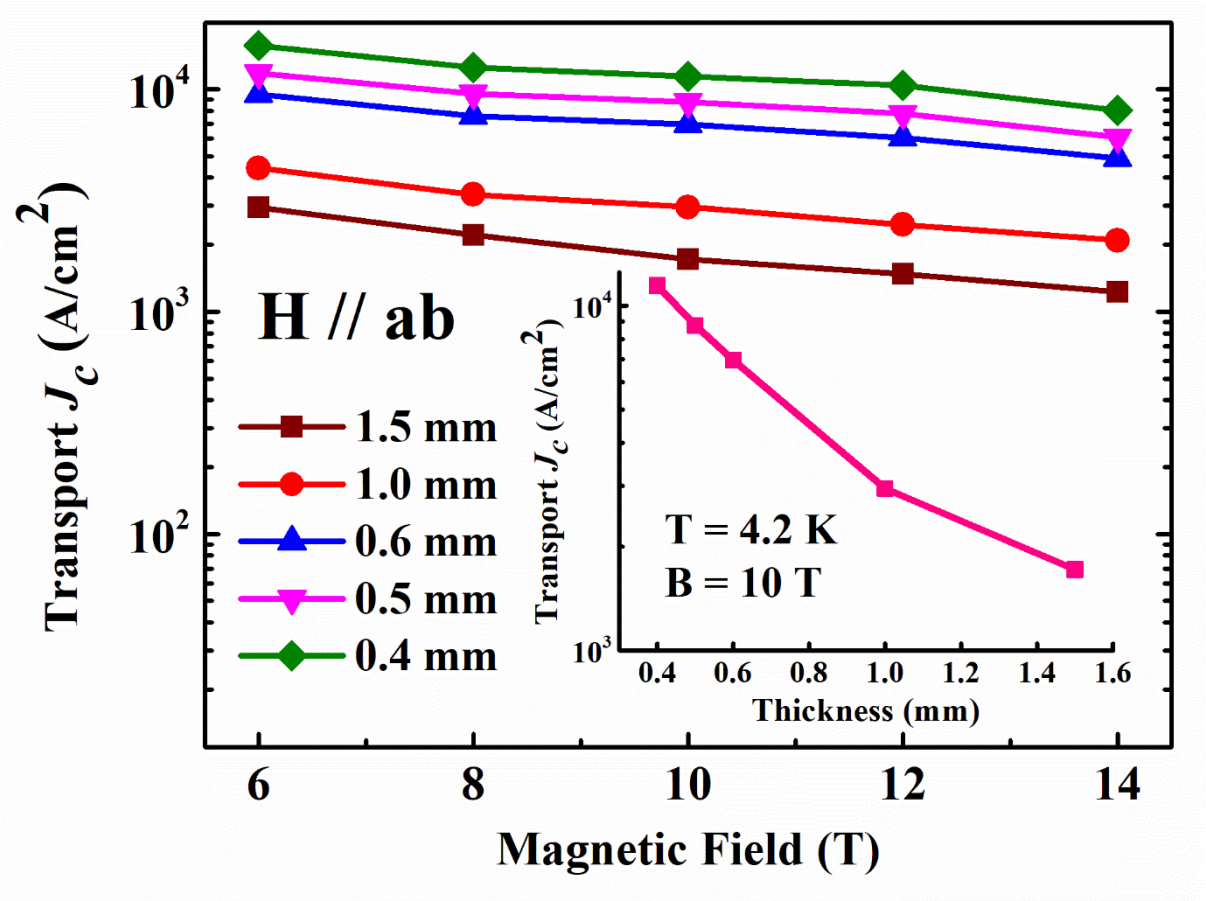
Fabrication process for iron-based tapes
(Powder-in-tube method)

Simple, Scalable, Low cost

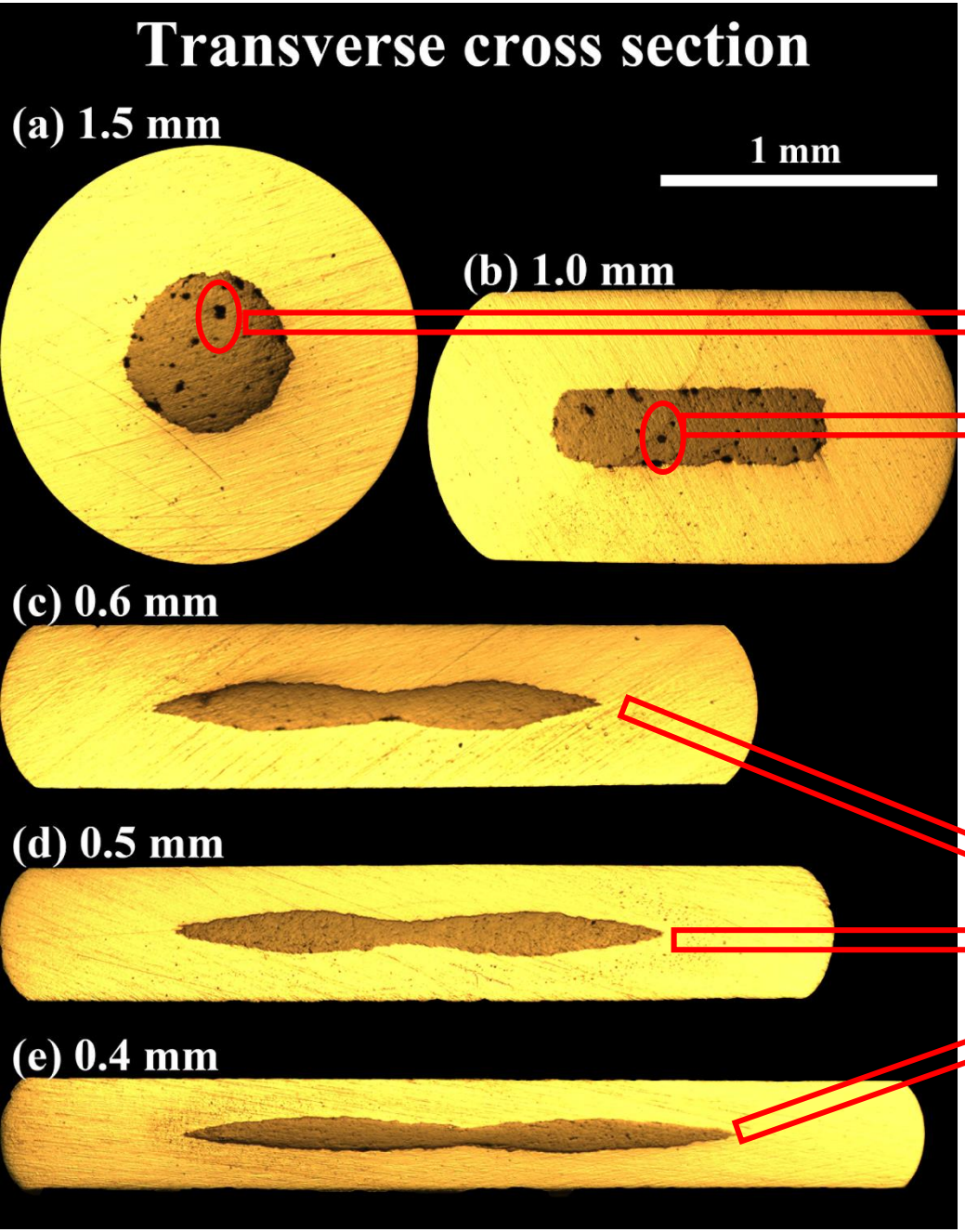


Tape thickness is an important parameter to the J_c properties;
The silver sheathed Sr-122 wires or tapes with thickness of 1.5 mm, 1.0 mm, 0.6 mm, 0.5 mm and 0.4 mm are fabricated.

