Development of Superconducting MgB_2 Wires

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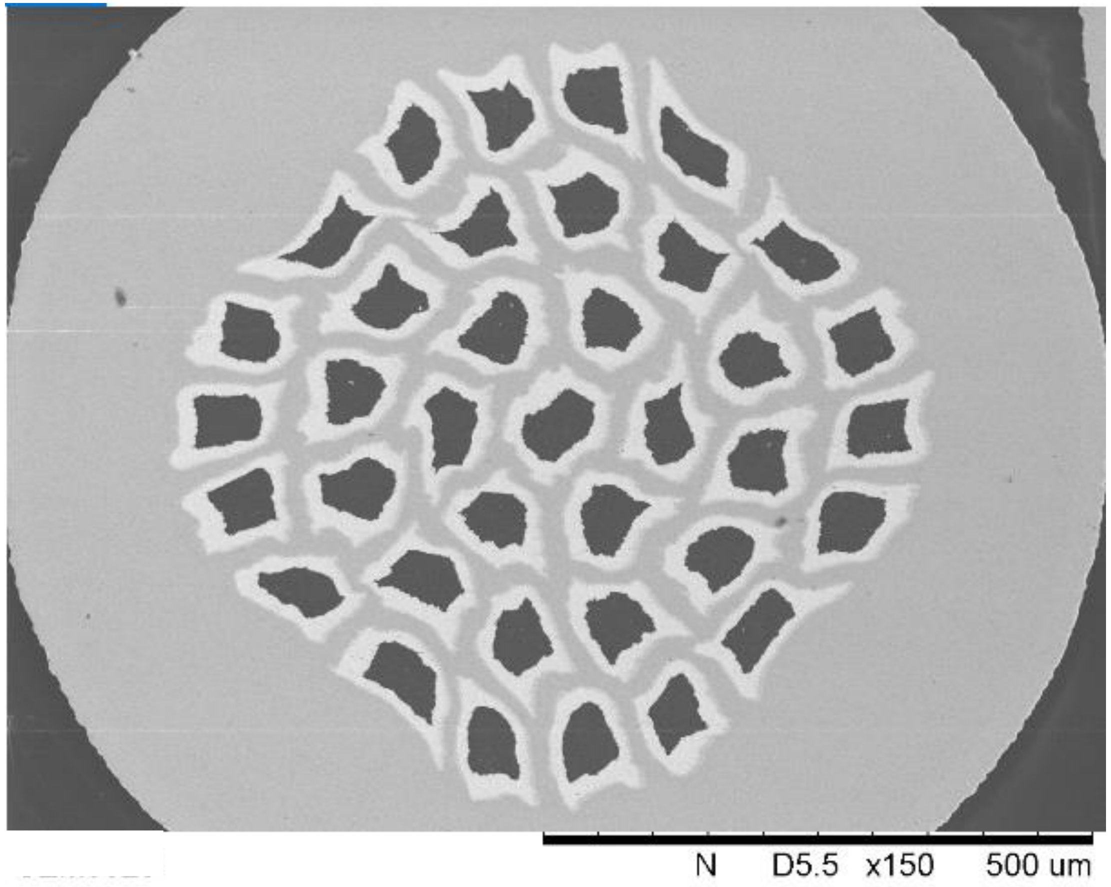
ASG Superconductors

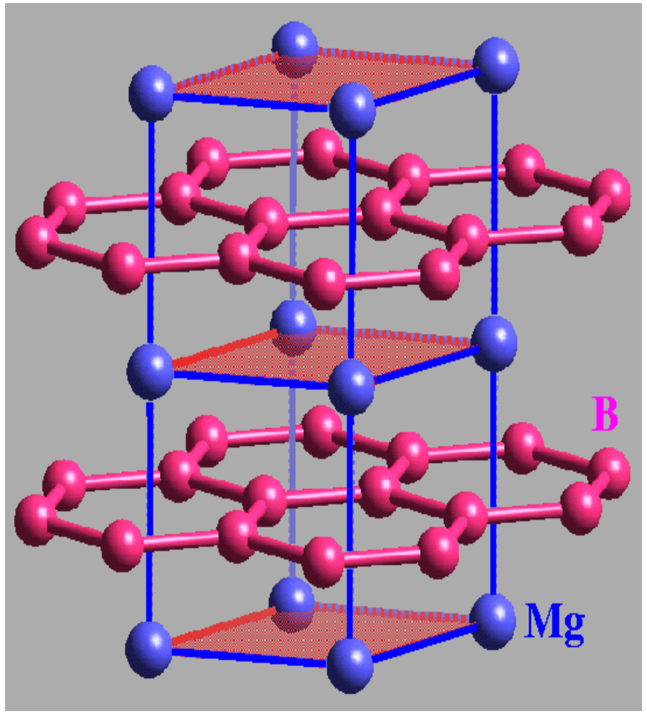
EASITrain – European Advanced Superconductivity Innovation and Training. This Marie Sklodowska-Curie Action (MSCA) Innovative Training Networks (ITN) has received funding from the European Union’s H2020 Framework Programme under Grant Agreement no. 764879

