Ba122 at CNR-SPIN: from powder synthesis to practical P.I.T. wires/tapes

Collaboration Agreement CERN – CNR-SPIN

Andrea Malagoli

CNR-SPIN

Motivations

Current main limitations and challenges of HTS conductors specific to high-field magnets

- **ReBCO:**
  - conductor shear stress sensitivity and degradation
  - Magnetic hysteresis, coupling and eddy currents (AC losses) are serious drawbacks of ReBCO tapes and cables. With a substantial modification of the tape architecture (filamentation) ReBCO tapes could comply with losses in Nb_3Sn in high-fields (> 10 T)
  - Quench protection of accelerator size magnets due to low quench propagation velocity and high stored energy density in coils made of ReBCO as well as Bi-2212
  - Uniformity of ReBCO tapes and cables along the length and lot to lot, impacting on magnet protection
- **Bi-2212:**
  - conductor stress/strain sensitivity and degradation
  - Very complex Reaction Heat Treatment if OP is necessary
  - …

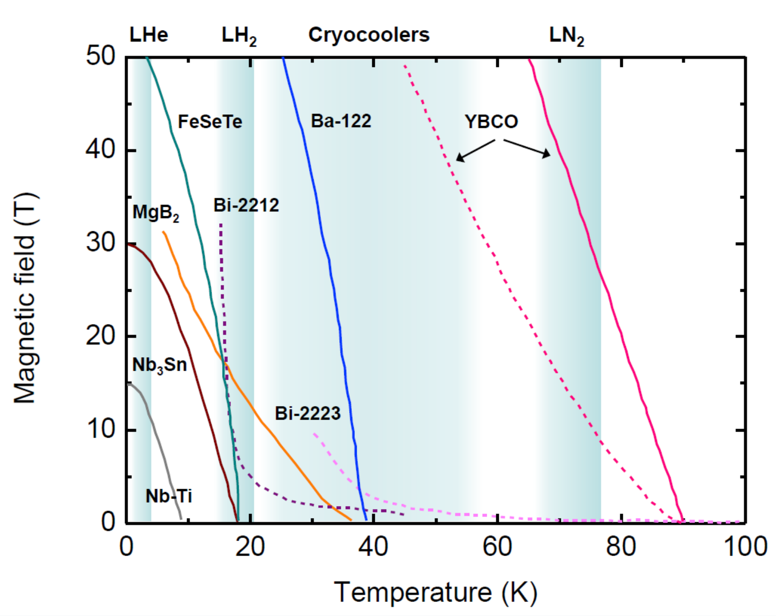
Nowadays, most of the efforts are on increasing the performances and over all the technological issues of such well established materials, but we think that developing other superconductors is a clever strategy which might give an alternative way in getting the desired conductor.

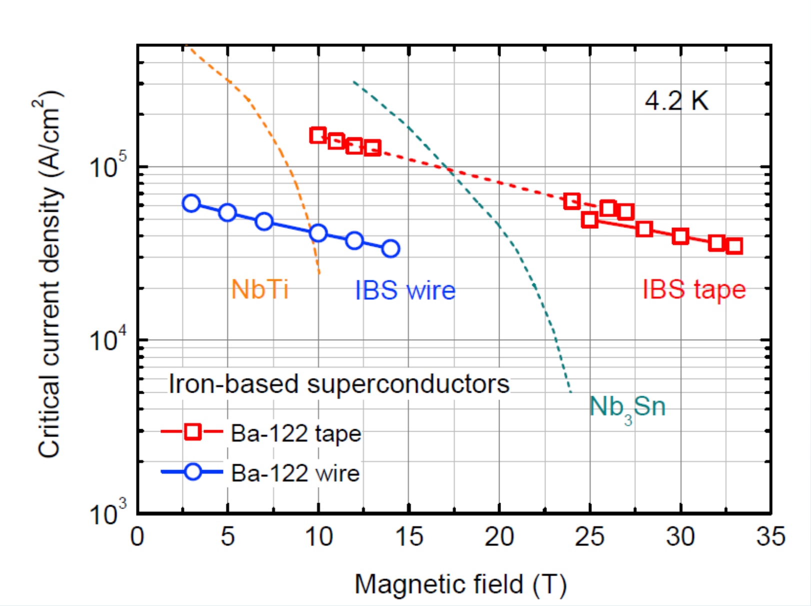
Iron Based Superconductor

Ba-122

Why?

- High H_{c2}
- H_{irr} close to H_{c2}
- $T_C \simeq 38$ K
- Low anisotropy
- Processable by P.I.T
  - Multifilamentary architecture
  - Round wires

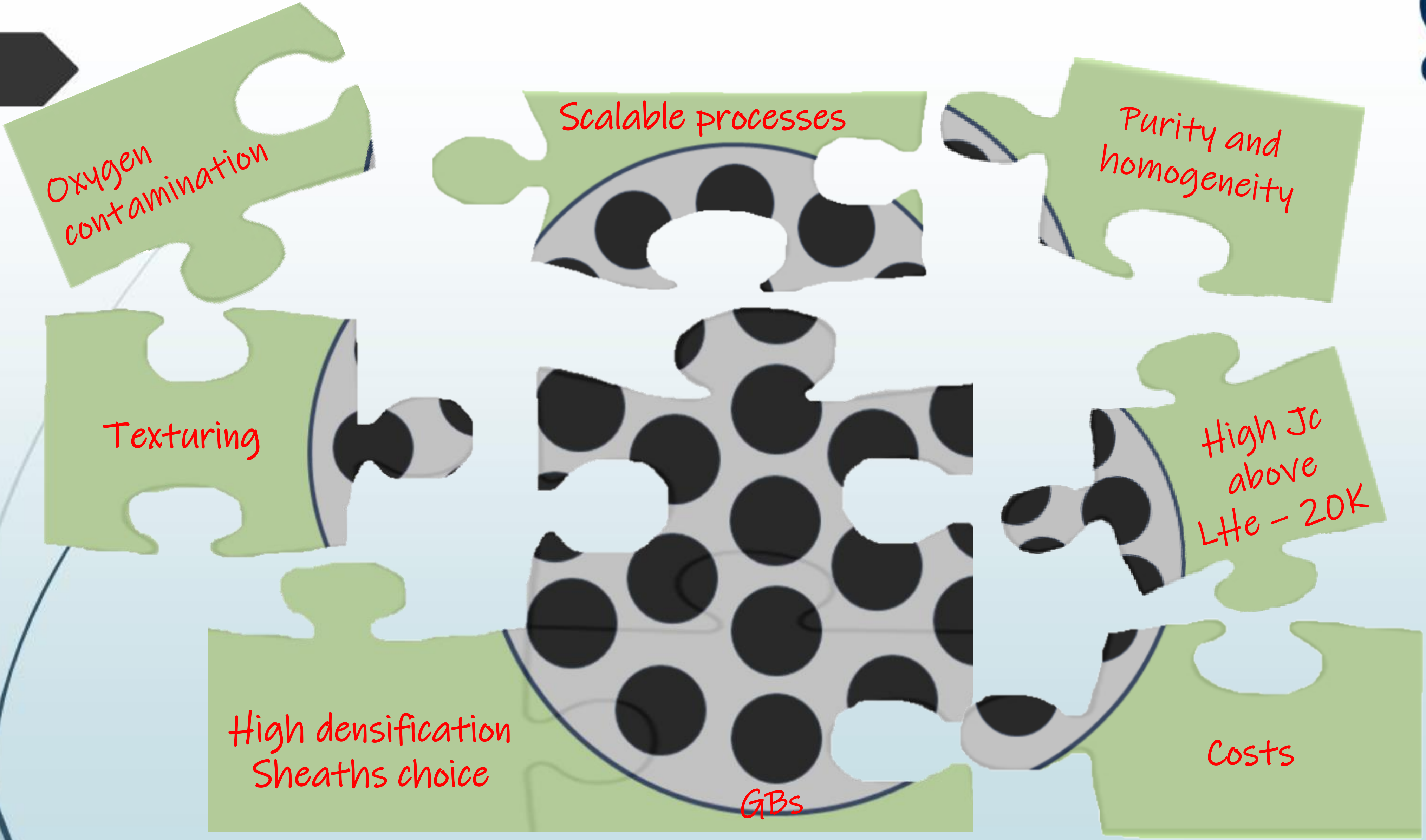




- A Gurevich, Ann. Rev. Cond. Matt. Phys **5** (2014) 35
- C Yao and Y Ma, iScience **24** (2021) 102541

