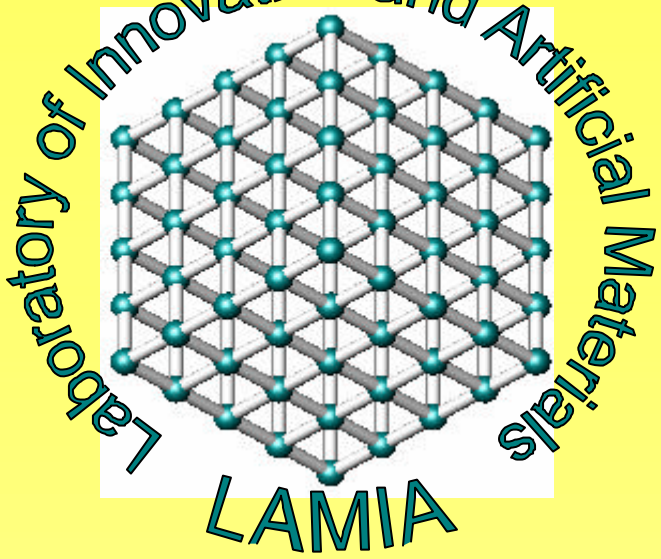


Bi(2223) activity at INFM-LAMIA

G. Grasso, S. Roncallo, A. Malagoli, C. Fanciulli, A.S. Siri

http://www.lamia.infm.it

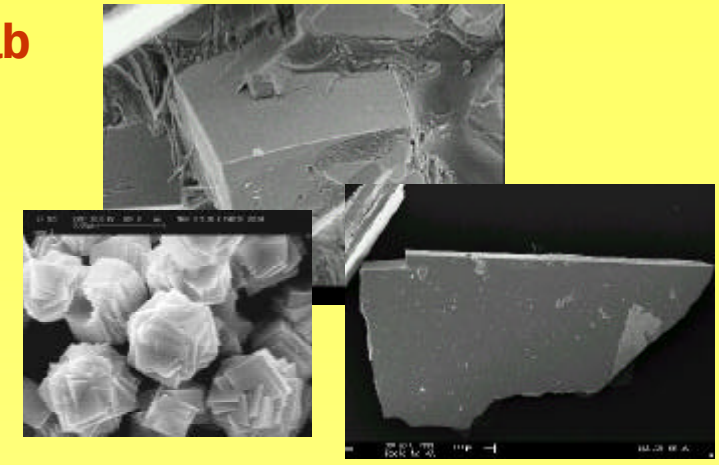
Summary

- INFM-LAMIA research activities
- Fabrication of Bi(2223) multifilamentary wires & tapes
- Very high magnetic field behavior
- Partial replacement of silver sheath
- Example of application of modified Bi(2223) on a small superconducting device

Instrumentation and Research Facilities

Powder synthesis Lab

2000 Bar Isostatic press
Uniaxial presses
Ball milling
Furnaces up to 1700°C

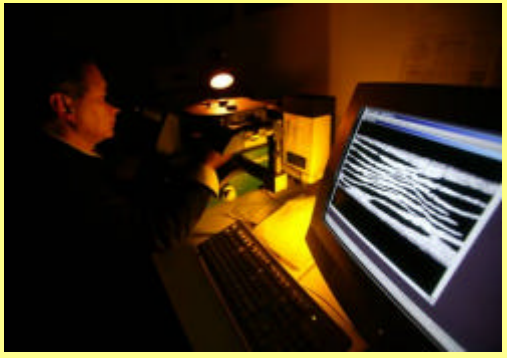


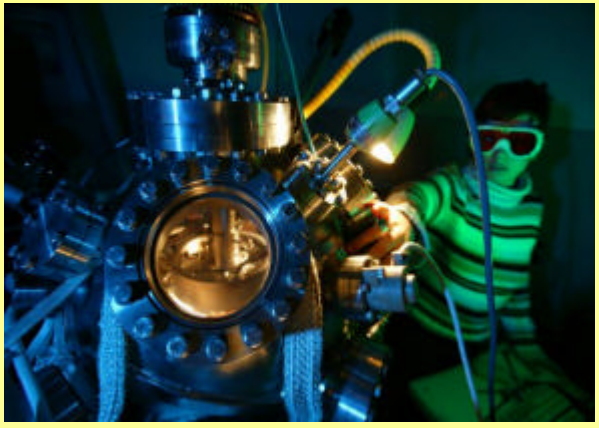
Tapes & Wires Lab

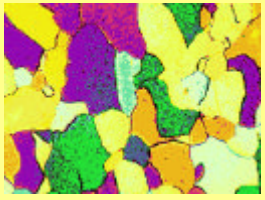
Deformation
(Groove and flat rolling,
Drawing, swaging, twisting)

Thin films Lab

2 high vacuum Pulsed Laser
Deposition system
In situ RHEED analysis





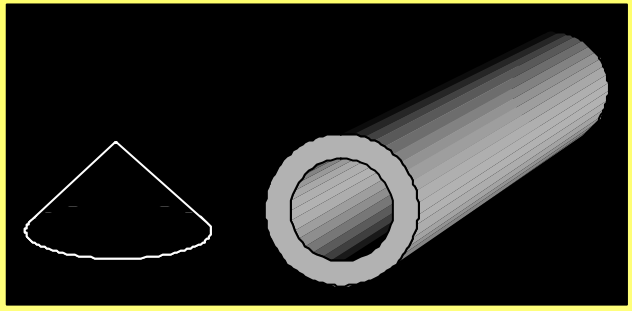


Metallographic Lab

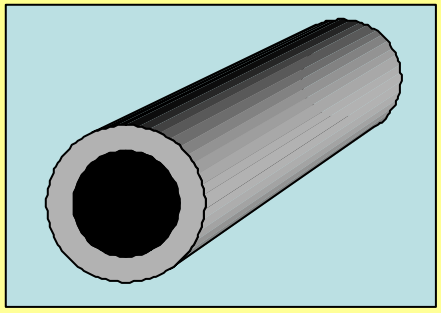
Polishing
SEM & Optical microscopy
4-circle x-ray diffractometer
Atomic adsorption and UV-visible spectrophotometers
μ–hardness