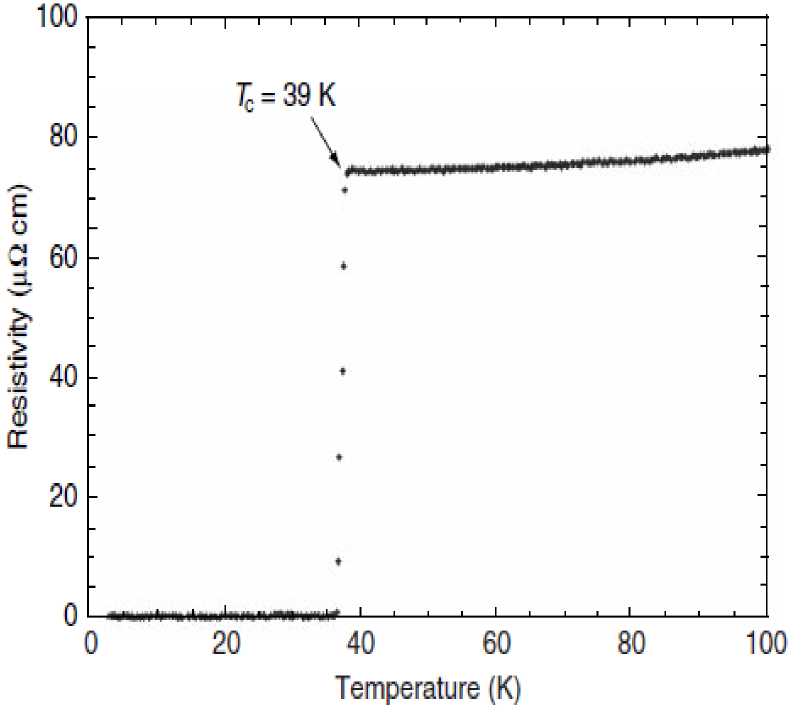
Outline

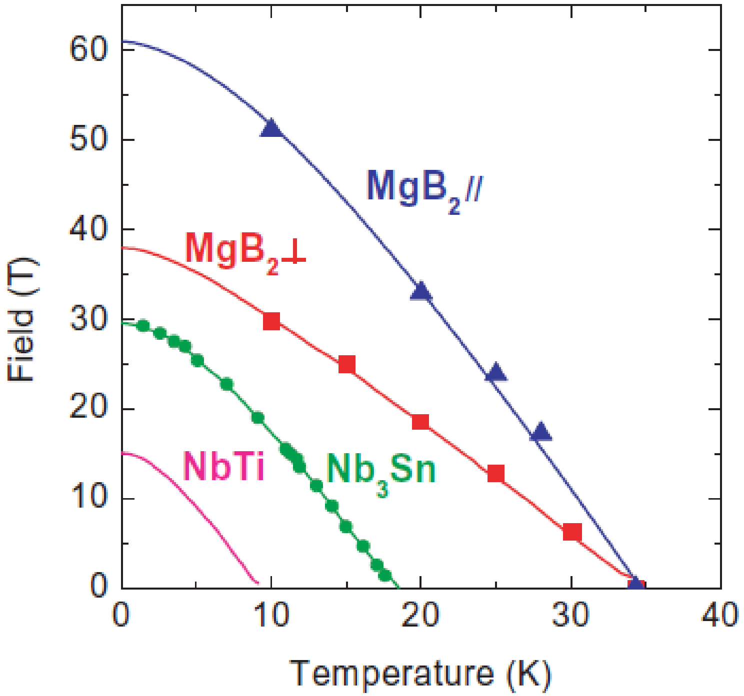
- Why MgB2?
- MgB2 application matrix
- ASG Superconductors company
- Columbus MgB2 Unit
- MgB2 production process
- MgB2 wires production process
- MgB2 wires quality control
- MgB2 wire configurations
- Conclusion



Why MgB2?







Simple composition and structure:
- 2 elements
- Hexagonal crystal structure
- Graphite type structure

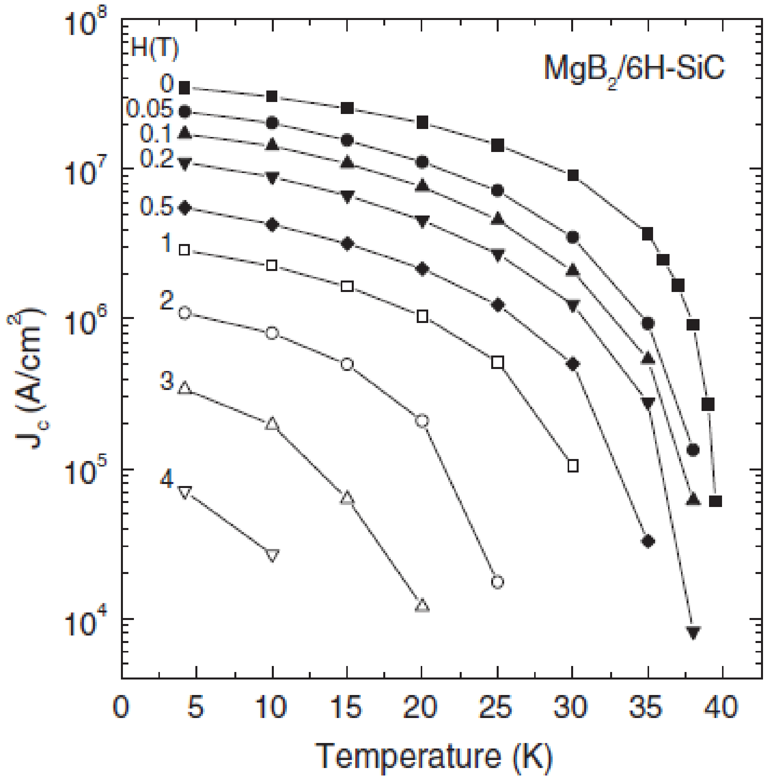
Relatively high Tc

Nagamatsu et al. 2001
Superconductivity at 39K in magnesium diboride
Nature 410 63-4

High critical field

Iwasa Y et al. 2006
A round table discussion on MgB_2: towards a wide market or a niche production?
IEEE Trans. Appl. Supercond 16 1457-64

WHY MGB2?



Large critical current density

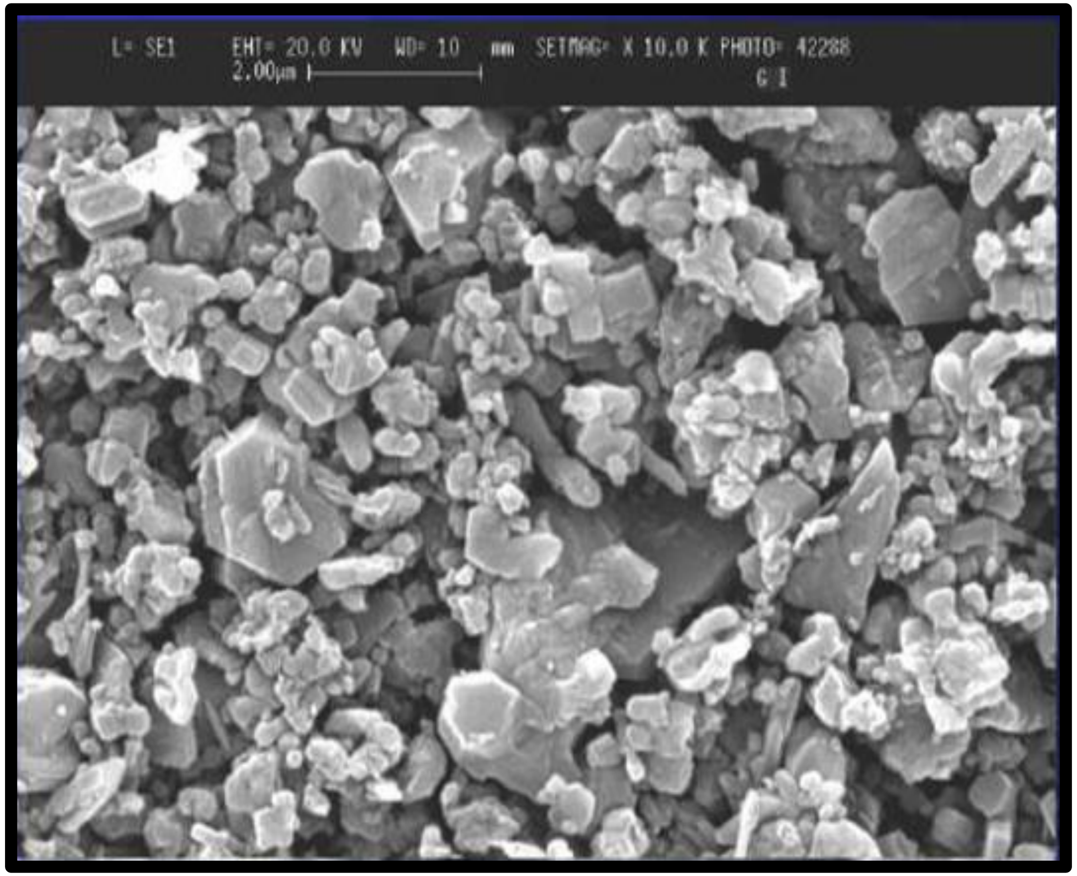
Zeng et al. 2003
Superconducting MgB_2 thin film on silicon carbide substrate by HPCVD
APL 82 2097-9