- Ba-122 tapes/wires have been developed mainly in China and Japan
- Very few efforts in Europe
- We need a more intense R&D activity to establish its applicability in high field magnets

Some issues to face

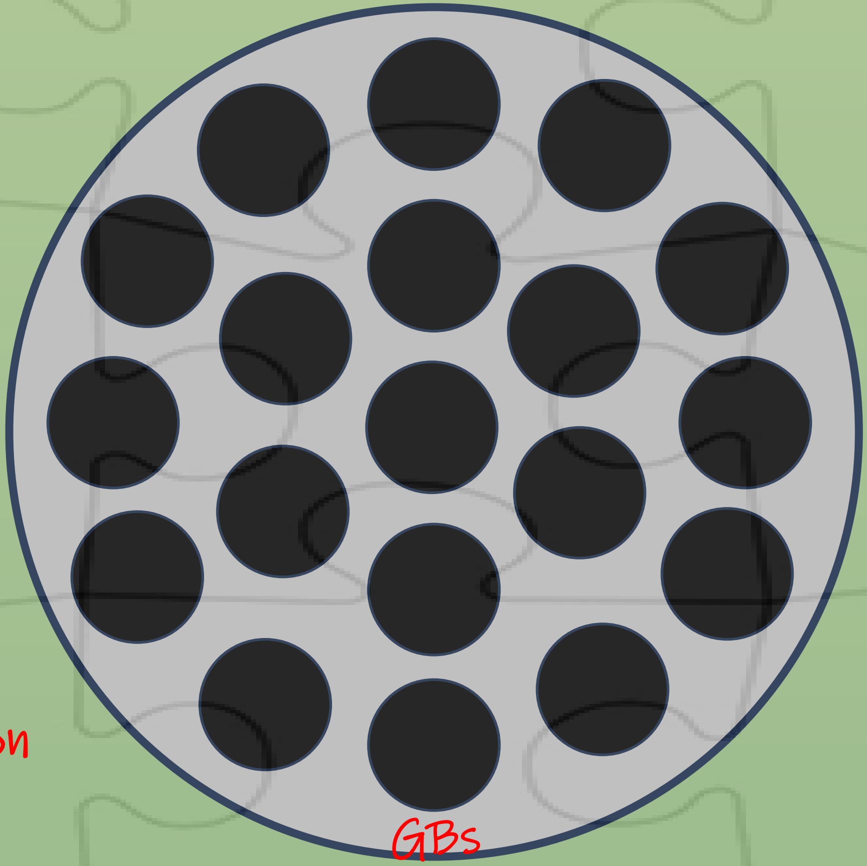


Some issues to face

Scalable processes

Oxygen contamination

Purity and homogeneity



Texturing

High Jc above LHe – 20K

High densification
Sheaths choice

Costs

Memorandum of Cooperation for the High Field Magnet (HFM) Research and Development Programme

HFM Activities – Other Superconductors
Collaboration CERN/CNR-SPIN – Iron Based Superconductors

The programme aims at developing a practical wire produced with a technology that could enable a large-scale production at an affordable cost.

The Objectives are:

- The definition of a scalable process to produce high quality powders in terms of critical temperature and homogeneity;
- The development of PIT wires via the ex-situ method through a mechanical process optimized to reach a high densification and texture in the powder core;
- The fabrication of multifilamentary wires with Jc at least 10^5 A/cm^2 at 16 T at the temperature of interest

The planned path, step by step

Milestone	Deliverable	Description	Required delivery date	CERN's support and date (if required)
M1		**Implementation of the laboratory infrustructure**		
	D1	Report on laboratory upgrade and visit of the partners on-site	April 30th 2024	
M2		**Production of monofilamentary wire with a Jc ≥ 10^4 A/cm²**		
	D2.1	Report on the Ba-122 powder synthesis process	April 30th 2024	
	D2.2	Report on Ba-122 monofilamentary wire production including transport characterization Prototype monofilamentary wire ~ 10 m	October 31st 2024	Qualification of base materials. Transport characterization – August 31th 2024
M3		**Definition of a process to produce ~10g of Ba-122 powders with the highest purity and homogeneity**		
	D3	Report on powder compositional, structural and superconducting properties	April 30th 2025	TEM analysis - October 31st 2024
M4		**Development of multifilamentary Ba-122 wires**		
	D4	Report on deformation process, sheaths and architecture of multifilamentary wires Prototype multifilamentary wire ~ 10 m	October 31st 2025	
M5		**Definition of the process to produce optimized multifilamentary wires with Jc ≥ 10^5 A/cm²**		
	D5.1	Report on optimized production process including the heat treatment	April 30th 2026	TEM analysis - April 30st 2026
	D5.2	Report on superconducting characterization of multifilamentary wires Optimized prototype multifilamentary wire ~ 10 m	October 31st 2026	Transport characterization – August 31th 2026
M6		**Scaling up of the process to produce longer lengths of multifilamentary wires**		
	D6.1	Report on the laboratory adaptation for long length wire fabrication	October 31st 2027	
	D6.2	Delivery of a batch of ~200 m long multifilamentary wire from CNR-SPIN to CERN	October 31st 2027	