Magnetic field dependence of transport J_c for the Sr-122 tapes rolled to 1.5 mm, 1.0 mm, 0.6 mm, 0.5 mm and 0.4 mm, respectively.



Transport J_c values increase with decreasing the thickness of tapes

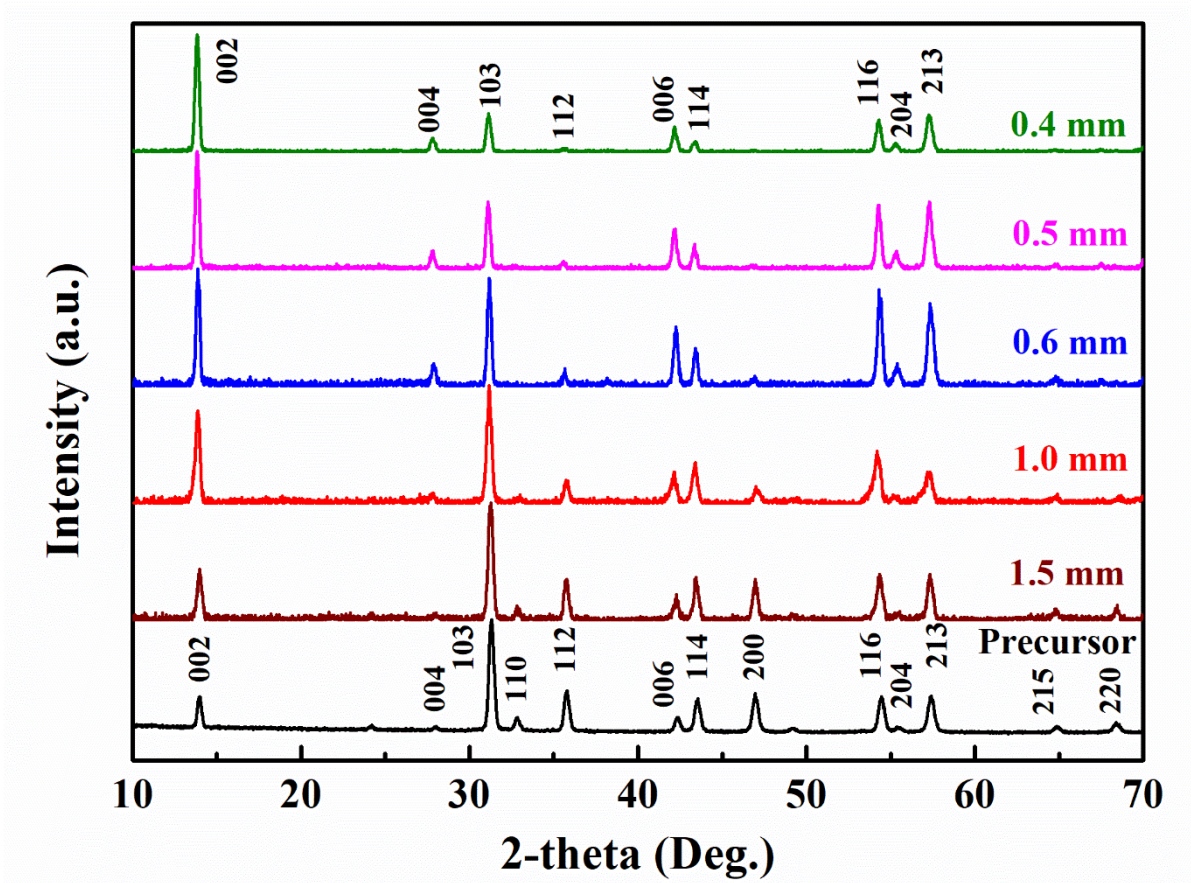


Transverse cross section optical images of superconducting tapes with different thickness

Because of the loose and low-density cores, there are some pores can be found from the 1.5 mm and 1.0 mm tapes