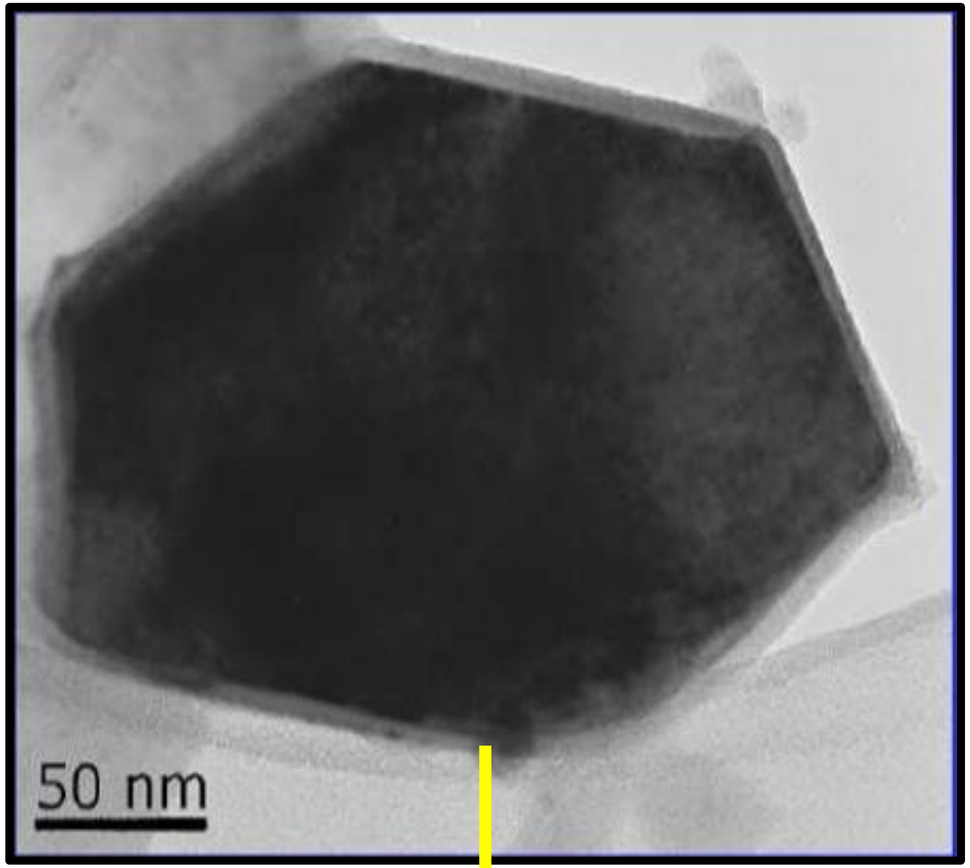
Compound	Mass density
Copper	8,96 g/cm^3
NbTi	6 g/cm^3
Nb3Sn	5,4 g/cm^3
YBCO	6,35 g/cm^3
BSCCO-2223	6,5 g/cm^3
MgB_2	2,6 g/cm^3

Low density

- **Low material cost**
- **PIT process for wire fabrication**
- **MgB2-based systems could be cooled by modern cryocooling devices**

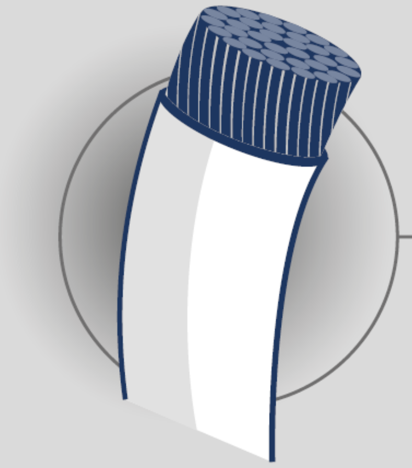
MgB2 Powder SEM Image





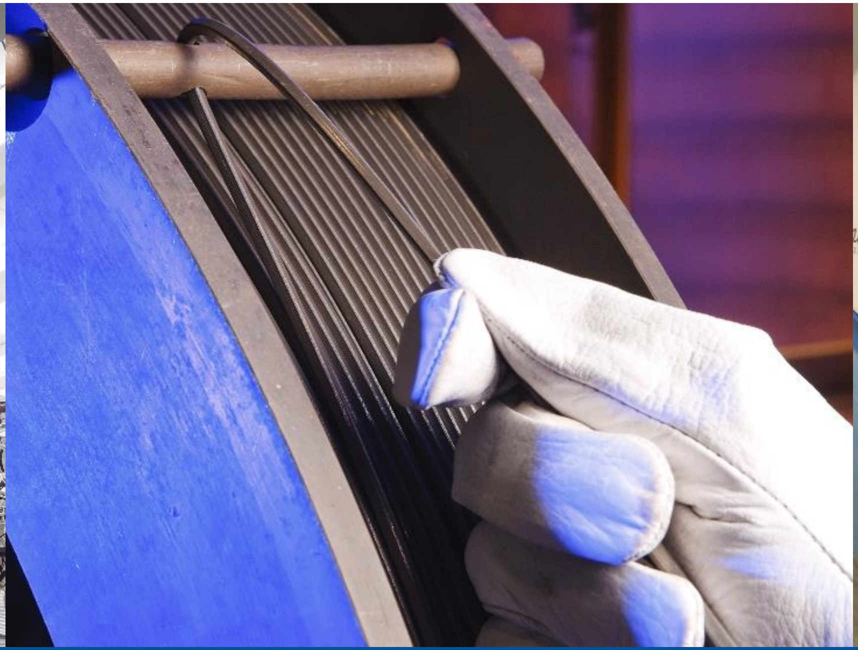
Hexagonal structure

MgB_2 APPLICATION MATRIX



	CABLES	ROTATING MACHINES (MOTORS/ GENERATORS)	MAGNETS	FAULT CURRENT LIMITERS	ENERGY STORAGE DEVICES
MEDICAL			✓		
ELECTRICITY/ GRID	✓			✓	✓
INDUSTRIAL	✓		✓		✓
AIRCRAFT/ AEROSPACE	✓	✓			
ENERGY GENERATION		✓			
NAVAL		✓		✓	