Fabrication of Bi(2223) tapes

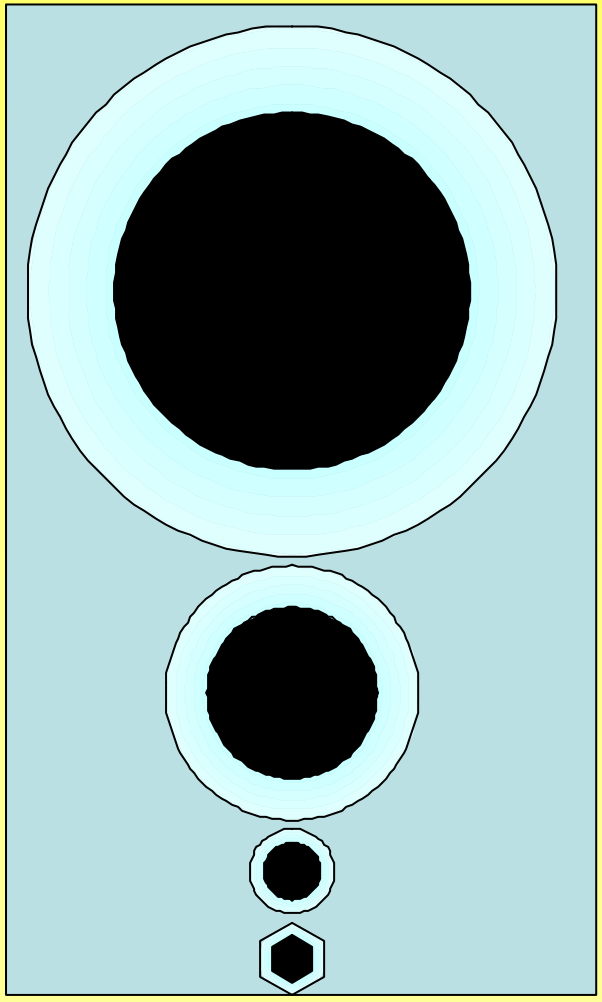
PRECURSOR POWDERS – Bi(2223)+…



PRESSING



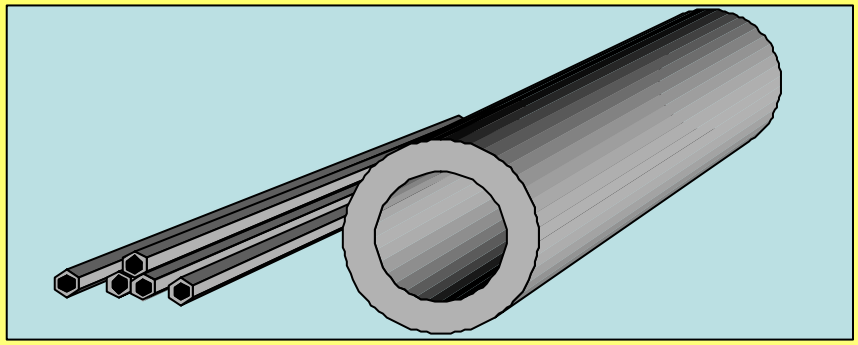
POWDERS ARE PACKED INTO Ag TUBES

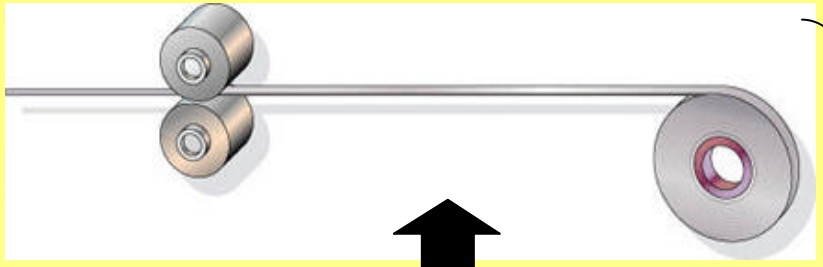


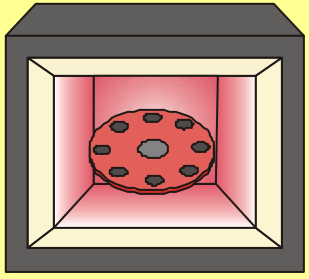
SWAGING and/or DRAWING

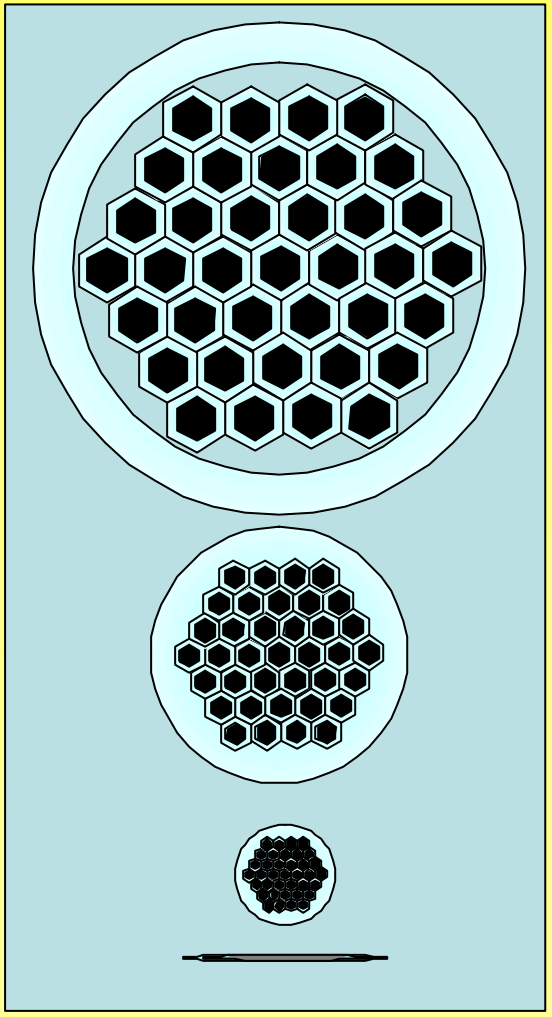
Fabrication of Bi(2223) tapes

FILAMENTS ARE PACKED INSIDE ANOTHER Ag TUBE