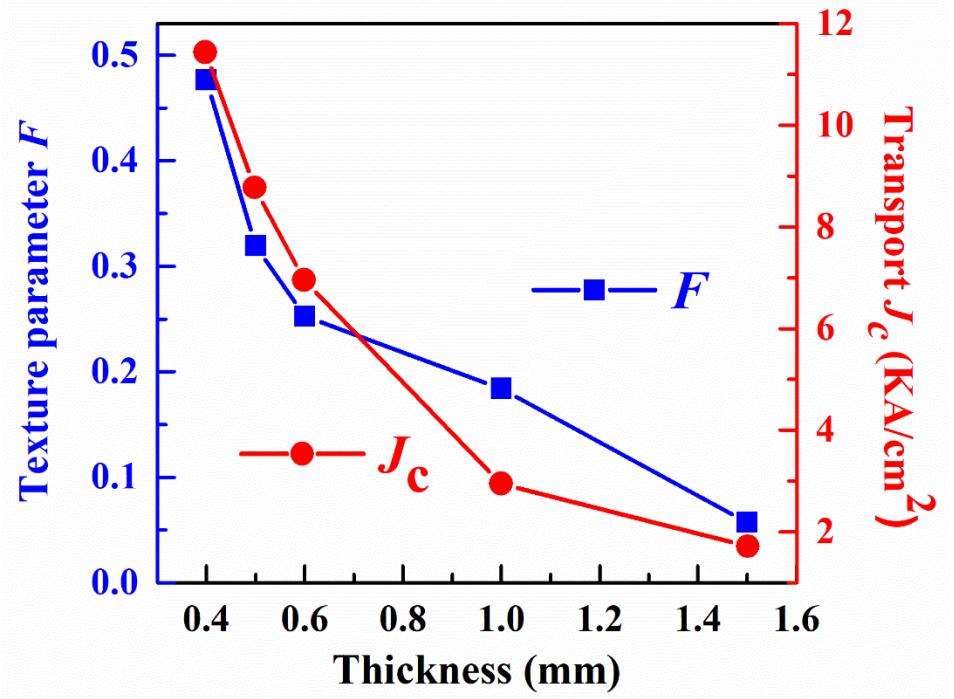
Smooth and no obvious pores or cracks

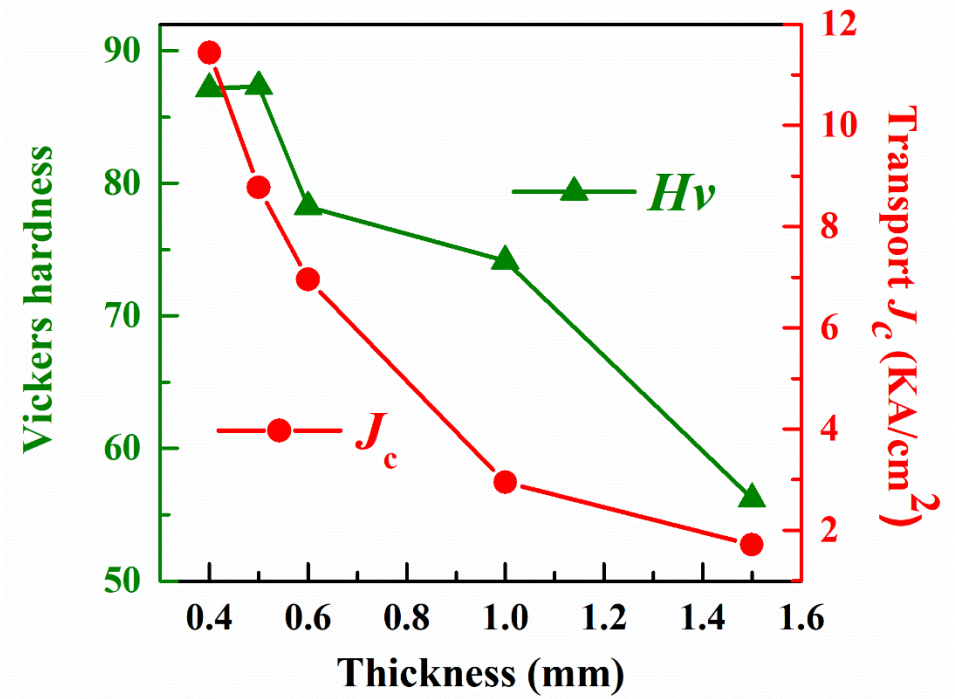
XRD patterns for the superconducting core of different thickness



- The (*00l*) peaks are enhanced in different degrees by the rolling deformation
- The relative intensity of (*00l*) peaks increase with decreasing the thickness of tapes.

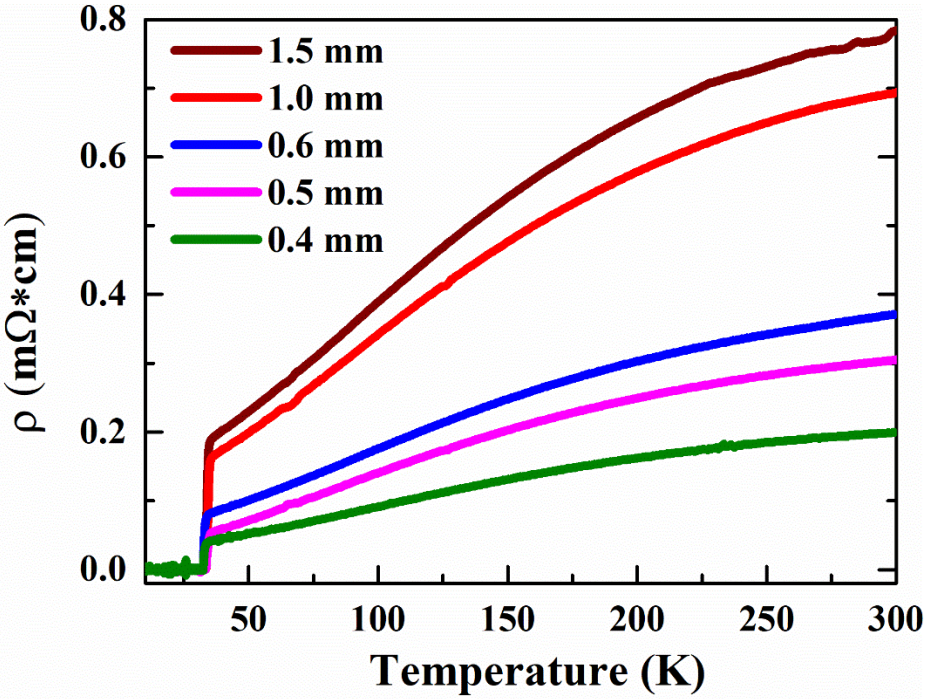
The relation between the Vickers hardness, the texture and transport J_c with different tape thickness

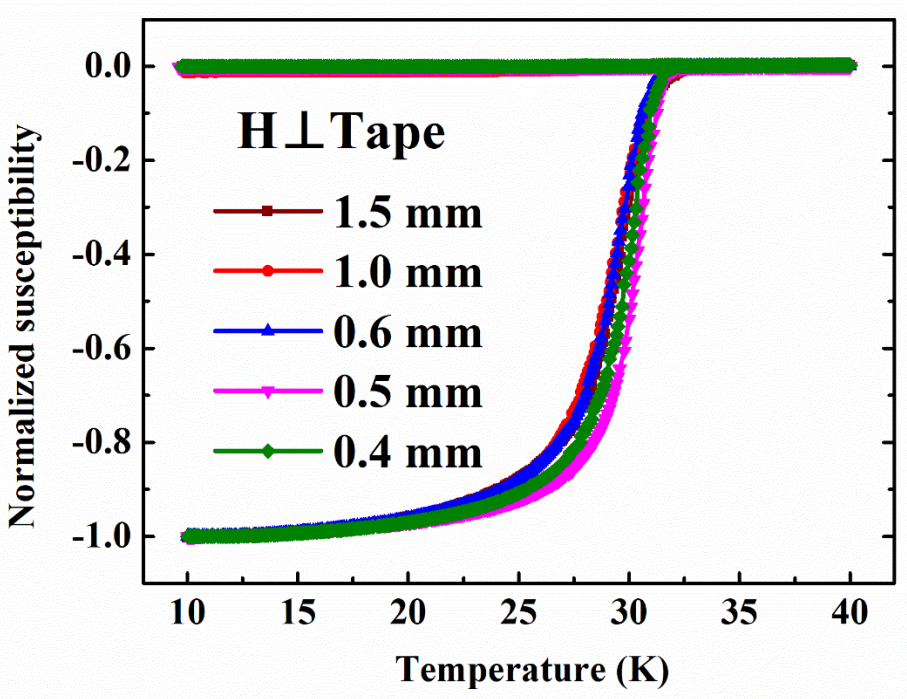




- A positive correlation between the transport properties and the texture of superconducting tapes;
- The J_c values increase with decreasing the tape thickness until the tapes rolled to 0.5 mm in thickness;
- The core density may be saturated within the experimental conditions.

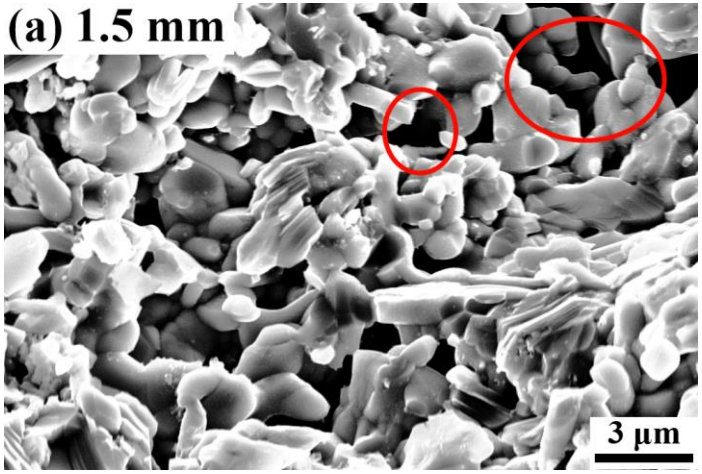
The temperature dependence of the resistivity at zero field and susceptibility of the superconducting cores for the tapes