SPIN Labs

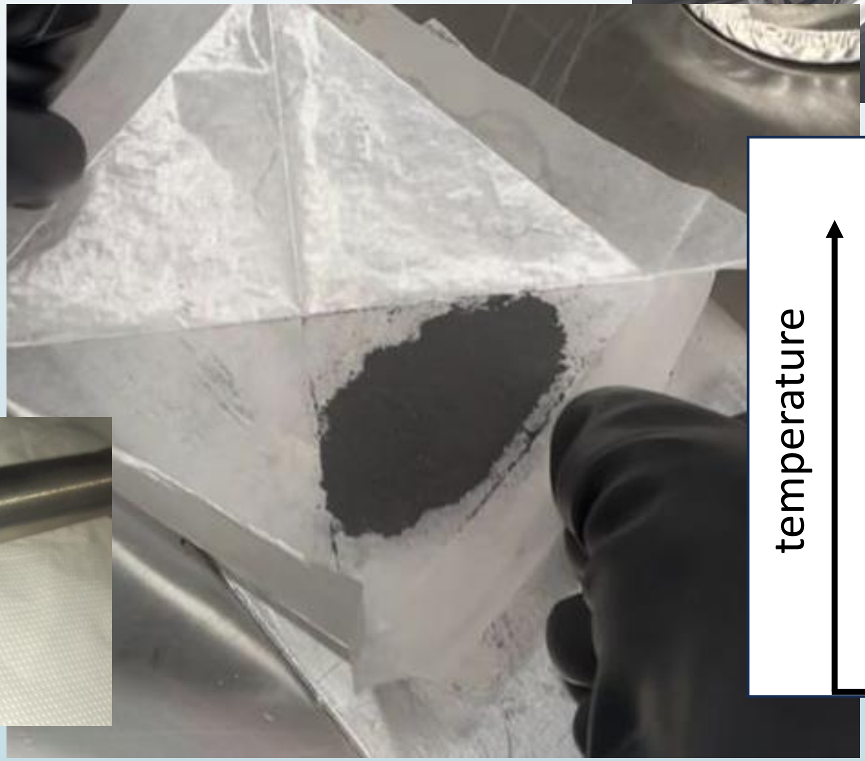
Powders

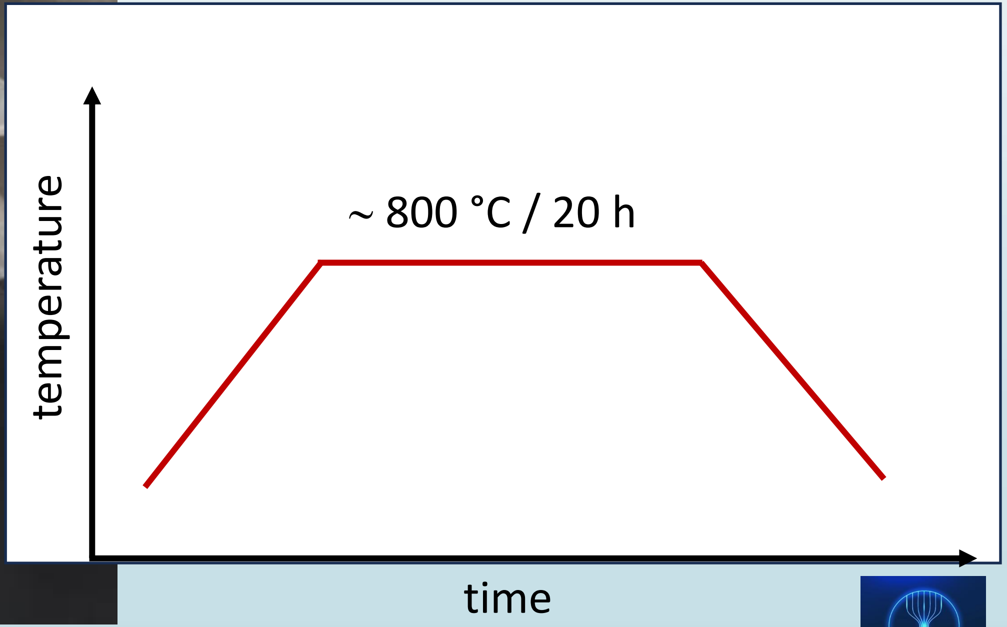
Wires

Characterization

Powder development acitvity

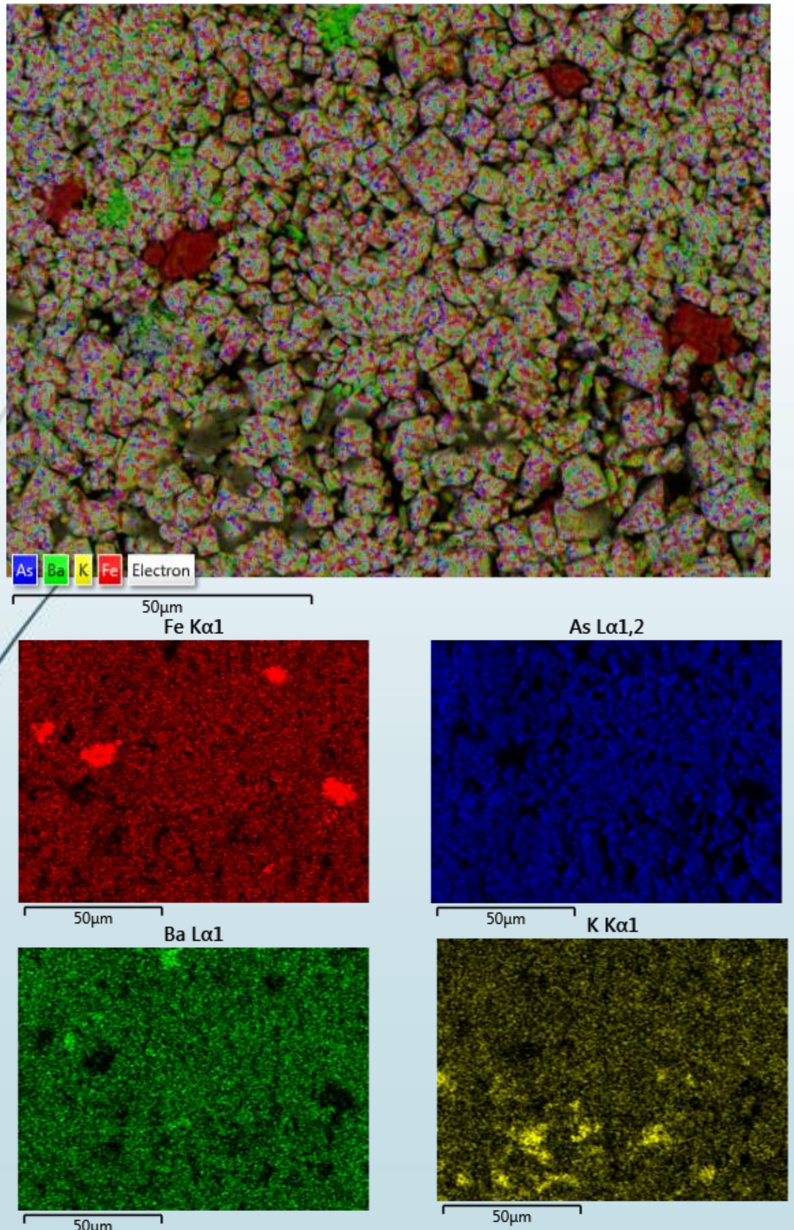
- Pure elements mixed by milling
- Stoichiometric ratio +K addition
- High performance glove-box to control the Oxygen contamination
- Double crucible Nb/SS sealed by TIG
- <u>1 step heat treatment</u>