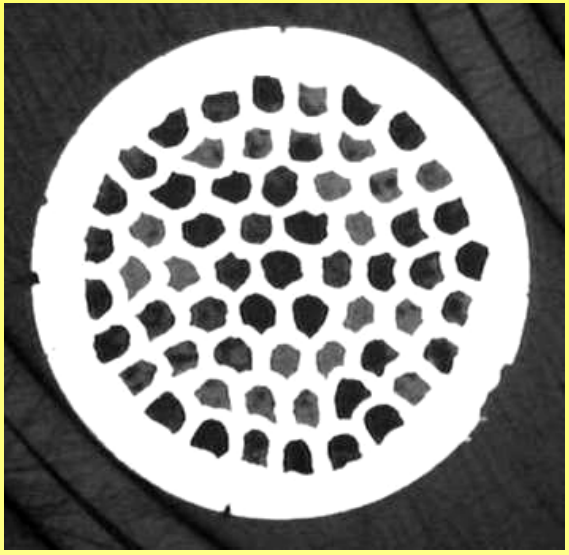


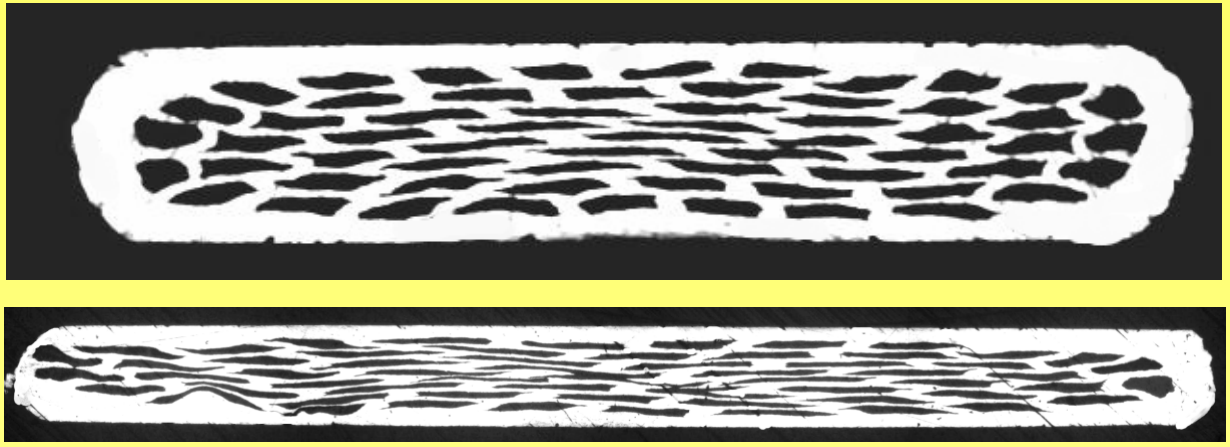




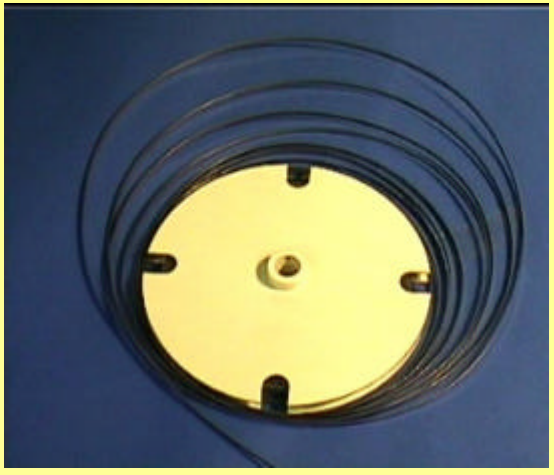
PACKED TUBES ARE COLD WORKED AGAIN AS THE MONOCORE WIRE

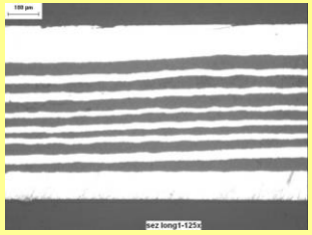
Experimental achievements

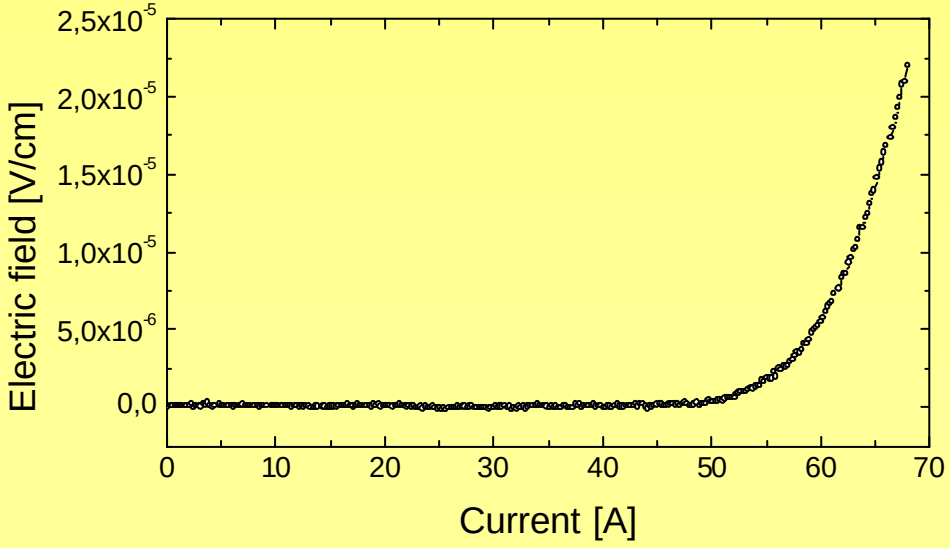




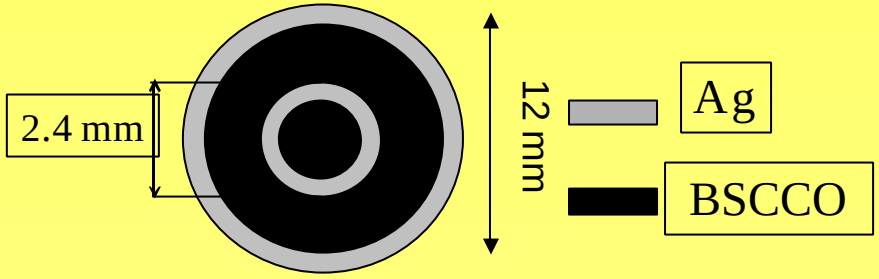
61 filaments – 100 meter long – 3.8 mm x 0.24 mm