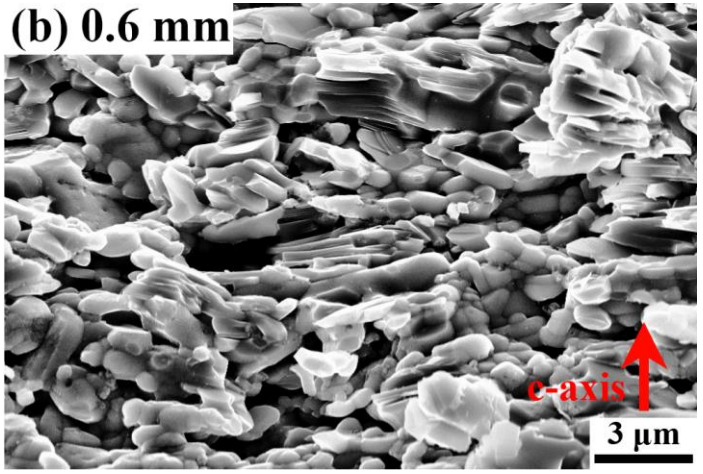


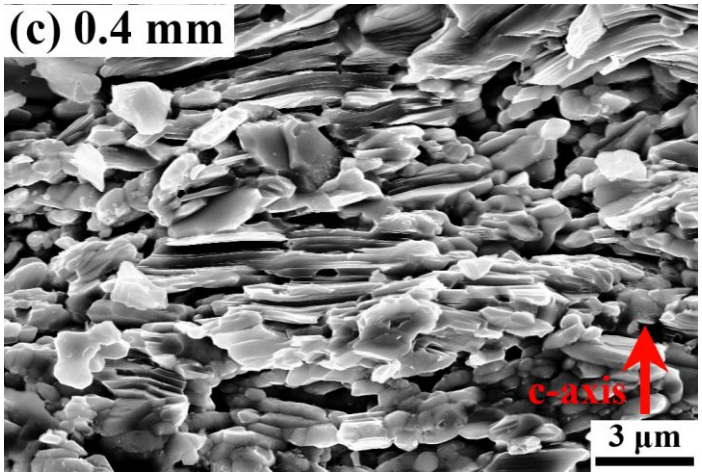


- Residual resistivity ratio RRR = ρ(300 K)/ρ(40 K) values for the tapes with thickness of 1.5 mm, 0.6 mm and 0.4 mm are 3.86, 4.19 and 4.40, respectively, indicate an enhancement of grains connectivity;
- High-quality precursors

SEM of the cores with 1.5 mm, 0.6 mm and 0.4 mm thickness tapes







- In the 1.5 mm wires, voids are observed and grains orientation are randomly distributed;
- Many plate-like grains in 0.4 mm tapes parallel to the tape surface;
- Consistent with the texture results

The core density and the texture have a combined influence on the performance of tapes & the J_c will be further improved by improving the core hardness and texture degree

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Methods to improve the core density and texture