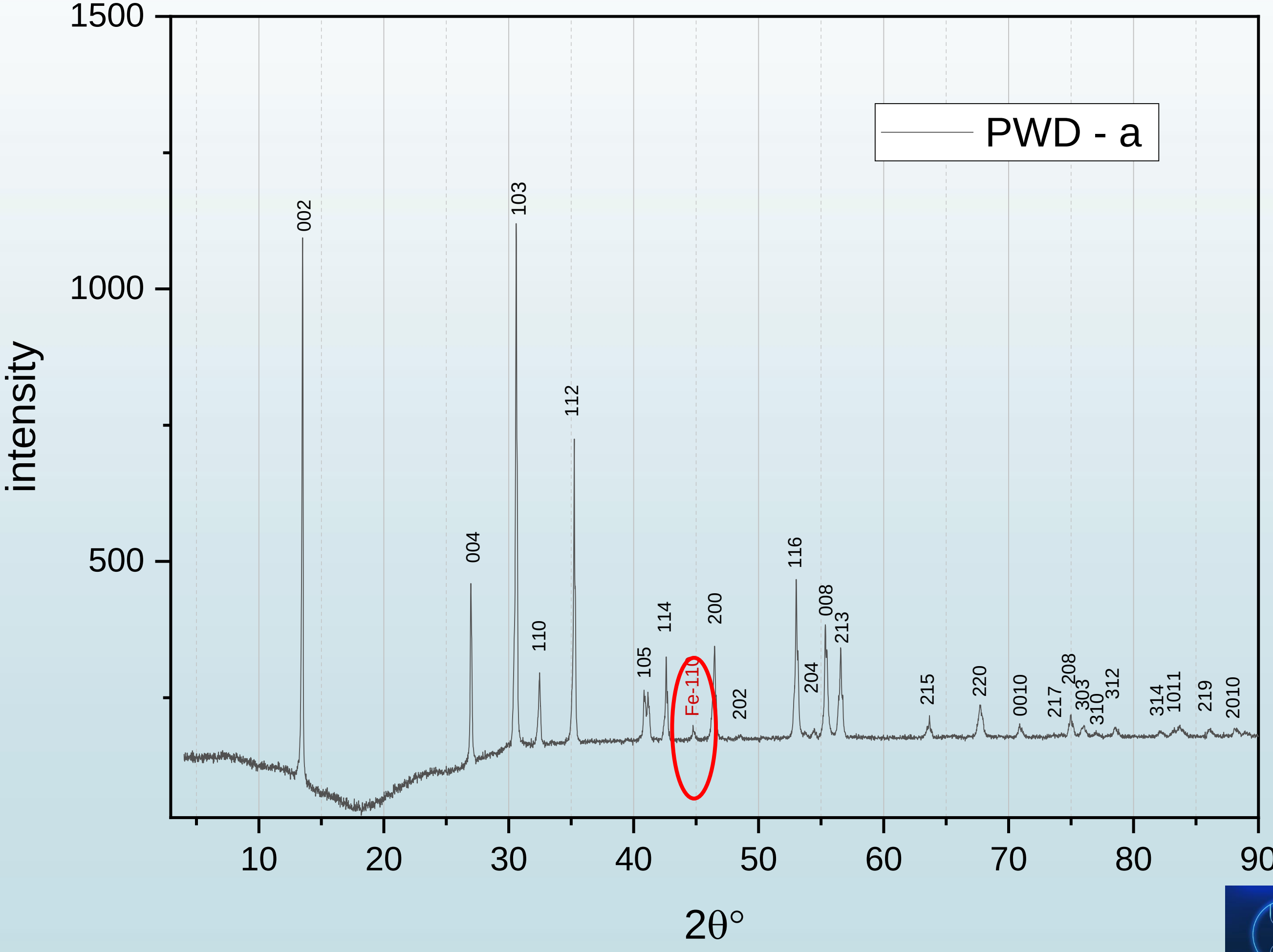


PWD - I

EDS Layered Image 9

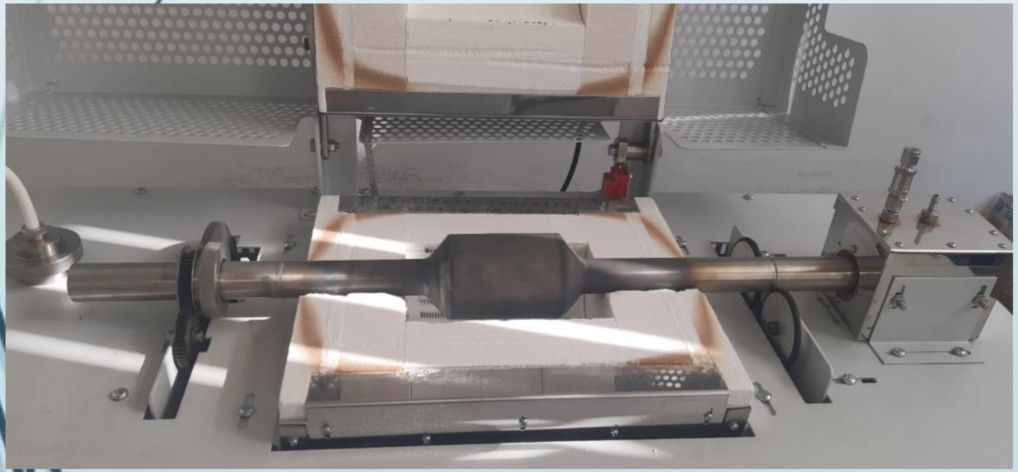


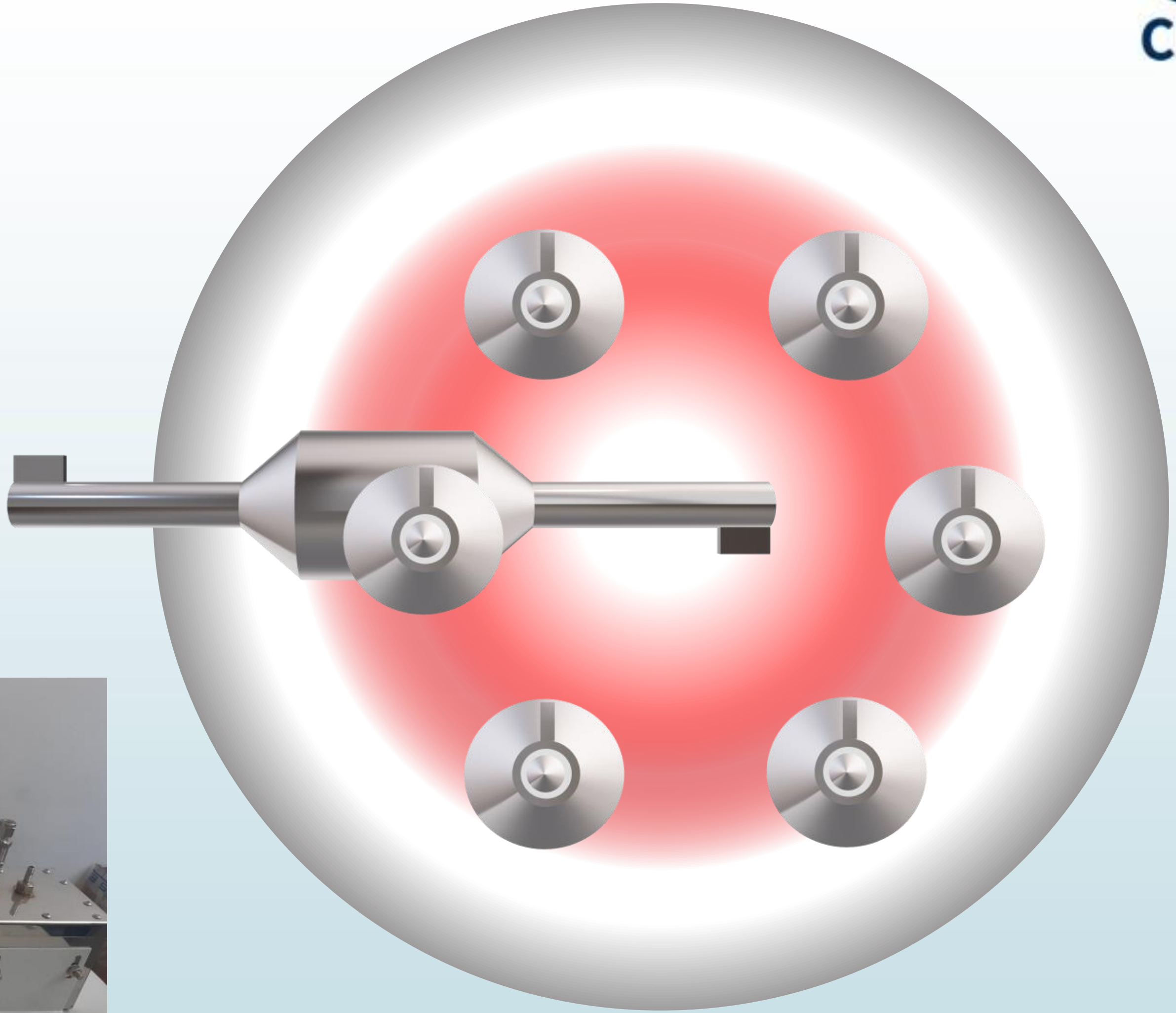
~$(Ba_{0.5}K_{0.5})Fe_2As_2$



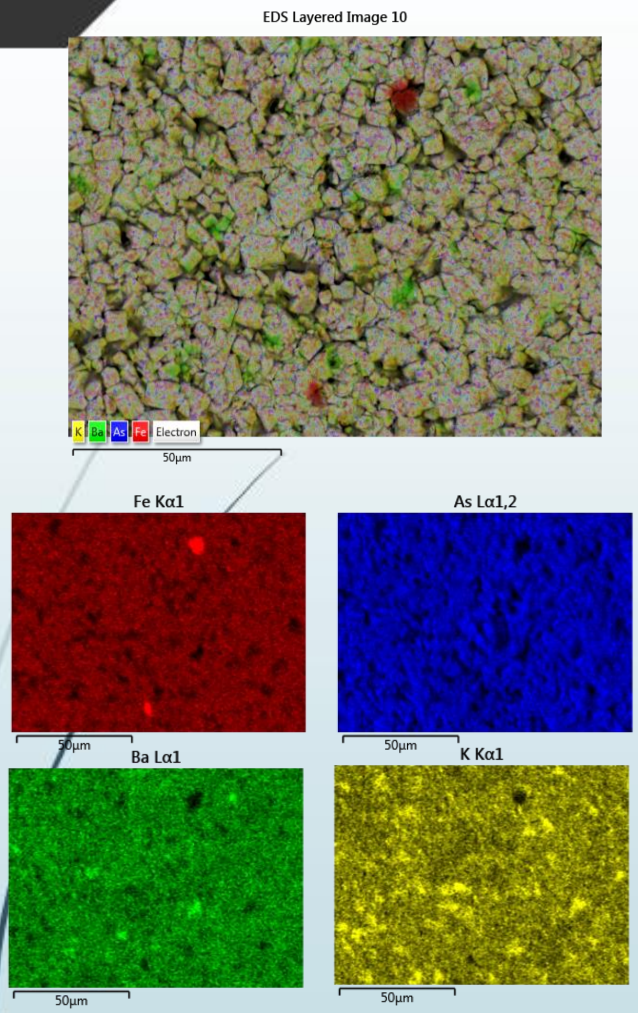
Rotating furnace