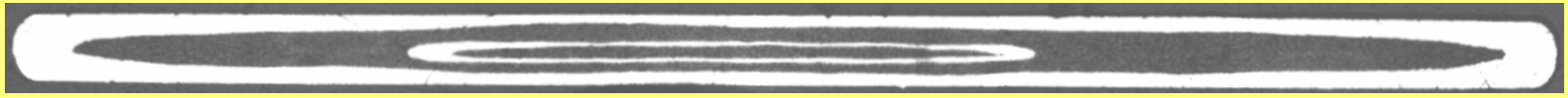




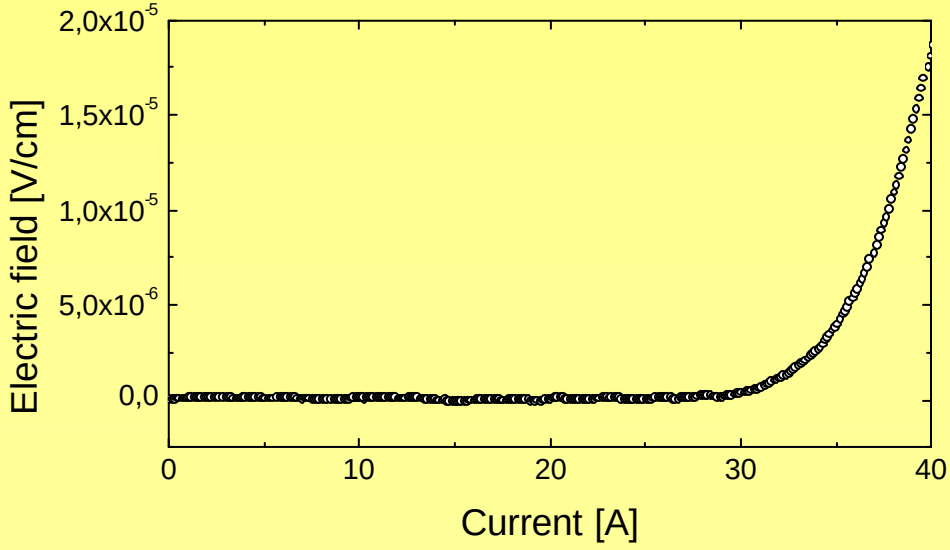
Concentric tape geometry



AgMg 1%
outer sheath



120 µm x 3 mm



Very thin Bi(2223) tape

Optimised for lower AC losses in transverse fields

Faster preparation process than multifilamentary tape

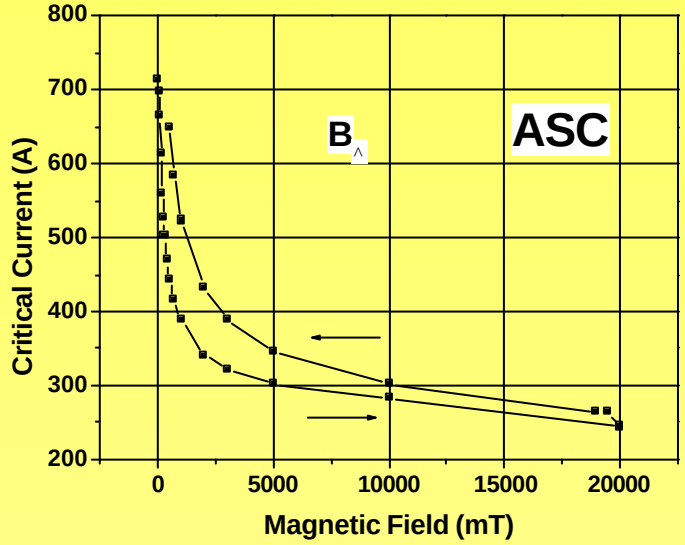
High magnetic field behavior - I

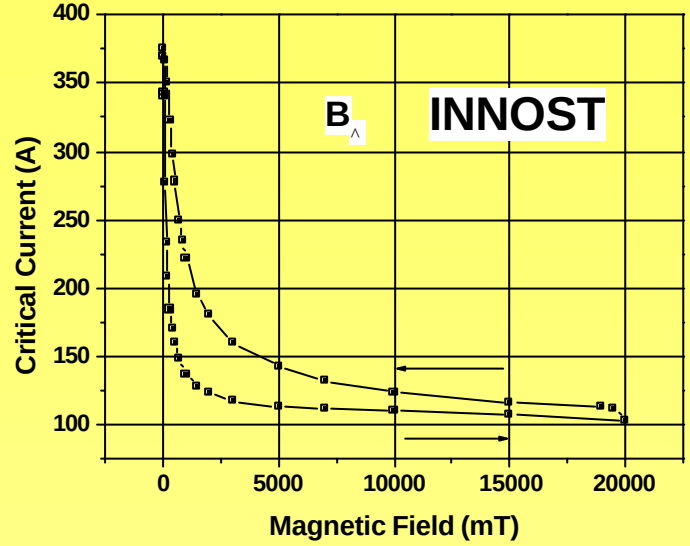
Four tapes have been measured at 4.2K up to 20T

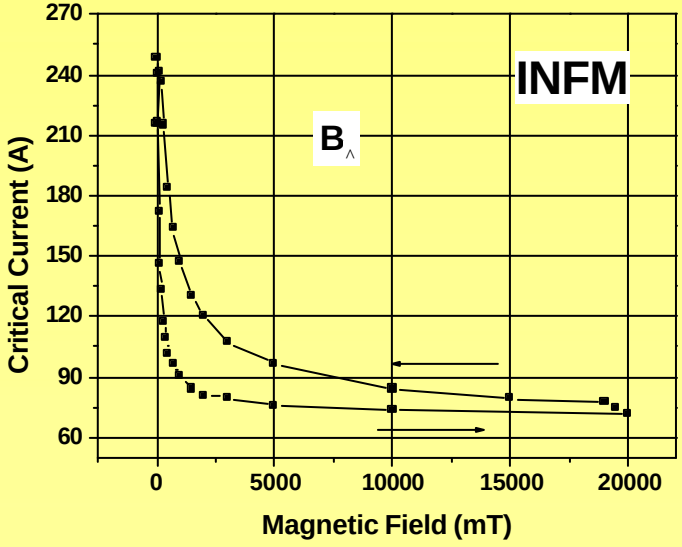
- American Superconductor Corp., USA with I_c^{77K} = 120 A
- INNOST, China, with I_c^{77K} = 65 A
- NST, Denmark, with I_c^{77K} = 40 A
- INFM tape with I_c^{77K} = 50 A

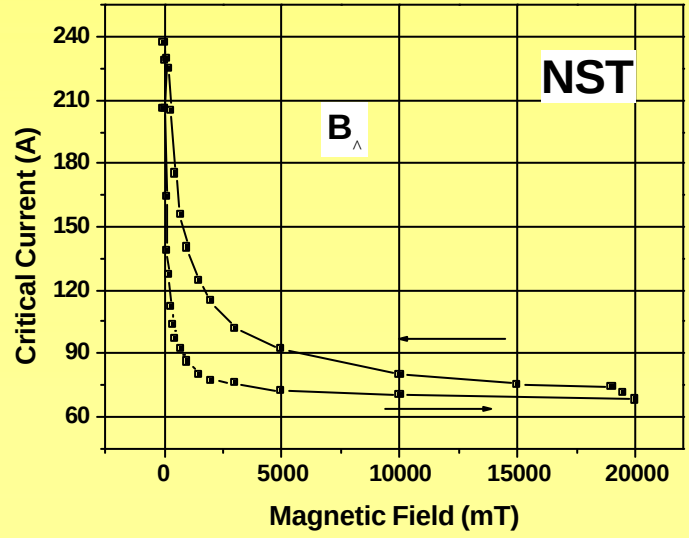
All of comparable cross section of approx. 4 x 0.25 mm