Metal tube

Powders

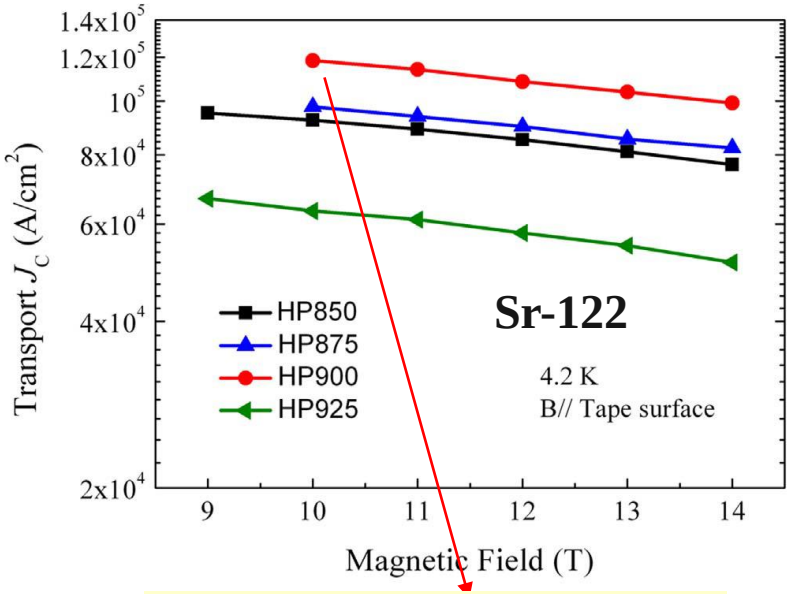
Swaging

Drawing

Rolling

Hot pressing

Sintering



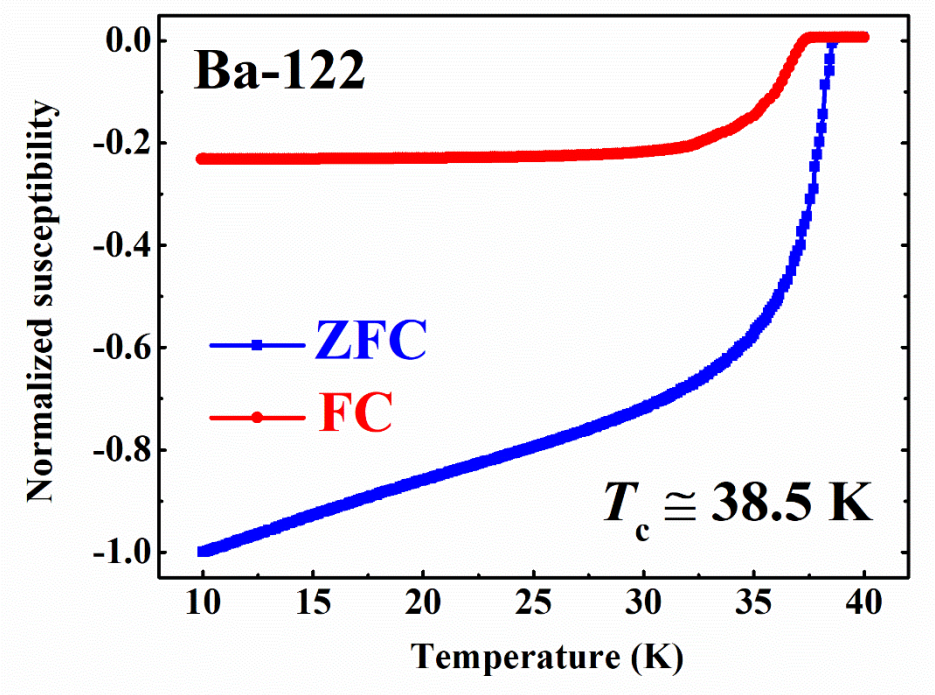
Exceed 10^5 A/cm^2 at 10 T

H. Lin, et al Sci. Rep ***4****, 6944 (2014)*

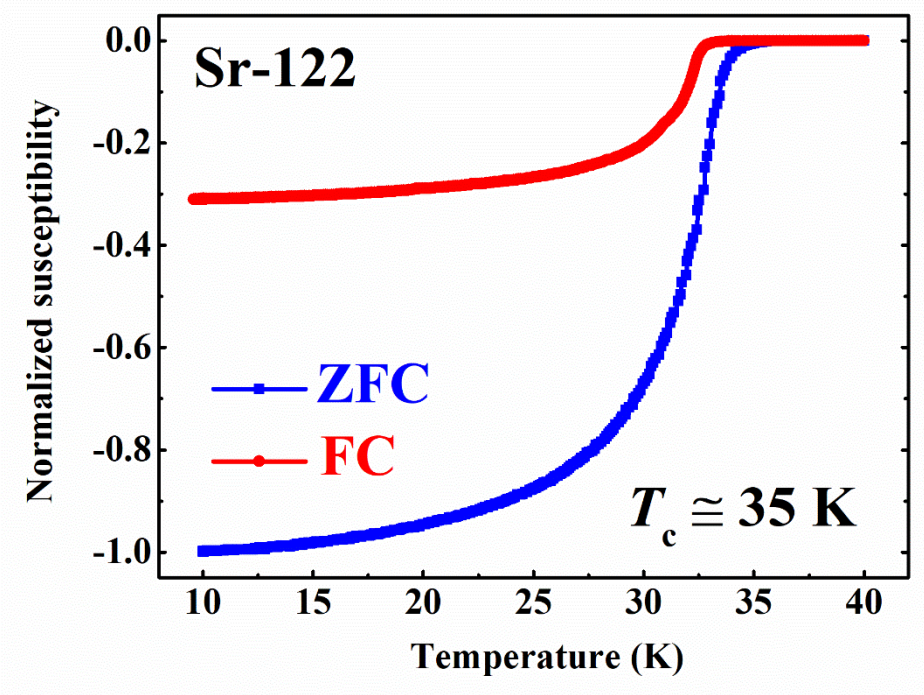
Very effective to improve the core density and texture

Why hot press with $Ba_{1-x}K_xFe_2As_2$

Precursor

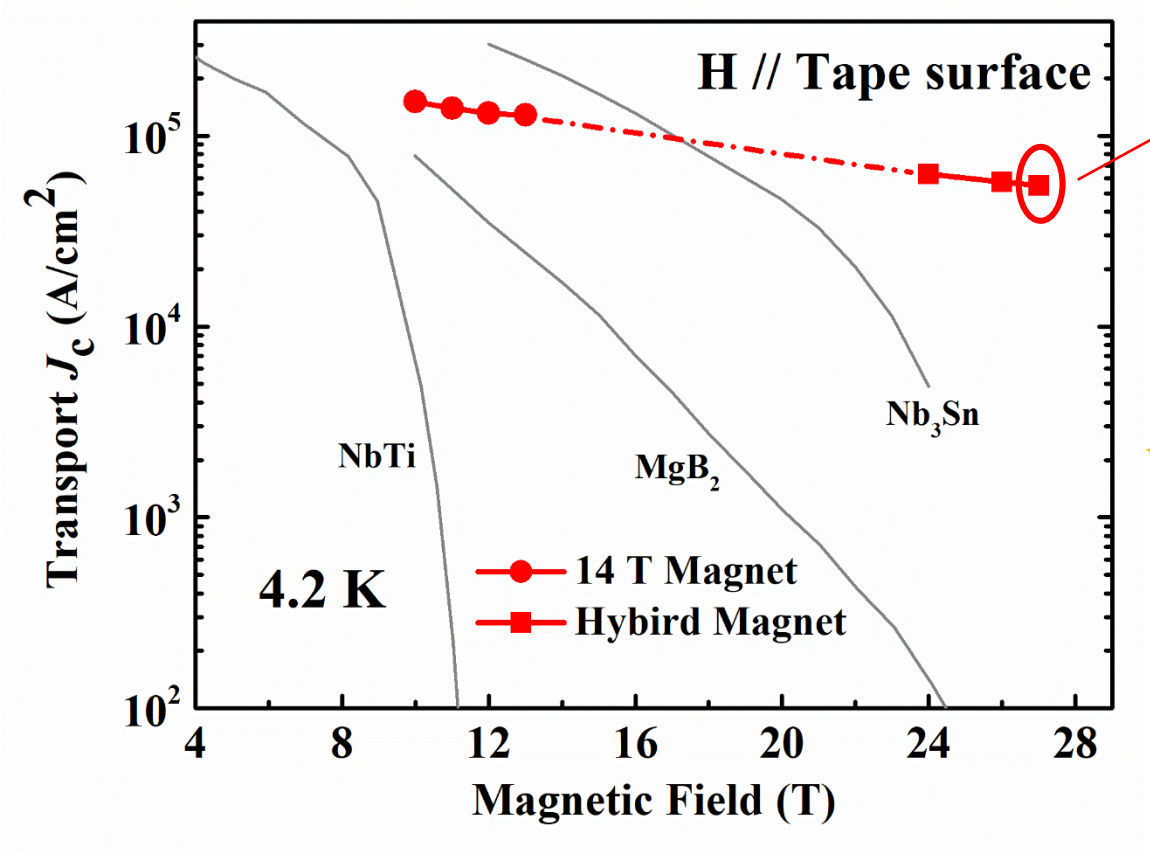


Precursor



The transition temperature of $Ba_{1-x}K_xFe_2As_2$ (38.5 K) is higher than that of the $Sr_{1-x}K_xFe_2As_2$ (35 K)

The transport J_c values of hot-pressed Ba-122 tapes



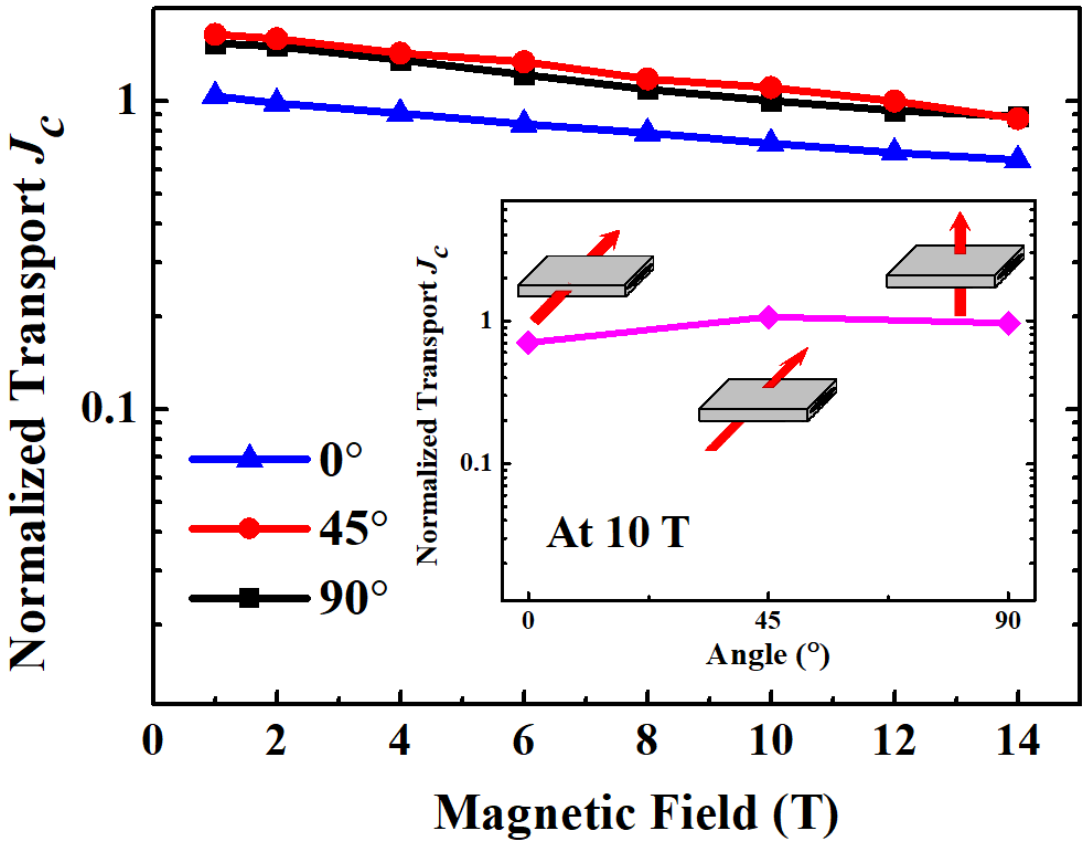
5.5×10^4 A/cm^2
@ 27 T & 4.2 K

1.5×10^5 A/cm^2
(I_c = 437 A) @
10 T & 4.2 K

The first report of hot-pressed Ba-122 superconducting tapes;