ASG SUPERCONDUCTORS



ASG SUPERCONDUCTORS
magnets & systems unit

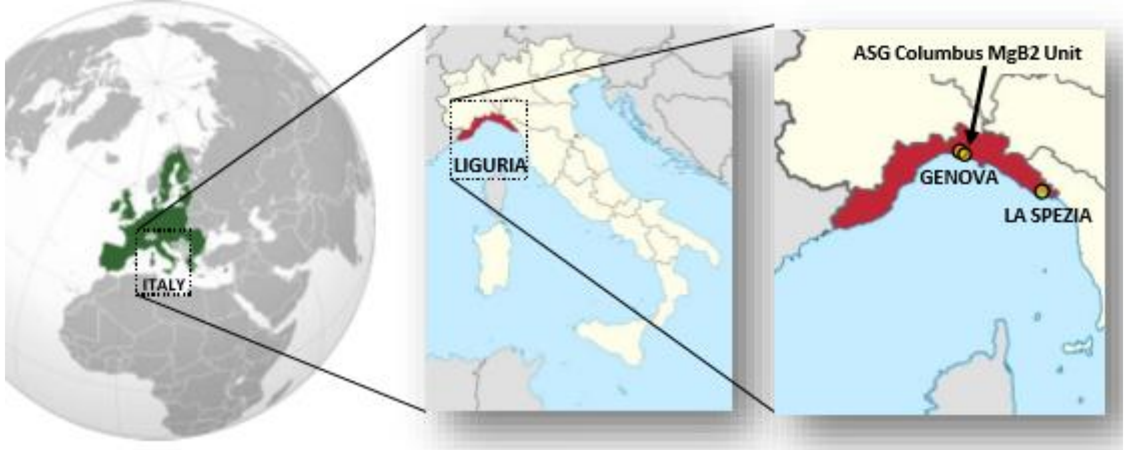
ASG SUPERCONDUCTORS
columbus mgb2 unit

ASG SUPERCONDUCTORS
paramed mri unit

Genoa,09/10/2020

Paola Mauceri - Student Workshop on Superconductivity and Applications

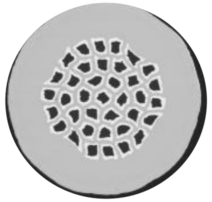
Columbus MgB₂ Unit

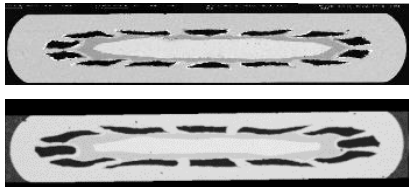


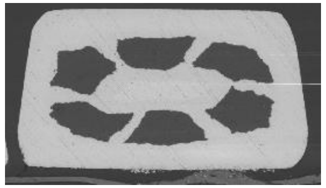
Round wires

MRO

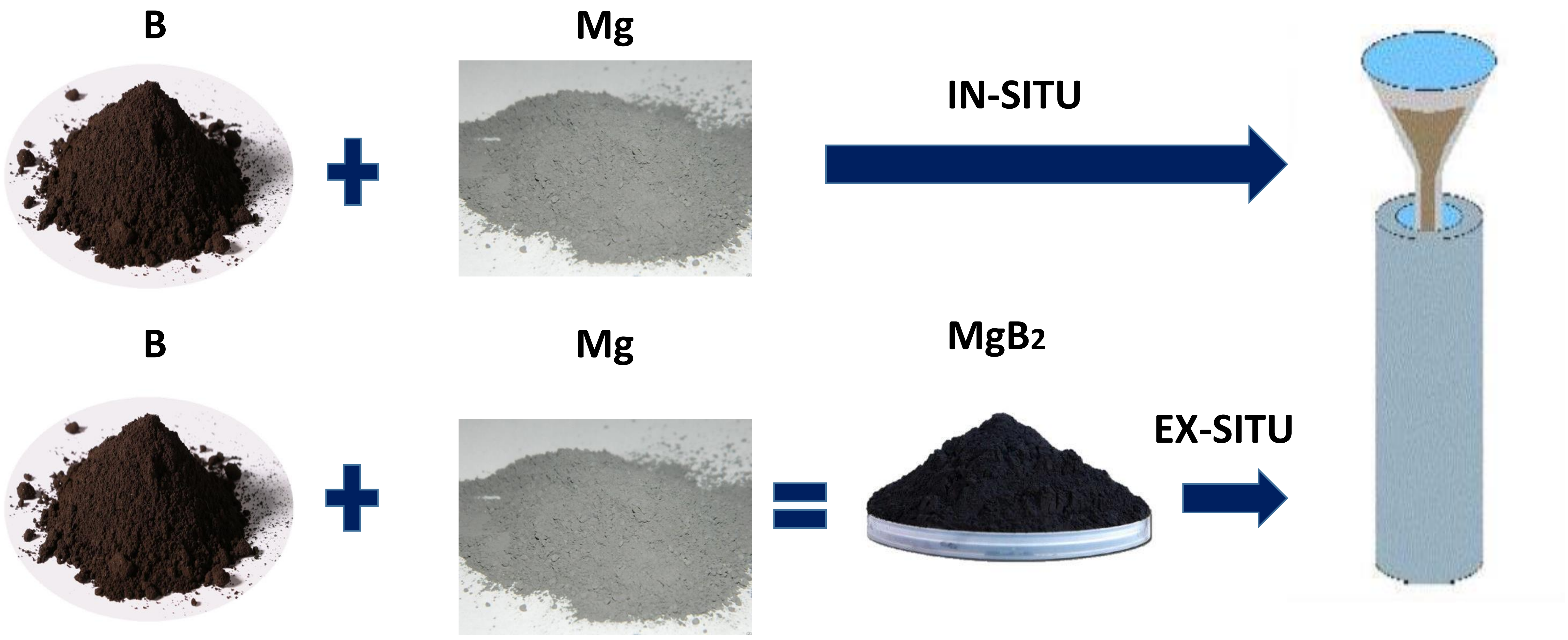
MRI







MgB_2 PRODUCTION PROCESSES



MgB_2 Production Processes

Advantages

In-situ	Ex-situ
Low cost	Easier process
High speed process	Homogeneity over long length
Easier insertion of doping	Control of the powder granulometry and purity