High magnetic field behavior - II



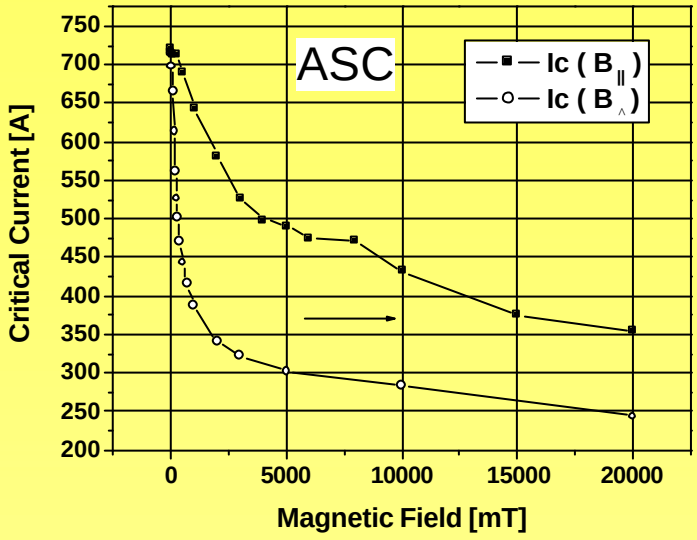


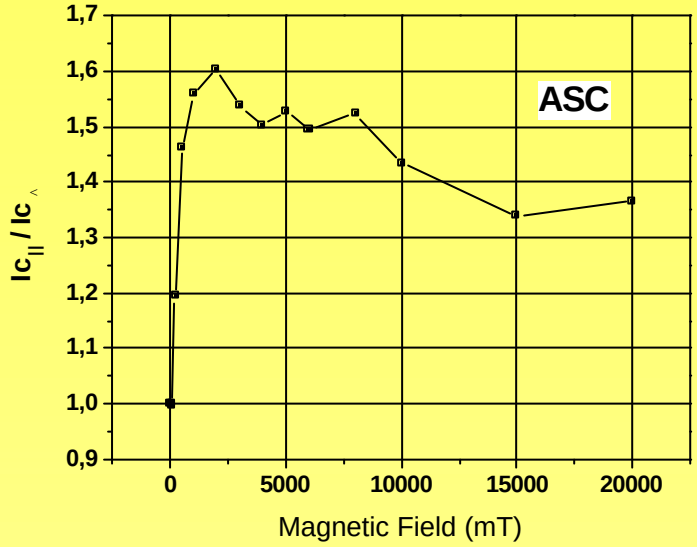


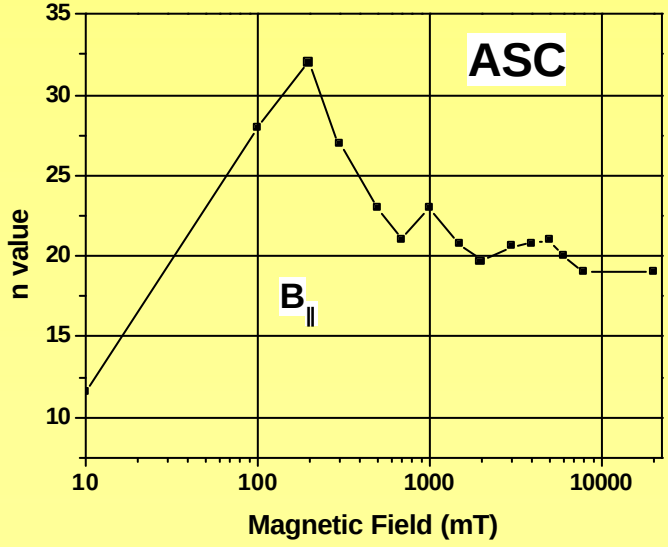


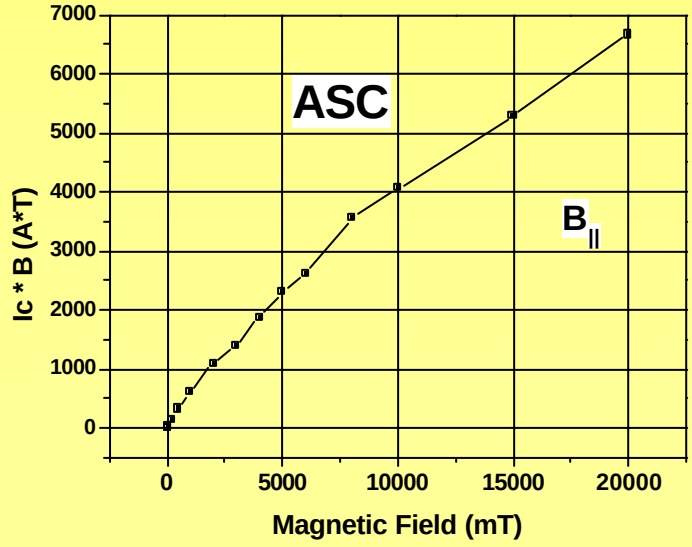
Measured at GHMFL in collaboration with L. Martini, Cesi SpA, Milan (I)

High magnetic field behavior - III







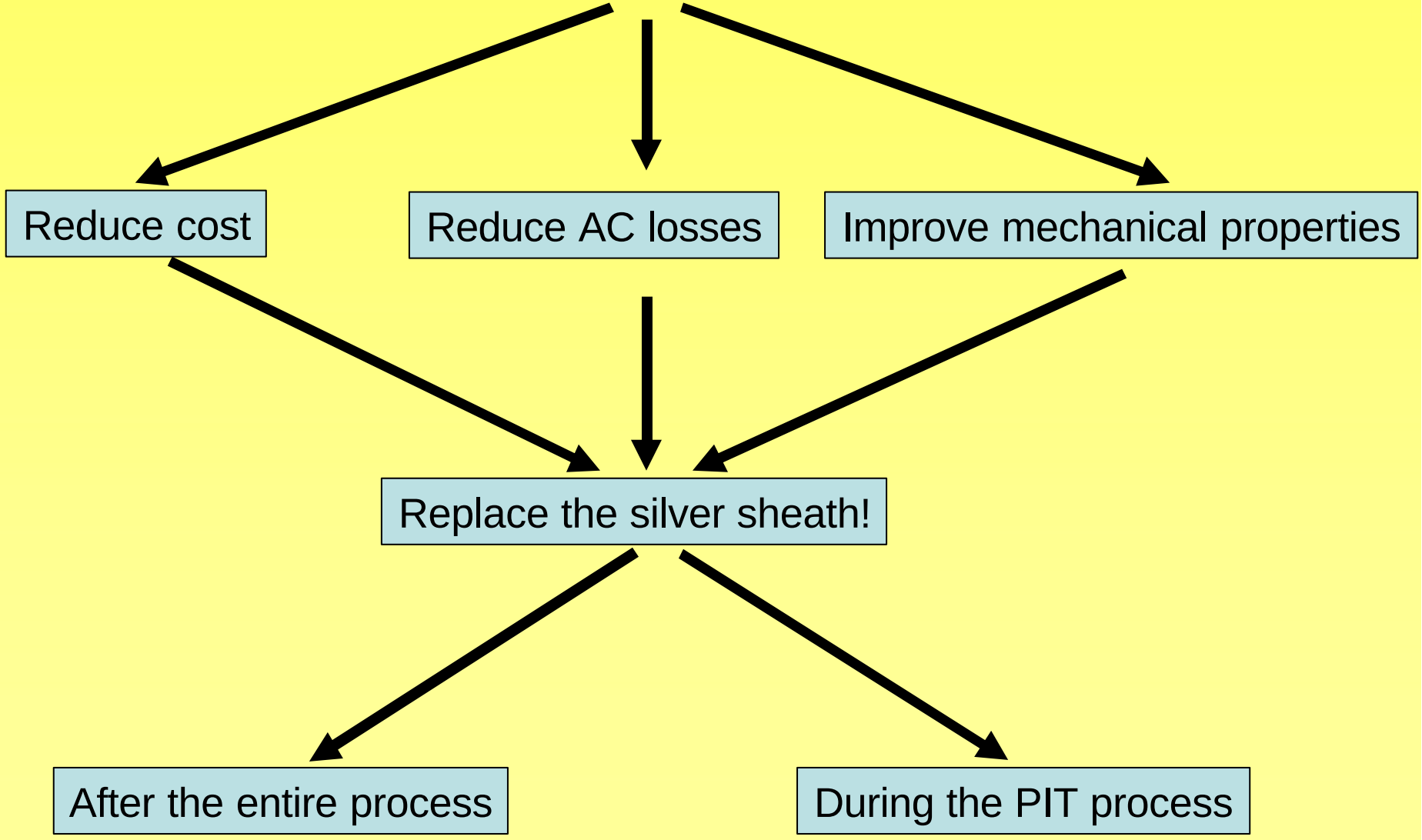


Measured at GHMFL in collaboration with L. Martini, Cesi SpA, Milan (I)