Scalable method to get homogeneous reaction of all elements

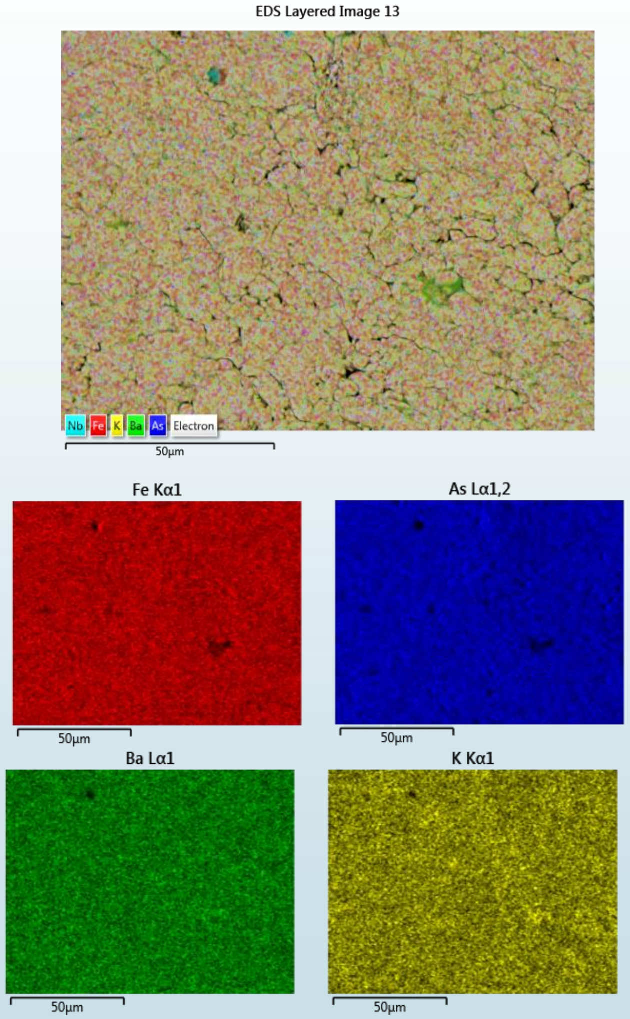




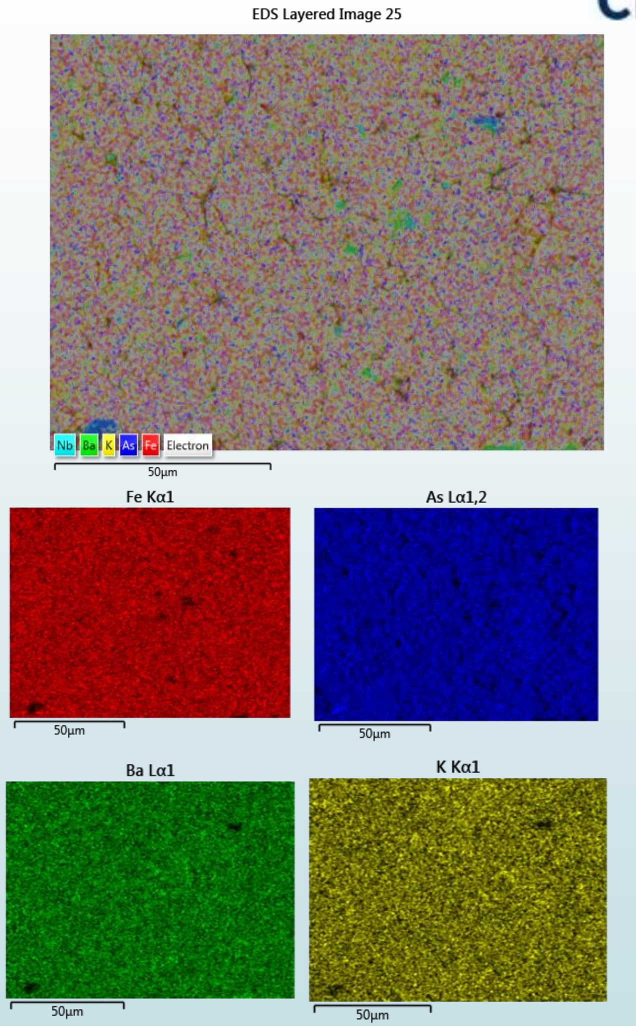
PWD – II



PWD – V

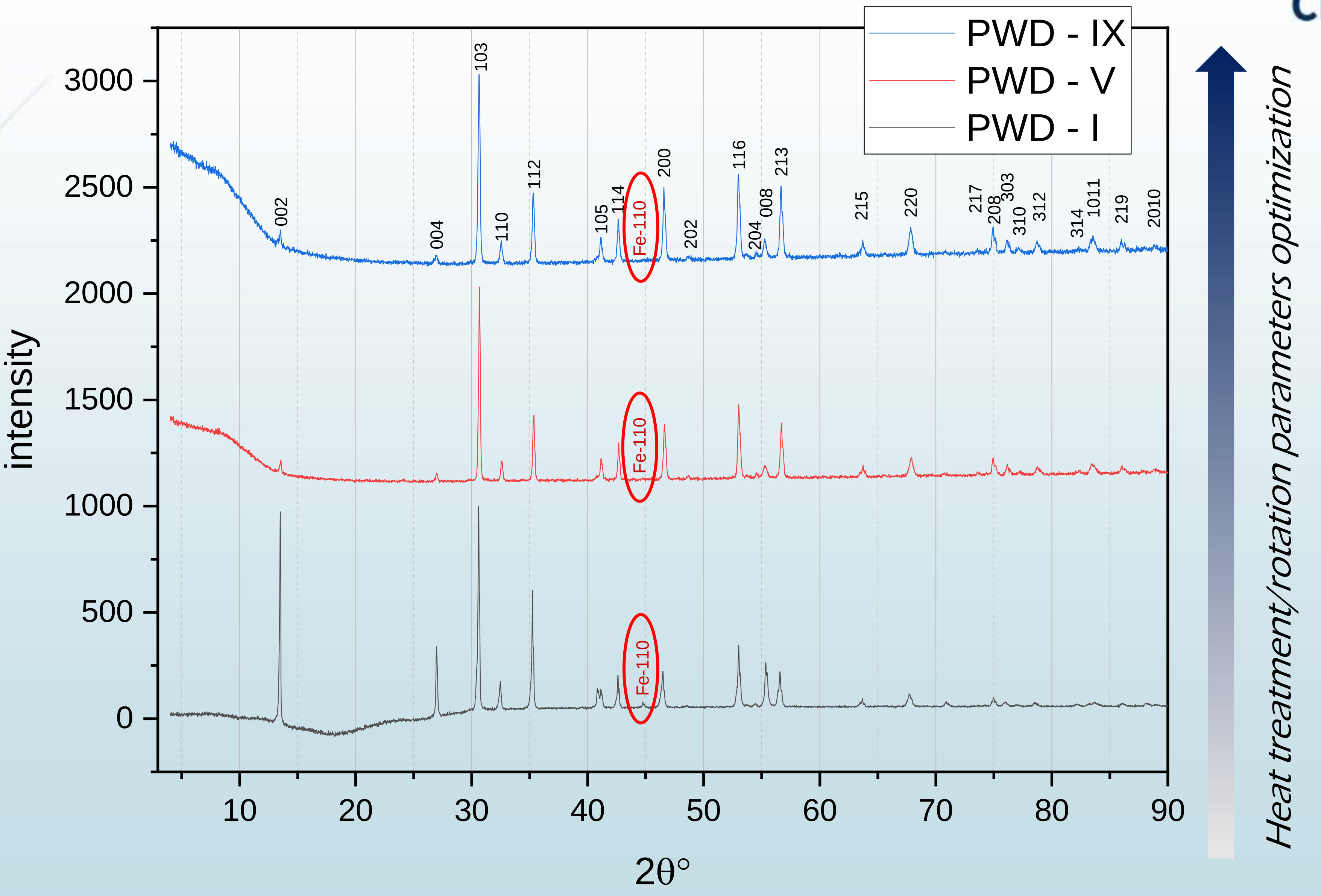


PWD – IX