MgB_2 Production Processes

In-situ

Ex-situ

Disadvantages

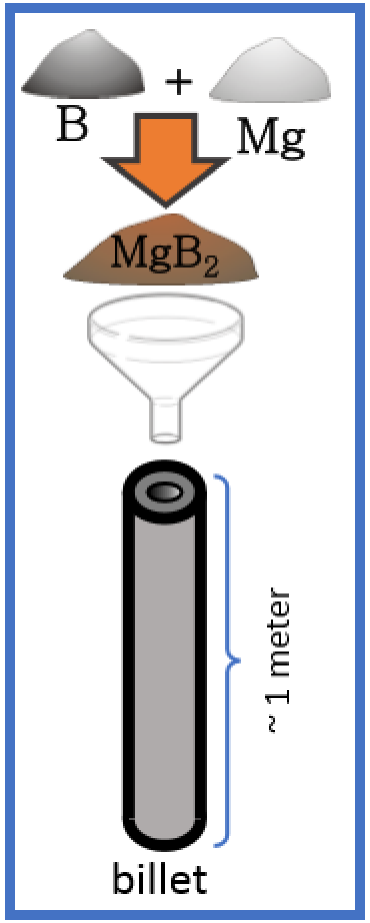
In-situ:
- Inhomogeneity over long length
- Need of inert sheaths

Ex-situ:
- Need of hard sheath materials

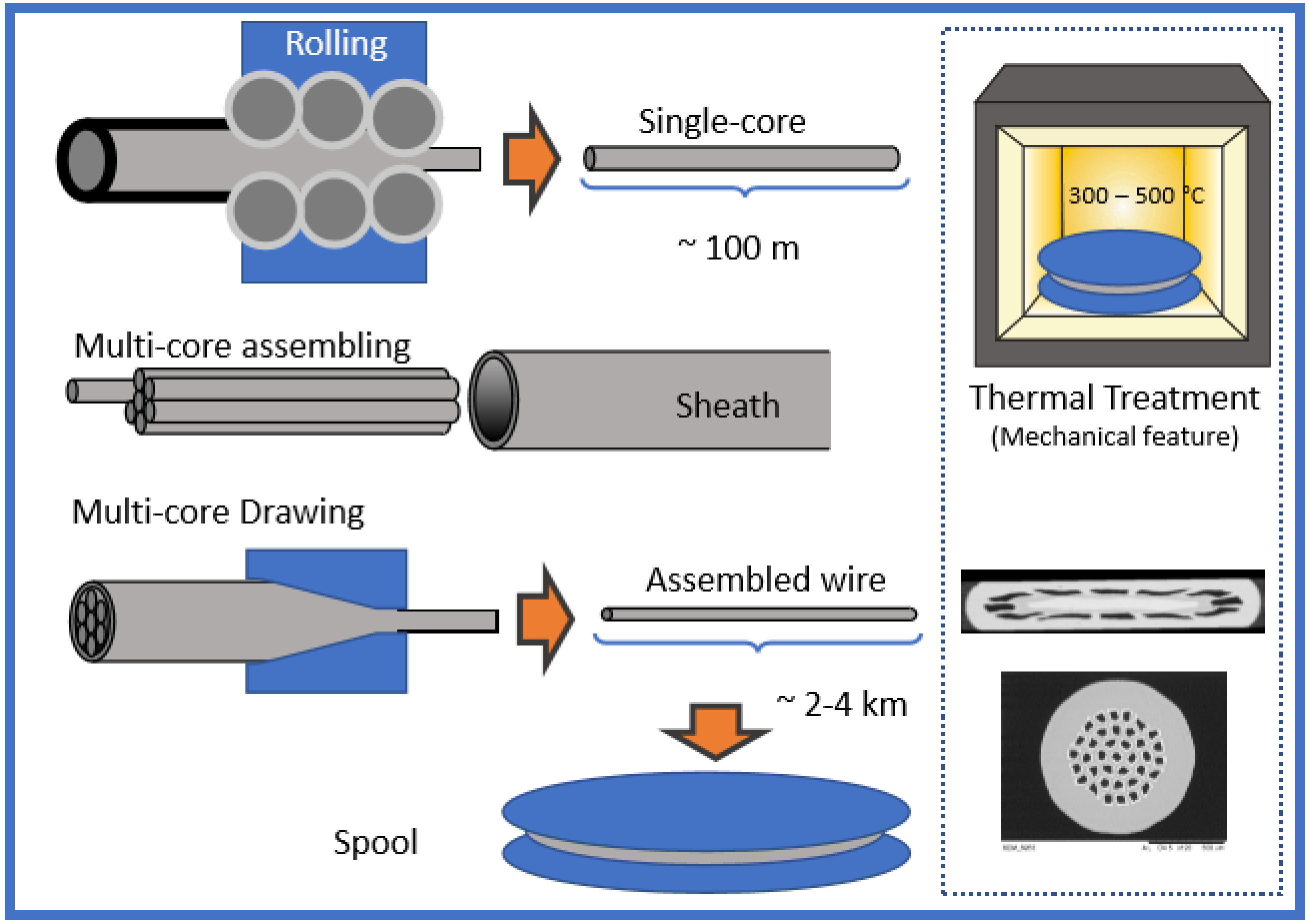
→ **More flexible and reliable method!!!**