High magnetic field behavior - IV

- ASC tapes are superior at all fields & temperatures
- Hysteretic behavior is reduced but still present in ASC tapes -> grain boundaries can be further improved
- Critical currents of ~ 300A (j_e=300 A/mm^2) are carried at 20 T
- At 4.2K & 20T, cost of Bi(2223) is ~80 \$·kA/m

To make Bi(2223) more attractive for users



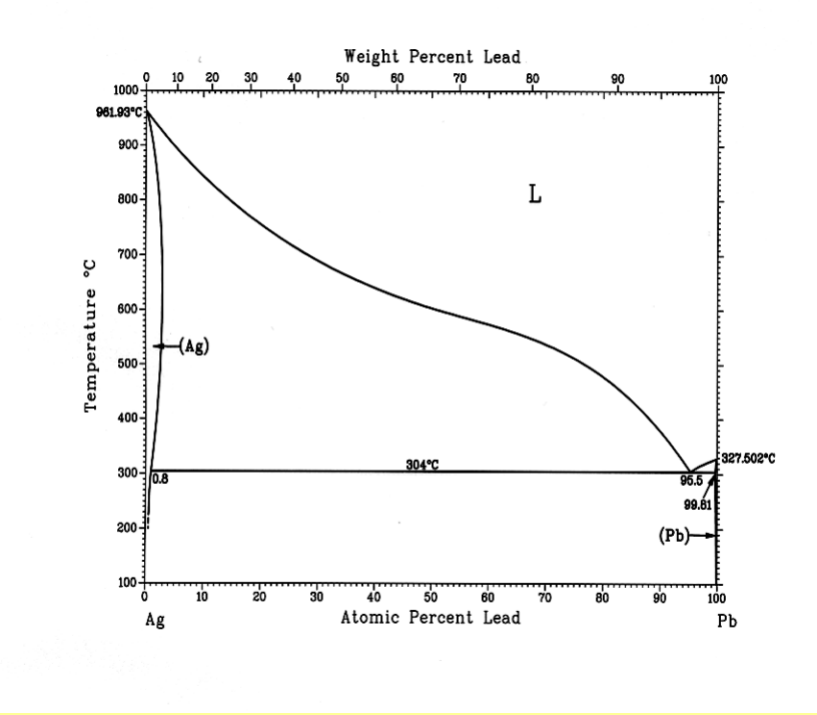
Ag replacement on reacted tapes

- Long lengths of multifilamentary tapes have been made available by BICC, NST, Pirelli and INFM
- Conductors showed critical currents between 25A and 56A at 77K prior to the treatment
- Optimized alloy has been used for partial Ag replacement (Bi 40%, Sn 30%, Pb 20%, Cu 10%)
- Outer sheath material has to be reinforced AgMg alloy to avoid damage during the treatment

Substitution of Ag by a low-melting temperature alloy

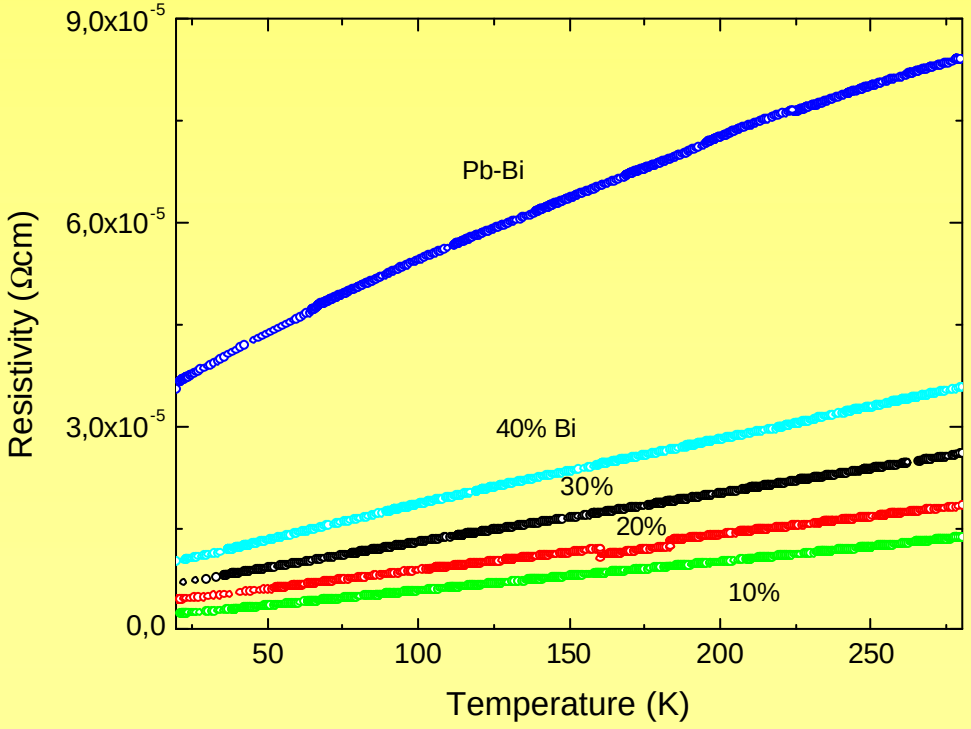
Metallic sheath:

Binary phase diagram of Ag-Bi



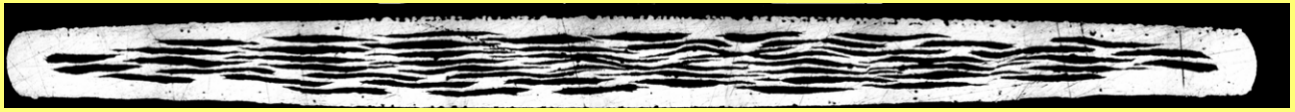
What type of alloy to be used?
The cheapest one!
Mixing of Bi to standard Sn-Pb soldering alloy

R^{77K}(alloy) > 100 R^{77K}(Ag)

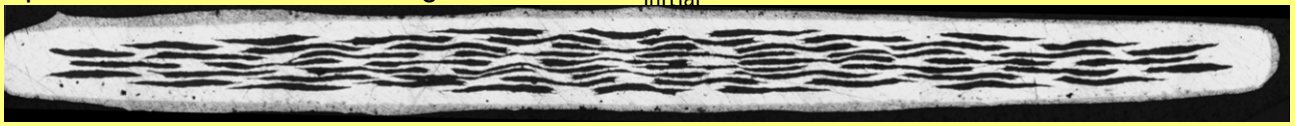


Example of Ag replacement

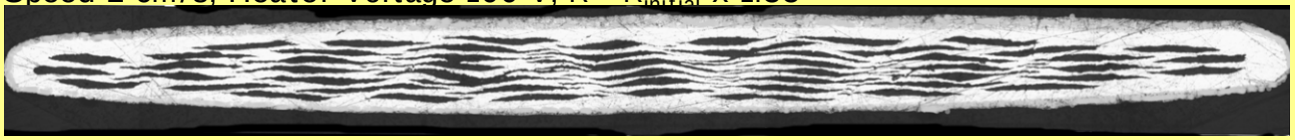
Starting tape (no replacement)