These J_c values are by far the highest ever reported for iron-based superconducting wires and tapes

The anisotropy (γ) of hot-pressed Ba-122 tapes

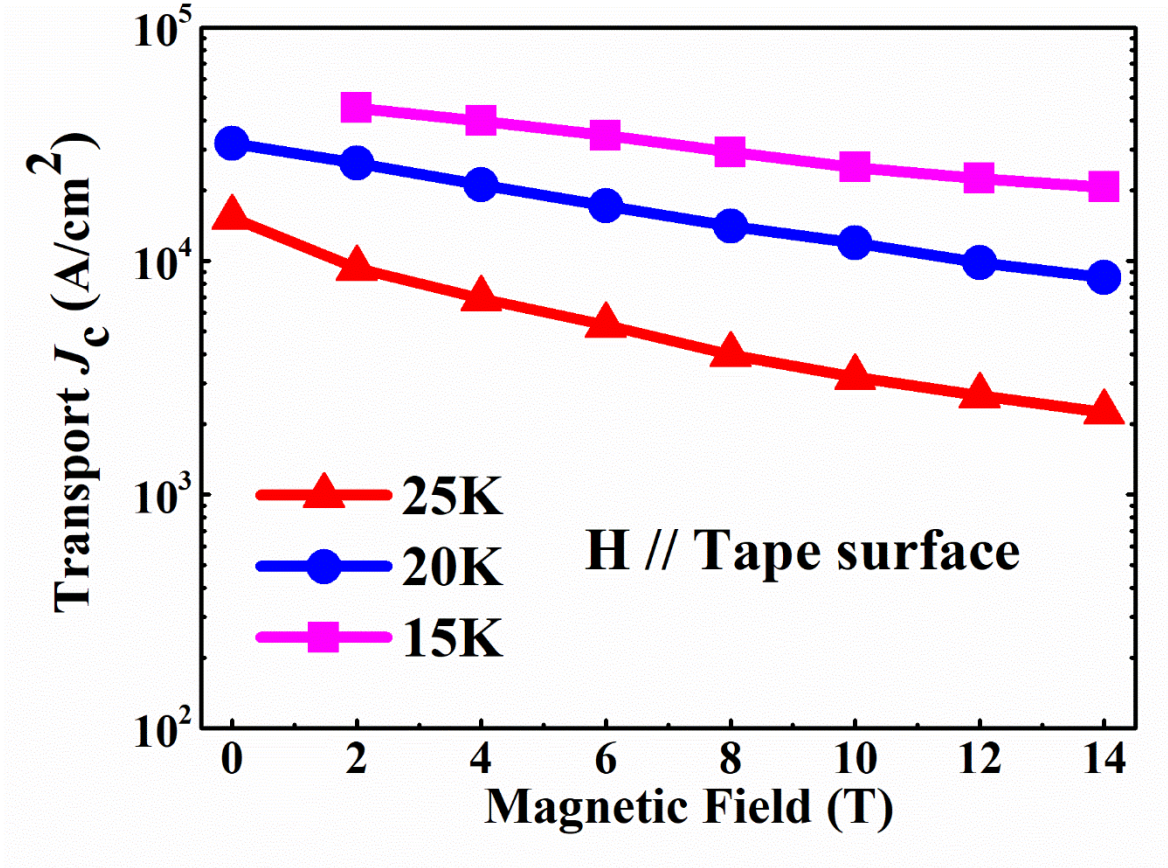


γ = 1.37 at 10 T

Clearly, the J_c values measured with the tape surface vertical to the field direction are higher than that of parallel to the field direction.

The transport J_c values at medium temperature

Measured at Kumakura's group

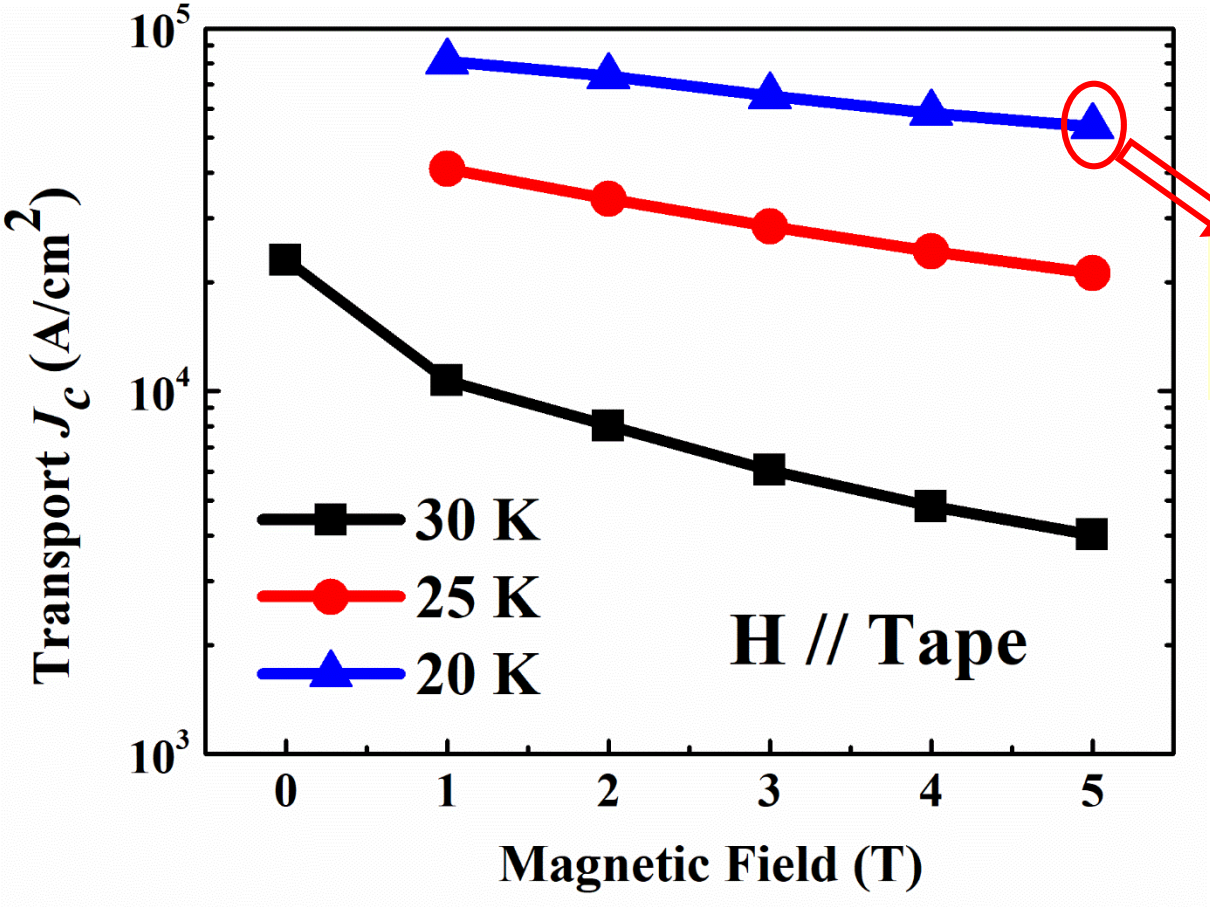


1.2×10^4 A/cm^2 @ 10 T & 20 K

The property of this sample may be degenerated because this is a old sample which measured after putting out and into the liquid helium repeatedly. It is unavoidable to hurt the superconducting core during soldering the tape from one sample holder to another.