MgB2 Wires Production Process

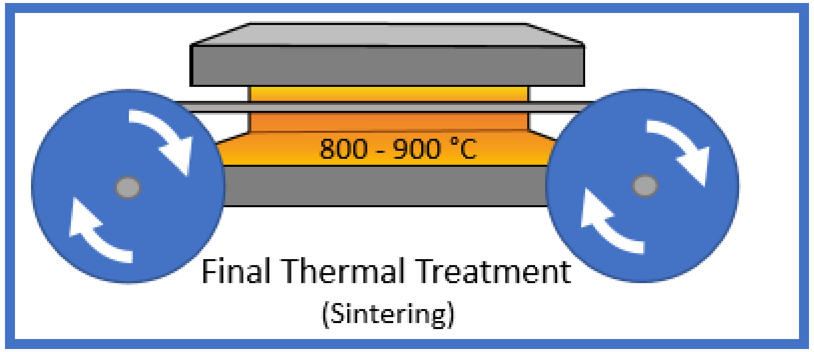
I phase



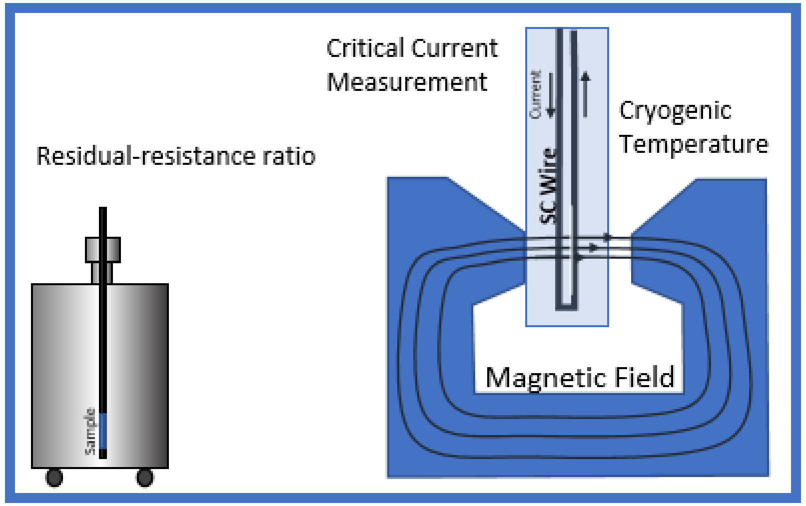
II phase



III phase



Quality Assurance



MgB2 Wires Production Process

Powders clean synthesis

Multistep rolling machine

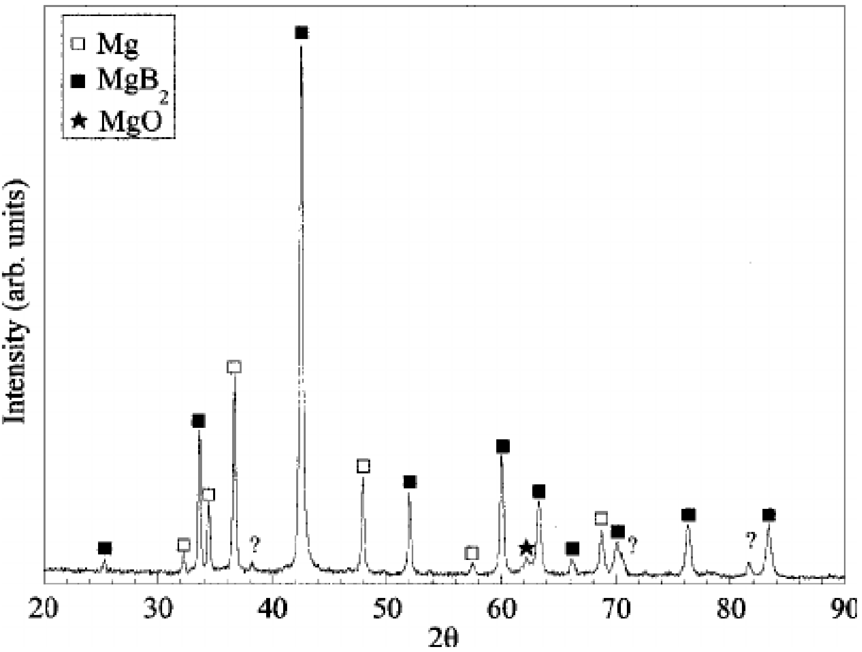
High power straigth drawing machine

20 m long in-line furnace

Multistep drawing machine

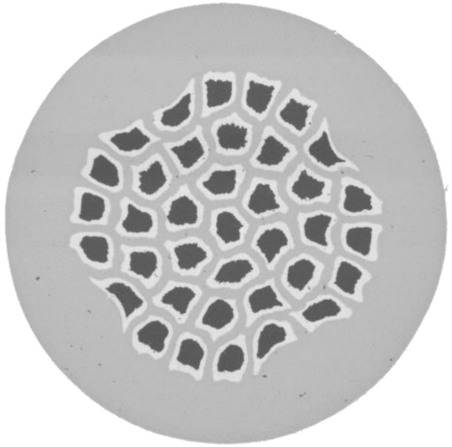