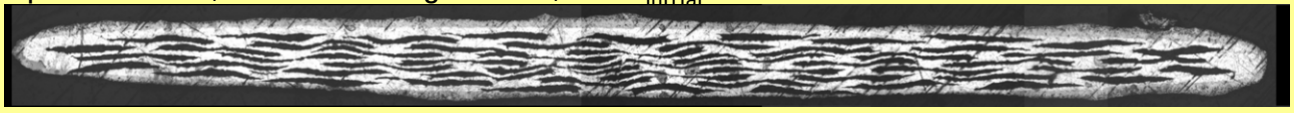
Speed 5 cm/s, Heater Voltage 100 V, R = $R_{initial}$



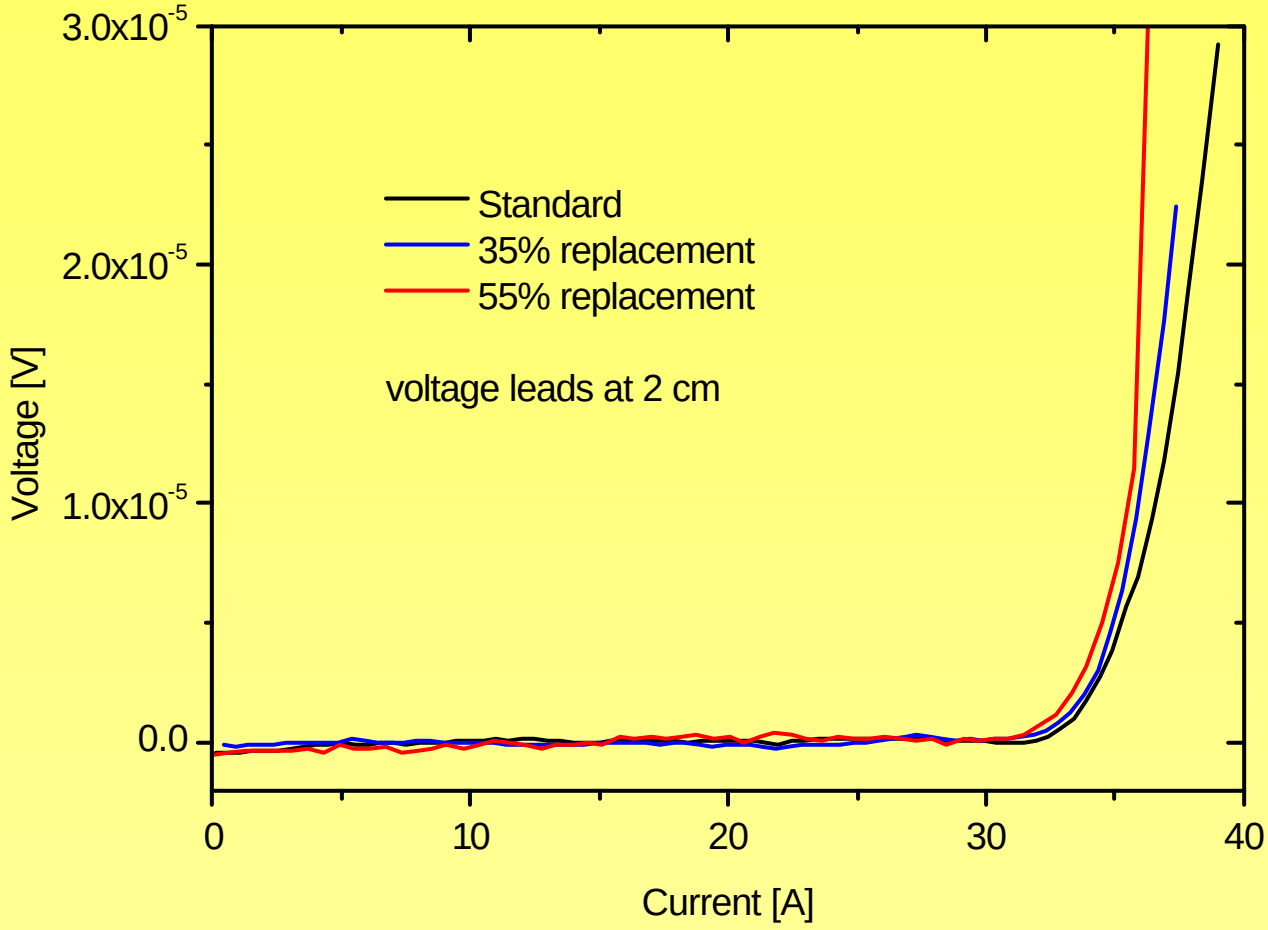
Speed 2 cm/s, Heater Voltage 100 V, R = $R_{initial}$ x 1.35