Heat treatment/rotation parameters optimization

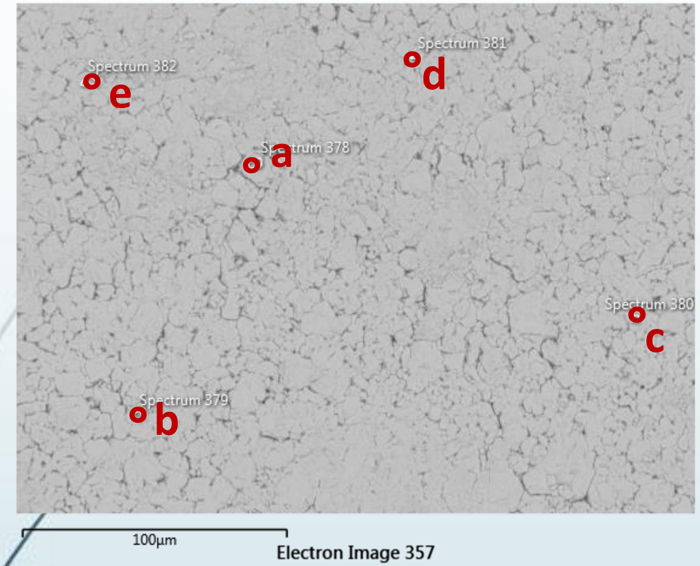
XRD analysis



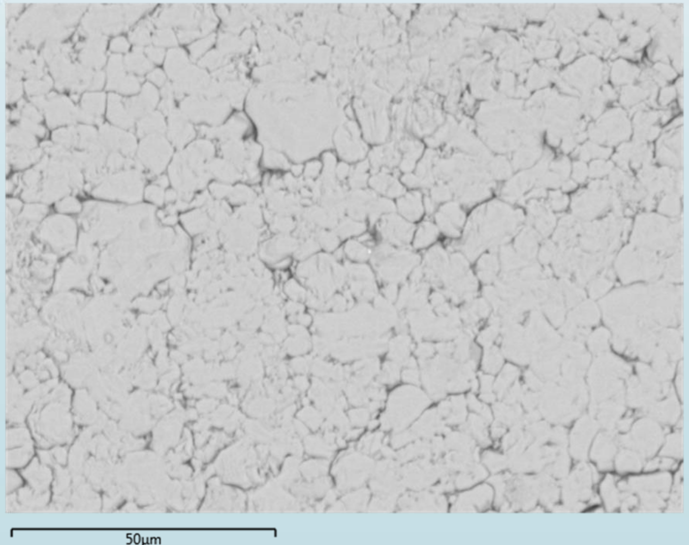
PWD – IX

High **Homogeneity**

Electron Image 365



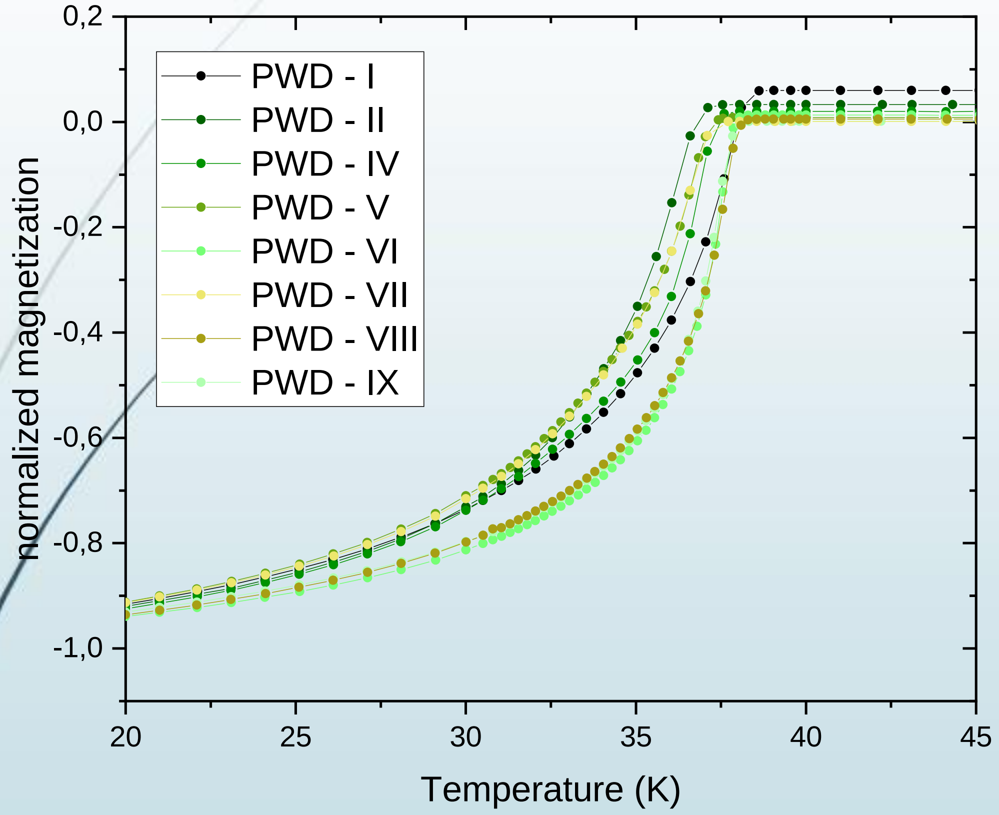
Electron Image 357