The transport J_c values at medium temperature

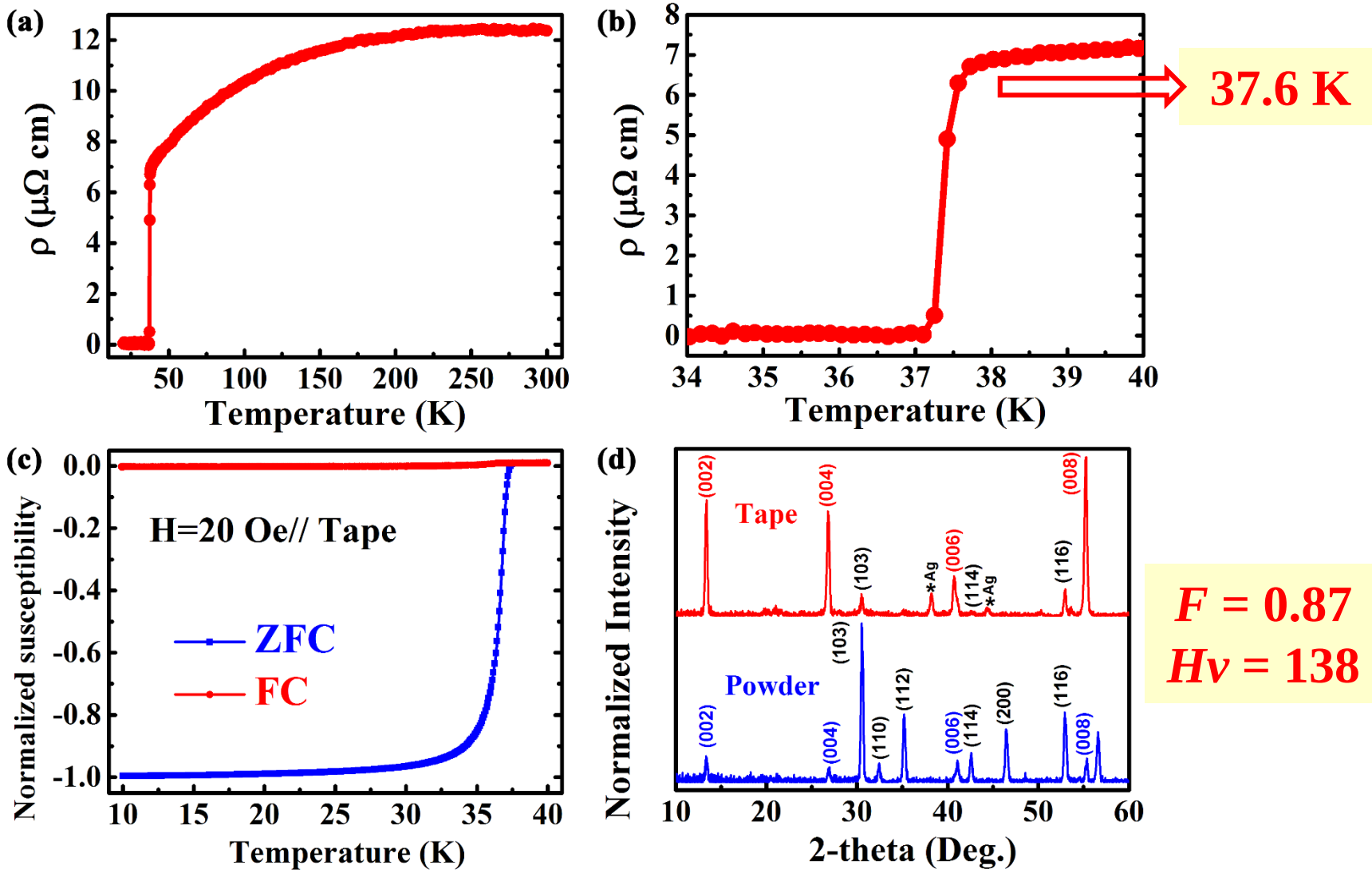
Measured at Northeastern University of China



5.4×10^4 A/cm^2 @ 5 T & 20 K

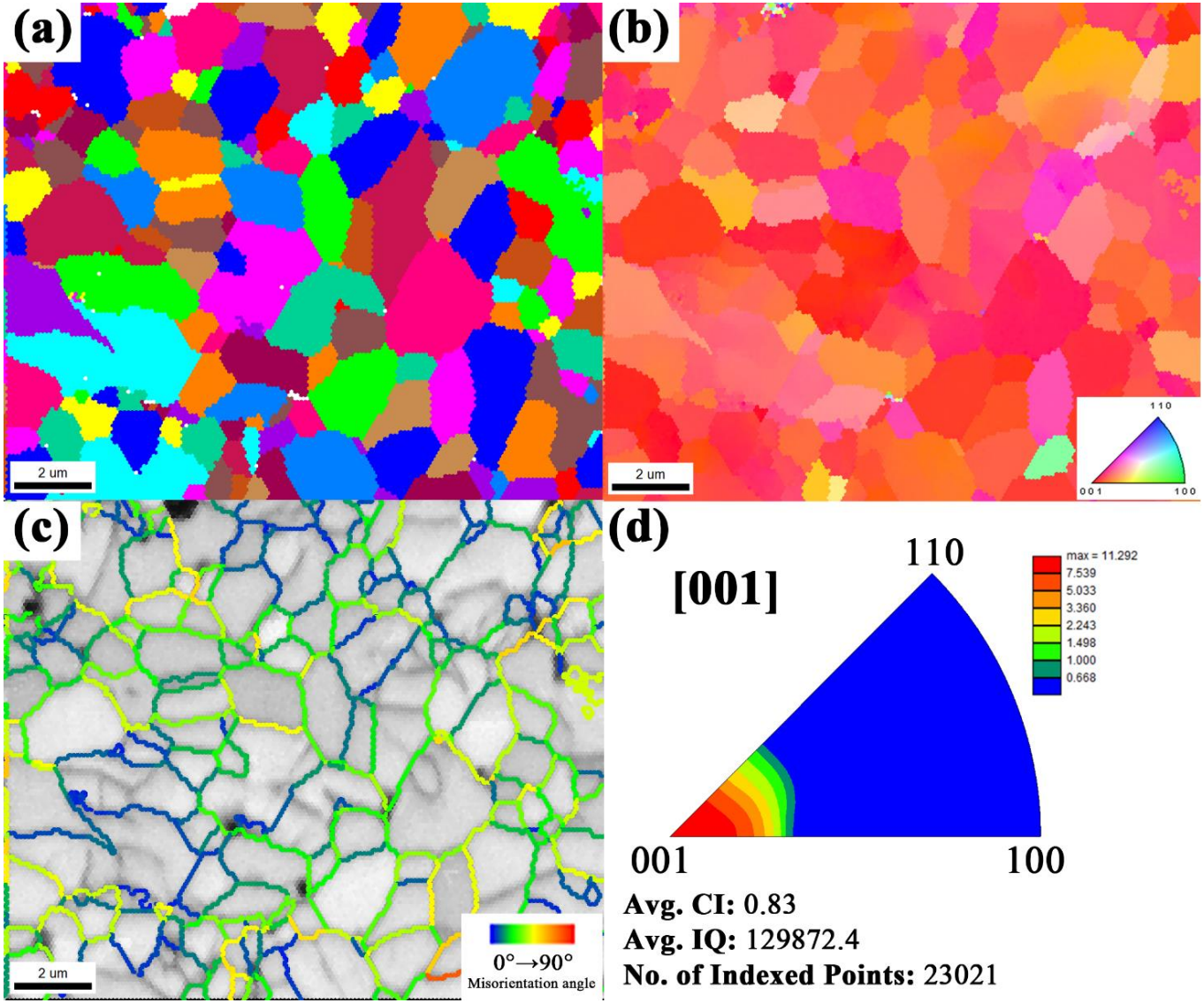
Potential applications at medium temperature of liquid hydrogen or cryogenic cooling