4 meter furnace for annealing HT

Structure characterization



XRD

SEM and EDS



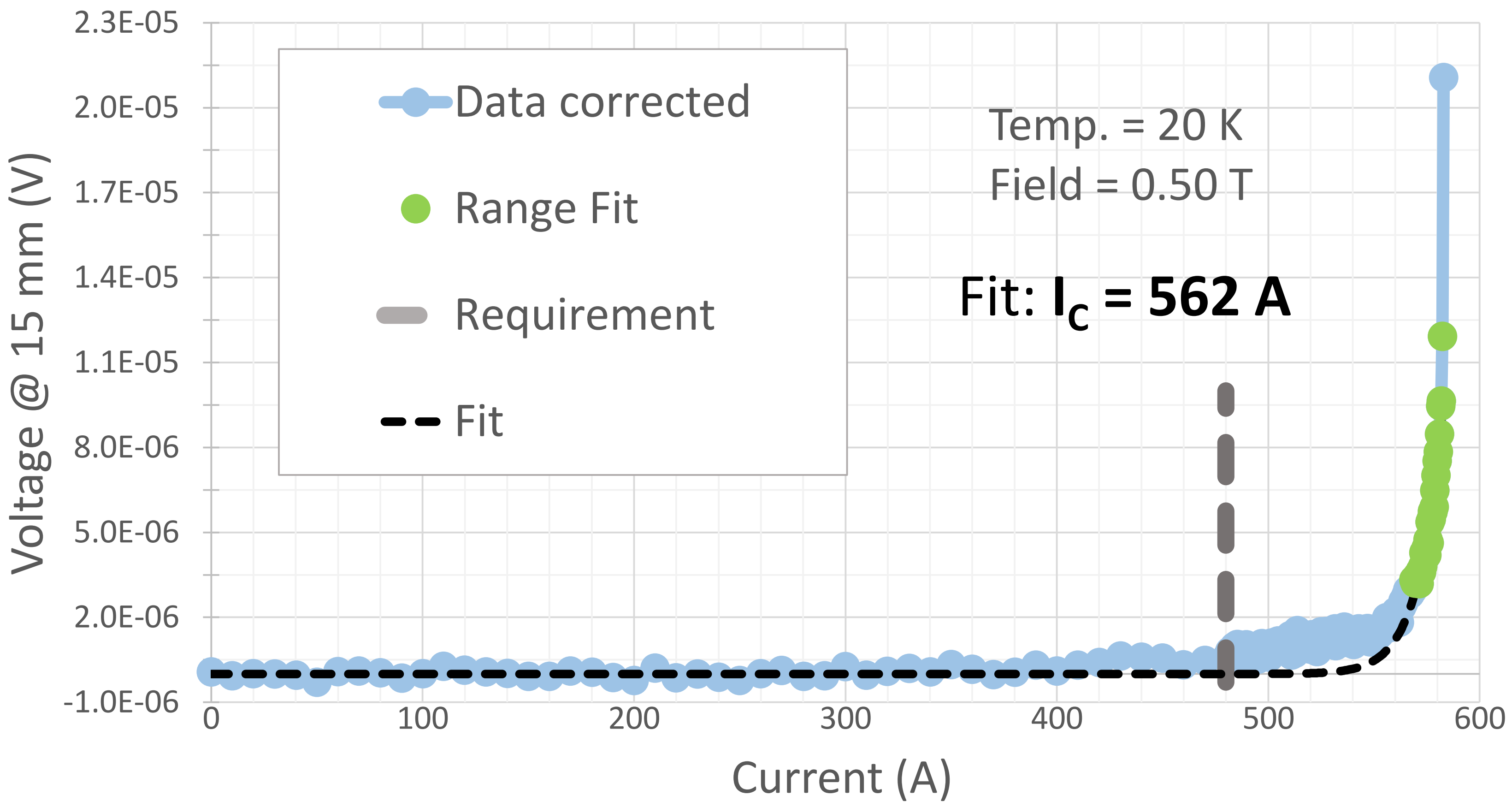
Current transport measurement

Tests parameters range

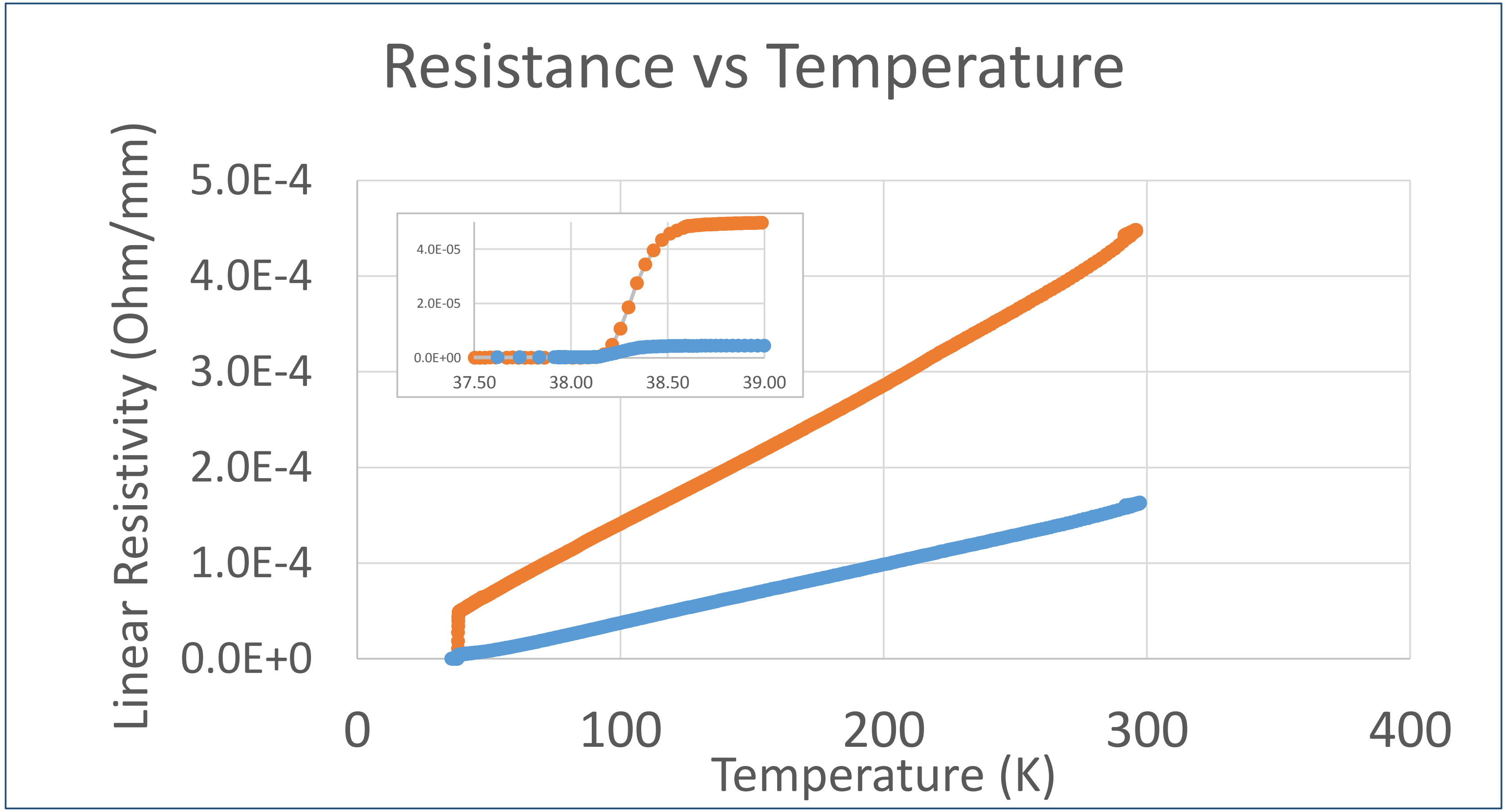
Field: **0 – 1.8 T**

Temperature: **20 – 30 K**

Current: **0 – 1000 A**



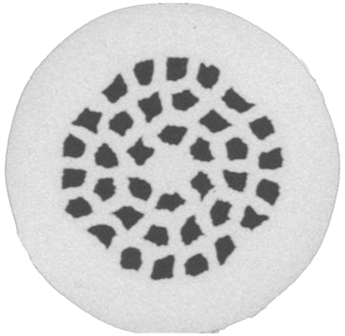
Residual-resistance ratio (RRR) and Tc Test