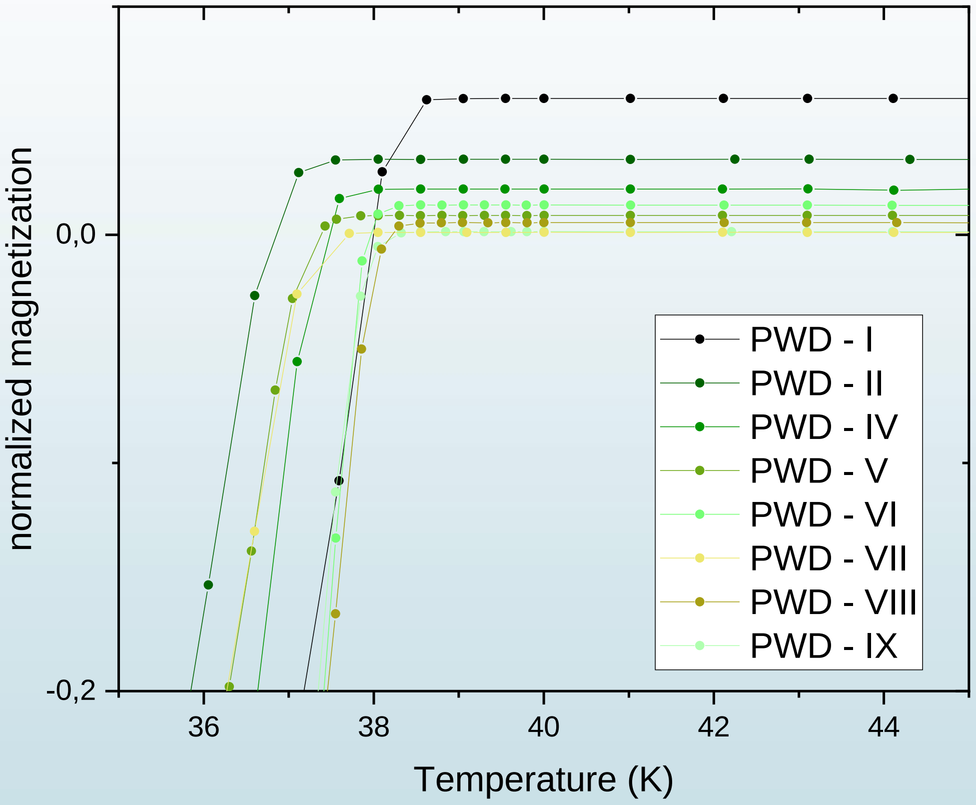


Spectrum label	Ba	K	Fe	As	total
a	13.17	7.63	40.38	38.81	100.00
b	13.26	7.85	39.69	39.20	100.00
c	13.27	7.76	40.19	38.78	100.00
d	13.43	7.92	39.96	38.69	100.00
e	13.11	7.65	39.97	39.27	100.00