Electromagnetic properties and crystal microstructure of the cores



EBSD images measured from the ND direction of the tape surface

Small & evenly distributed grains

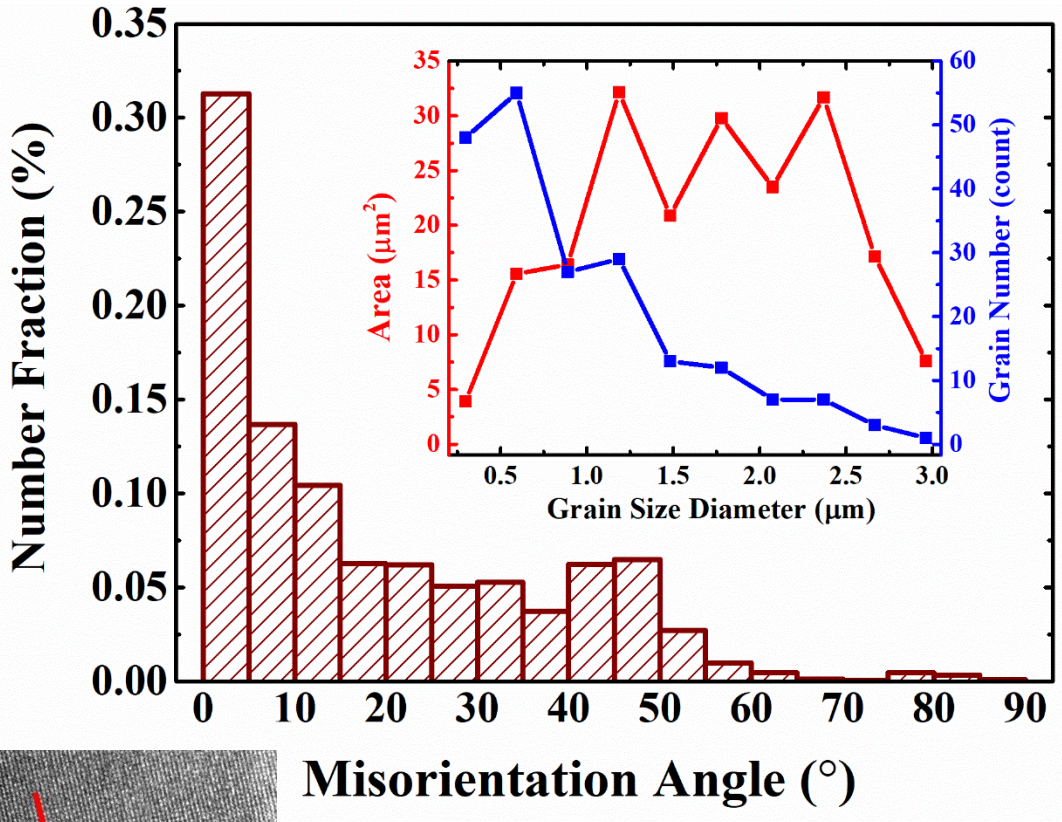


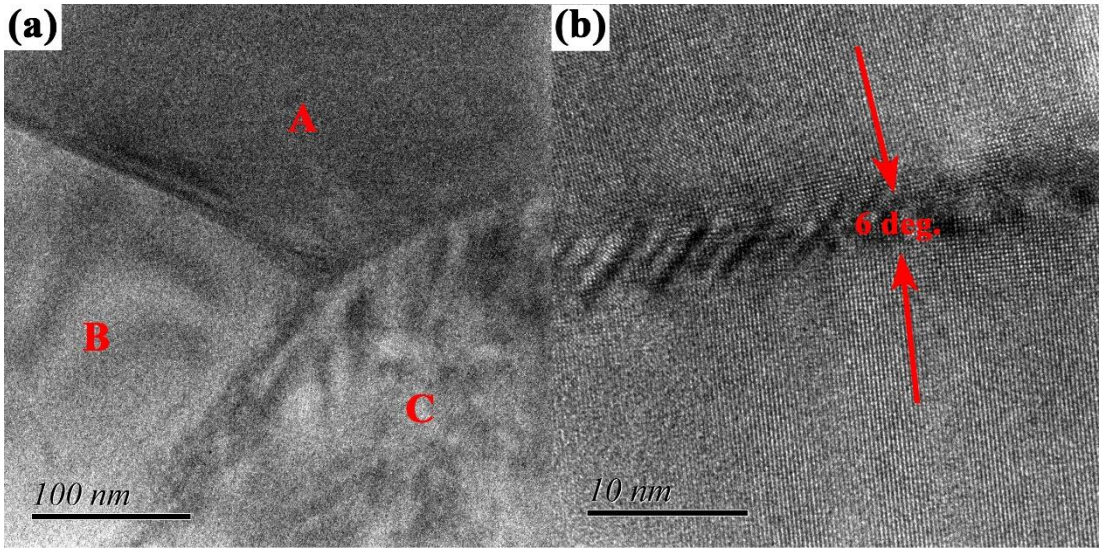
Small misorientation angle between grains

Electron backscatter diffraction

Misorientation angle distribution

- **Small grains accounted for a large percentage;**
- **The size of most grains are between 1-2.5 μm;**
- **42.8 % of number fraction are within 9° .**





Grain boundaries with low misorientation angle

Summary

- **The core density and texture have a combined influence on the properties of iron-based superconducting tapes and the J_c will be further improved by increasing the texture degree when the core density saturated within the experimental conditions;**

- **We demonstrate a high transport critical current density reaching 1.5×10^5 A/cm^2 (I_c = 437 A) at 4.2 K and 10 T and 5.4×10^4 A/cm^2 at 20 K and 5 T in $Ba_{0.6}K_{0.4}Fe_2As_2$ tapes hot-press technique and these values are by far the highest ever reported for IBS wires and tapes.**

- **The high degree of c-axis texture, the improved connectivity between grains and the strong pinning force at grain boundaries are the reasons to the high J_c values.**

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Thank you for your attention !

13th European Conference on Applied Superconductivity