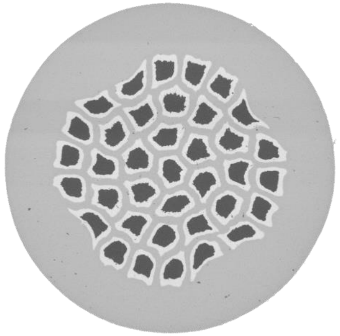
MgB2 Wire Configurations

Round Wires

Diameter: d = 1.33mm
36 filaments
Materials: Monel, Ni
FF: 17%

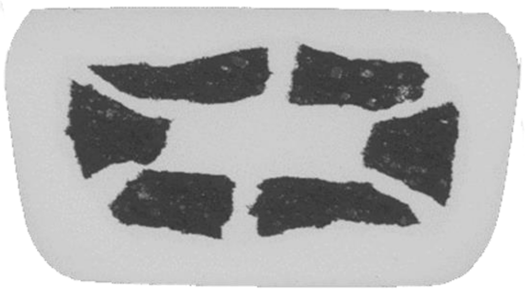


Diameter: d = 1mm
37 filaments
Materials: Monel, Ni
FF: 14%

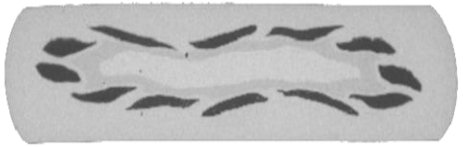


Tapes

Dimension: 2mm x 1mm
6 filaments
Materials: Monel, Ni
FF: 29%



Dimension: 3,67 mm x 0,65 mm
12 filaments
Materials: Ni, Iron, Copper
FF: 11%



MgB_2 Round Wires

Development of superconducting links for the Large Hadron Collider machine

Amalia Ballarino

CERN, European Organization for Nuclear Research, 1211 Geneva 23, Switzerland

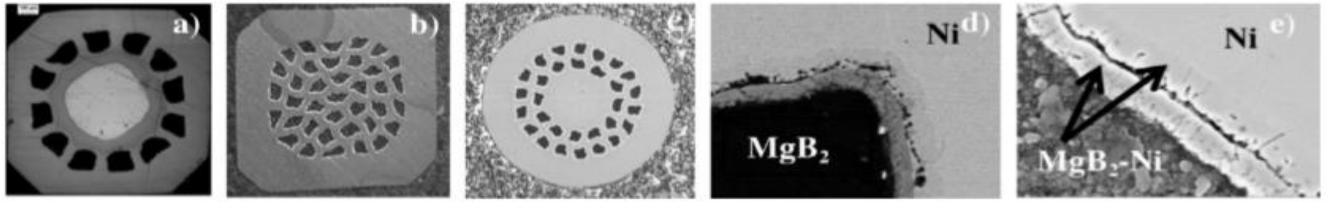
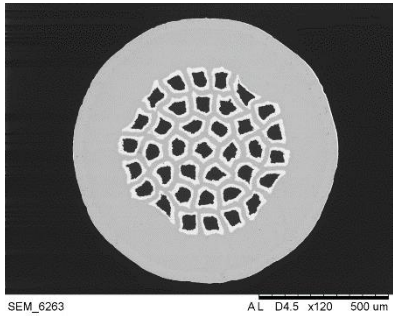


Figure 3. Different generations of MgB_2 Columbus round wires. From left: (a) S1 octagonal wire with nickel matrix and central copper stabilizer surrounded by iron barrier; (b) S2 quasi-square wire with Monel matrix and nickel barrier around the filaments; (c) S3 round wire with Monel matrix and niobium barrier around the filaments; (d) and (e) SEM cross section imaging of wire S2 [8]: porosity and detachment in between the two MgB_2–Ni reaction layers.

Diameter of MgB_2 wire, Φ	$0.8\ mm \leq \Phi < 1\ mm$
Diameter of superconducting filaments	$\leq 60\ \mu m$
Filaments twist pitch	≤ 100 mm
Filaments twist direction	Right-handed screw
Critical current at 25 K and 0.9 T	≥ 186 A
Critical current at 25 K and 0.5 T	≥ 320 A
Critical current at 20 K and 0.5 T	≥ 480 A
Bending radius (after final heat treatment)*	≤ 100 mm
Tensile strain at room temperature*	$\geq 0.28\%$
Copper fraction of the wire total cross section	$\geq 12\%$
RRR of copper stabilizer	> 100
*n-value*** @ 25 K and 0.9 T	> 20

Final configuration

Diameter: 0.93mm
37 filaments
Materials: Monel, Ni, Nb
FF: 11.5%
Copper-Tin electrodeposition

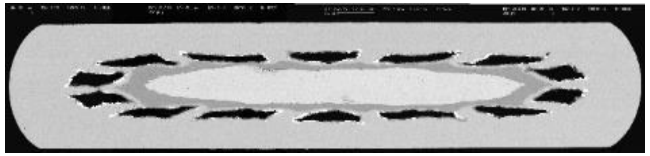


MgB_2 Tapes for MRI

MROpen

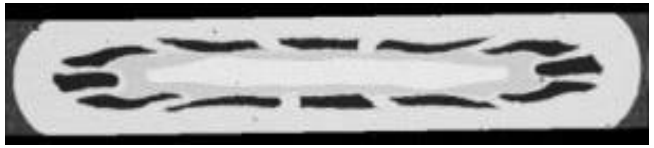
Wire layout in 2006:

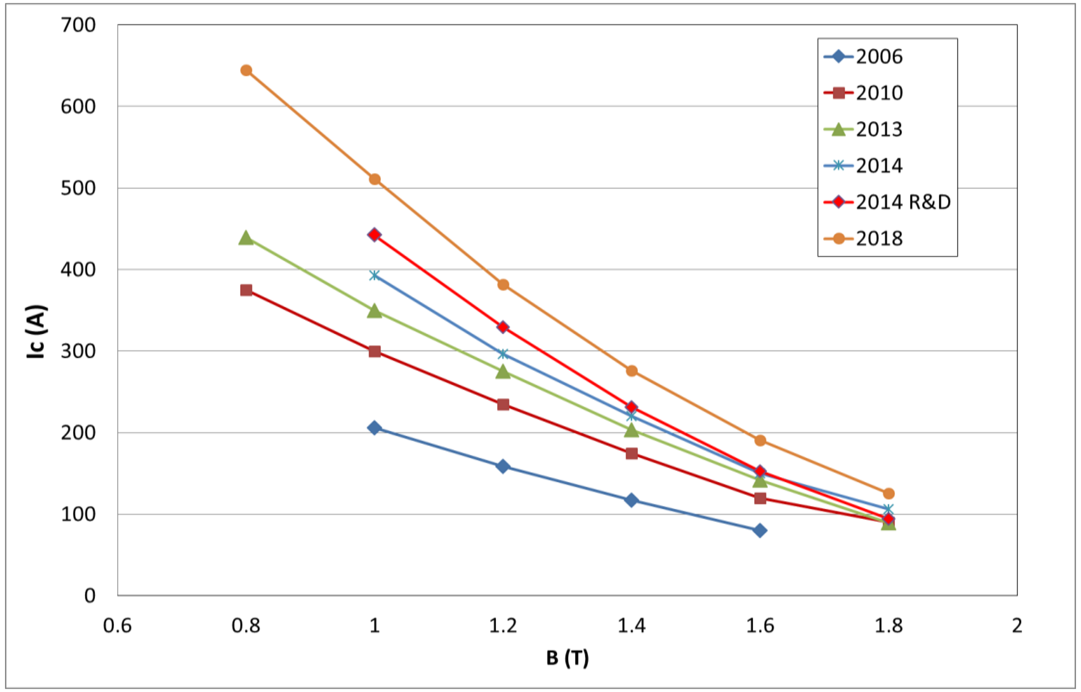
- 14 filaments
- Unit piece length 1.6 Km



Updated wire layout:

- 12 filaments
- Improved fabrication process
- Unit piece length 4.0 Km
- Synthesis in controlled atmosphere





CONCLUSION

- MgB_2 as a SC material, allow to produce high quality superconducting wires for the LHC.
- Ex-situ PIT technique has been industrially implement in the new Columbus plant
- Several wire configurations have been developed in the last years
- MgB_2 tapes are an optimal solution for the magnets development of MRI machines.
- ASG Superconductors is working in innovative projects that are exploring the opportunity to implement MgB_2 SC technology in many applications such as energy transmission, generation and storage


Kiitos!
Grazie!
Obrigado!
Dzięki!
Tak!
Thank you!
Bedankt!
Gracias!
Merci!
Díky!
Danke!
Novus
Tack!