$\sim(Ba_{0.6}K_{0.4})Fe_2As_2$

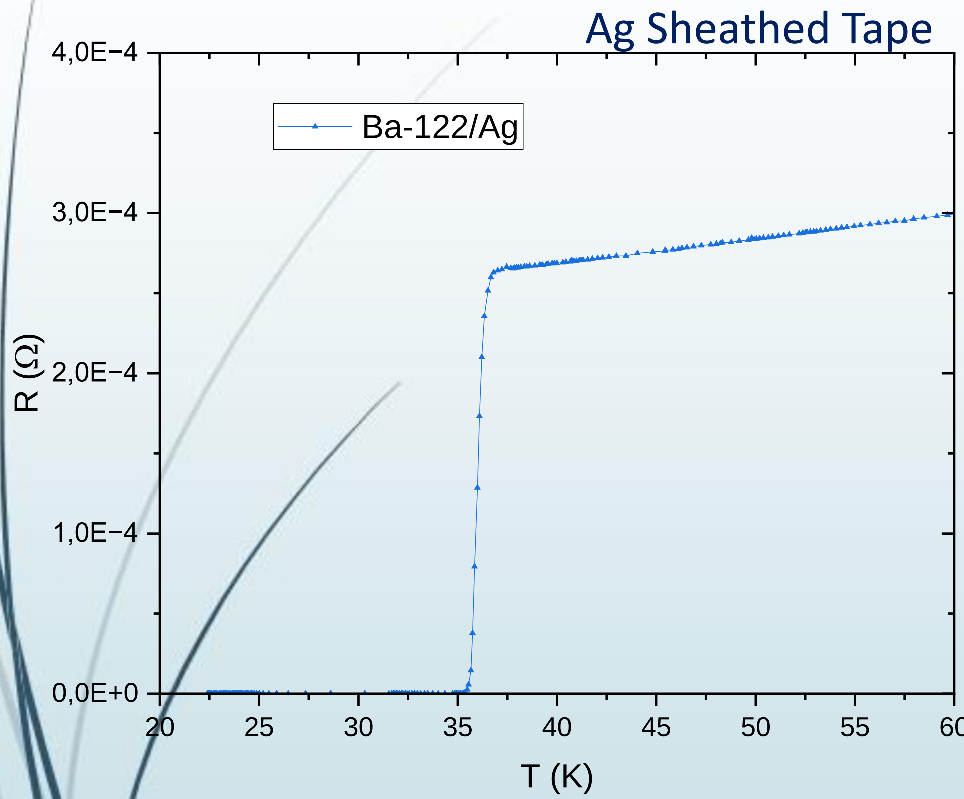
Magnetic Measurements

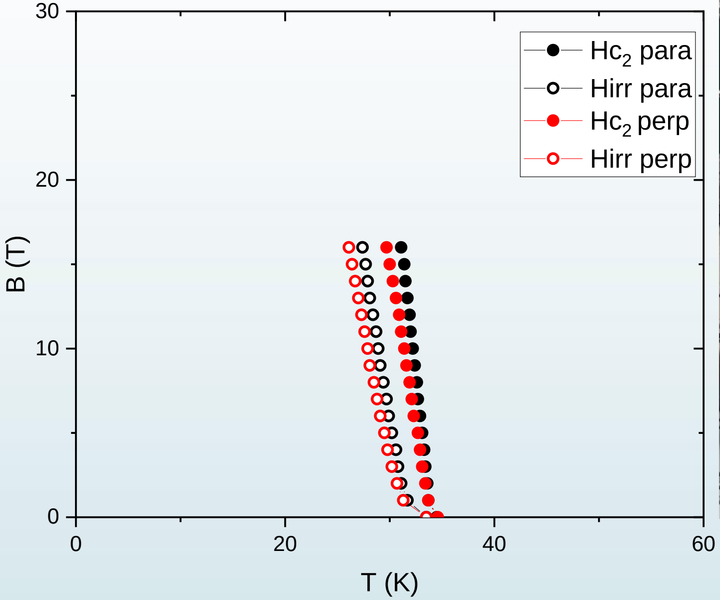




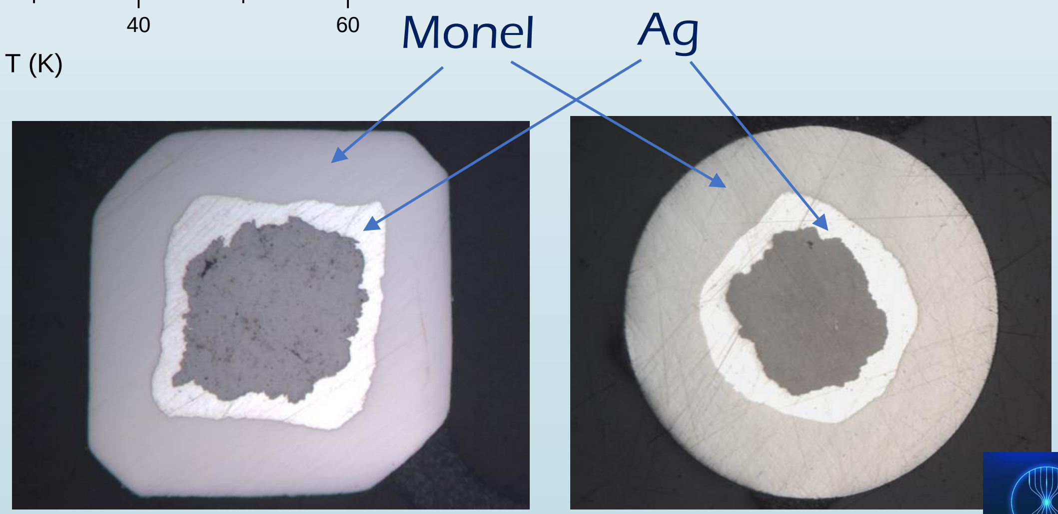
Confirmation of ameliorated homogeneity and drastic reduction of «magnetic» impurities

Initial work on wires development



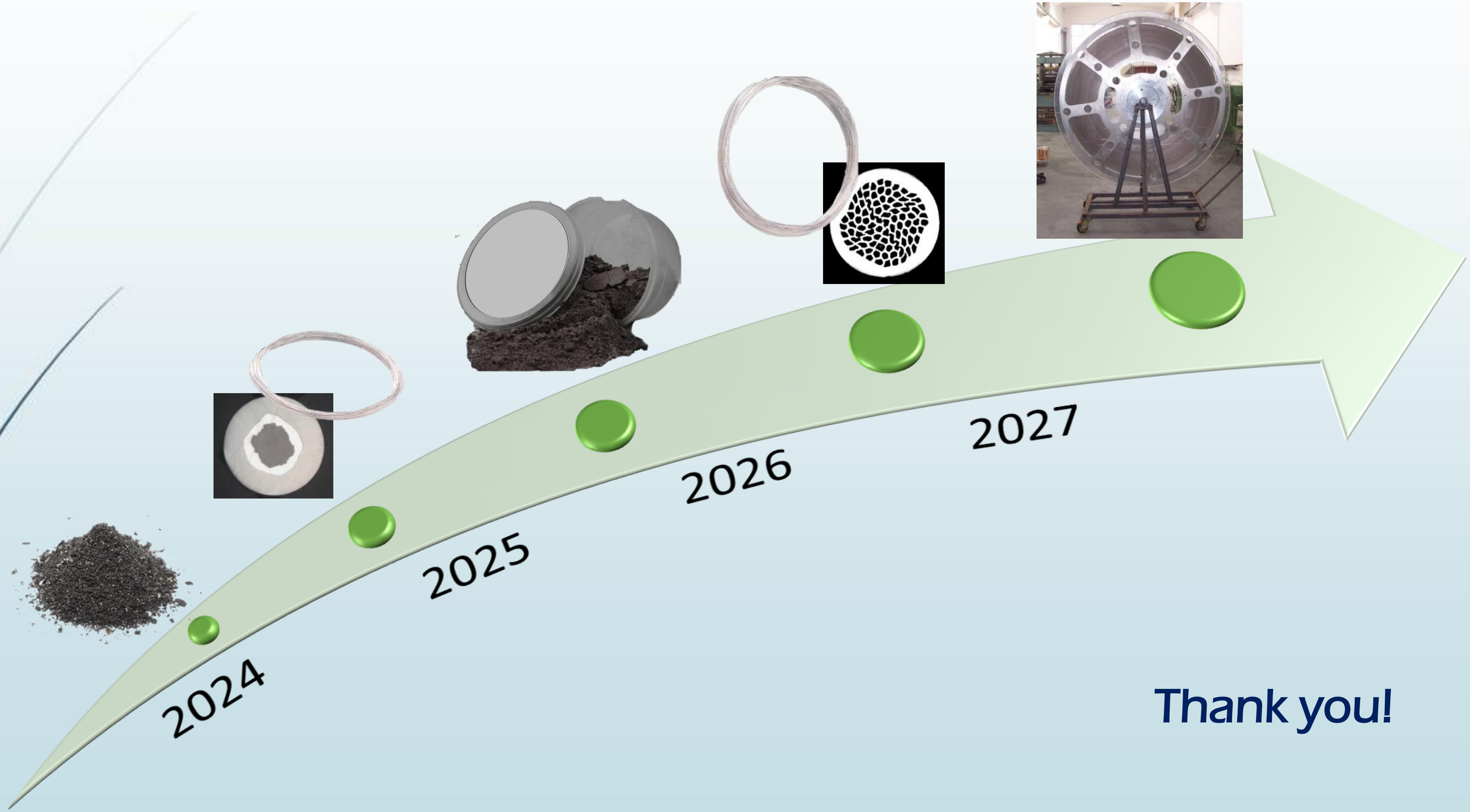


Transopprt measurements up 16 T cryogen-free



Towards wires with harder sheath and higher powder density exploiting our GDG method developed on Bi-2212

Plan's summary in a sketch



Thank you!