Speed 2 cm/s, Heater Voltage 105 V, R = $R_{initial}$ x 2.2



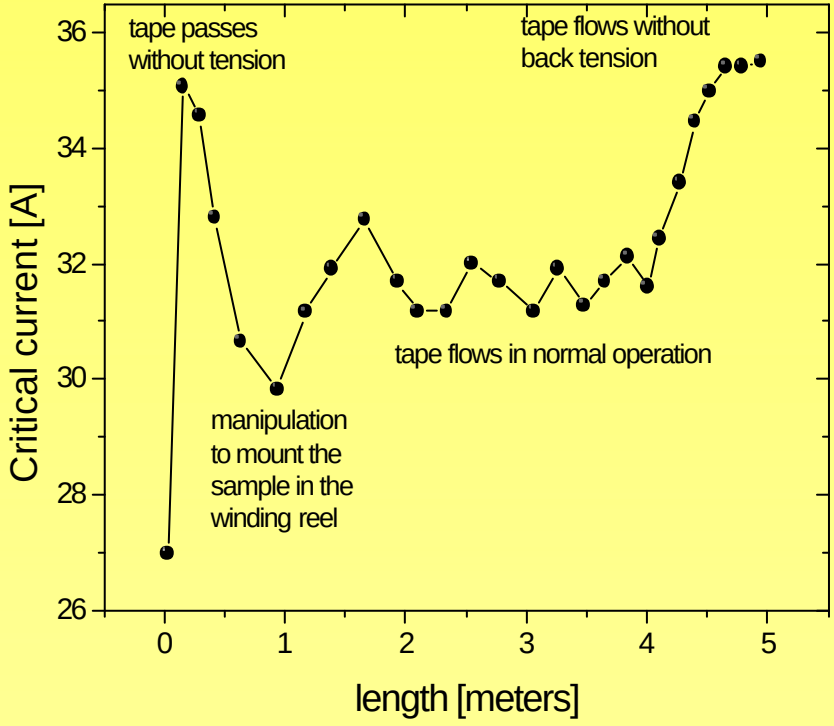
V-I characteristics

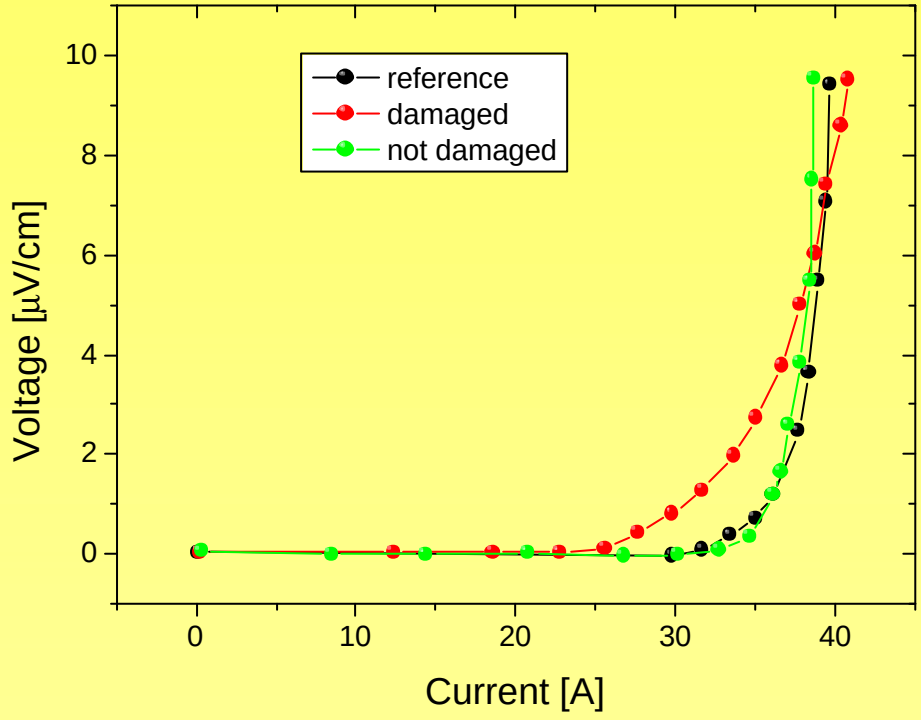


-almost no j_c degradation

-Visible effect on the n factor

Problems faced with long-lengths operation





10% I_c drop is due to residual back tension and bath viscosity

Reproducibility of processing has been achieved

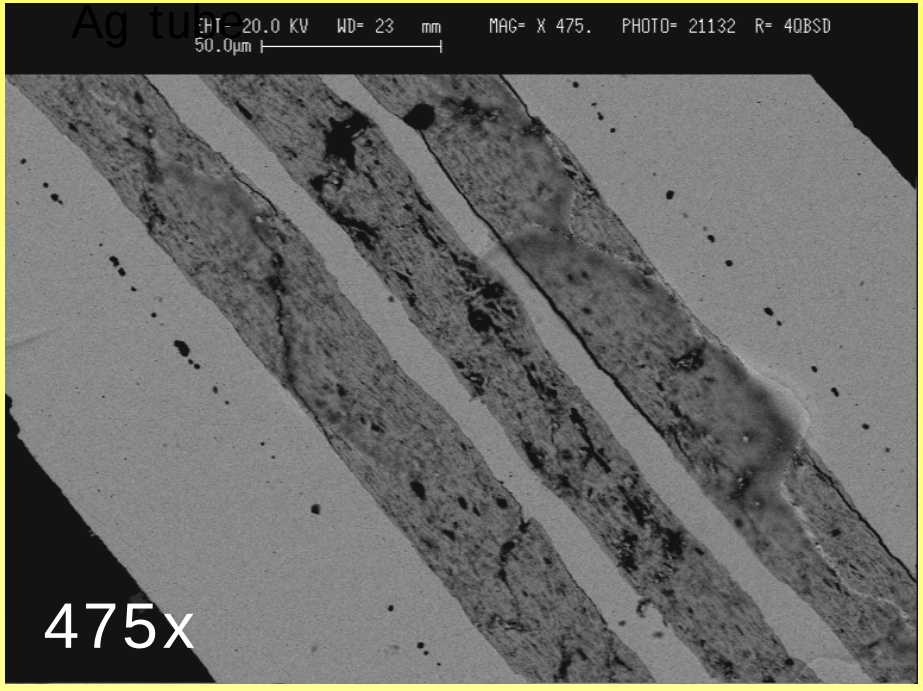
Manufacturer	Details	Critical current	% Ag replaced
BICC	Multifilamentary f.f. 25%	32A -> 30A	30%
Pirelli	Multifilamentary f.f. 30%	35A -> 32A	55%
NST	Multifilamentary f.f. 30%	53A -> 30-50A	40-50%
INFM (Merck pwd.)	Multifilamentary f.f. 25% Optimized with less Ag between filaments and more outside	28A -> 27A	70%

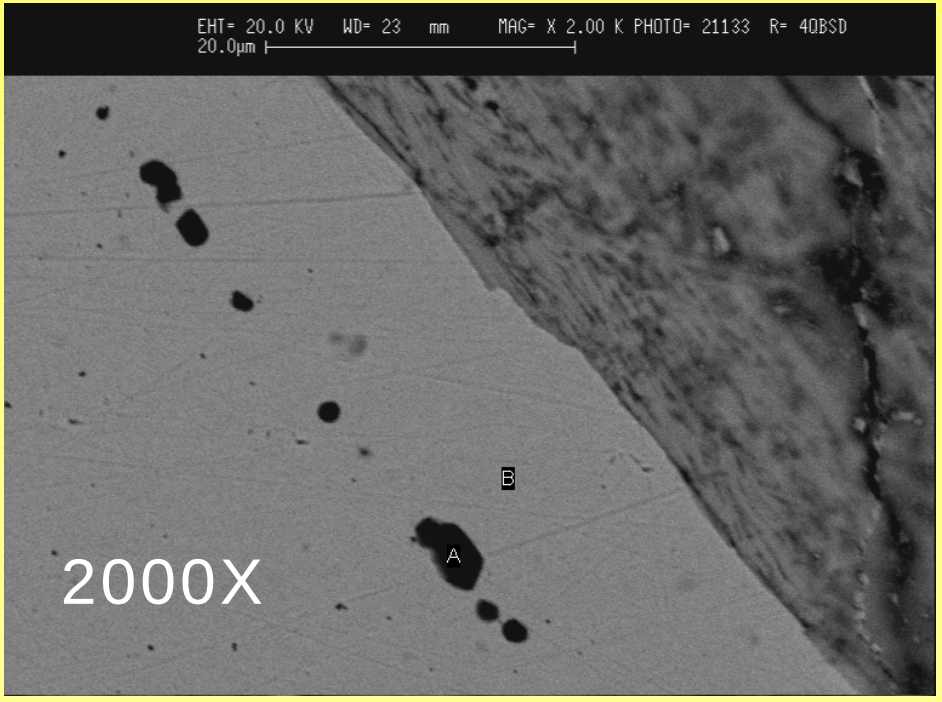
Substitution of the outer tube in a multifilamentary tape by different alloys:

a diffusion barrier has to be introduced to avoid BSCCO contamination

Electrodeposited metallic diffusion barrier

Cu,Ni,Fe layer deposited on the 19-filament pack before insertion in the outer Ag tube





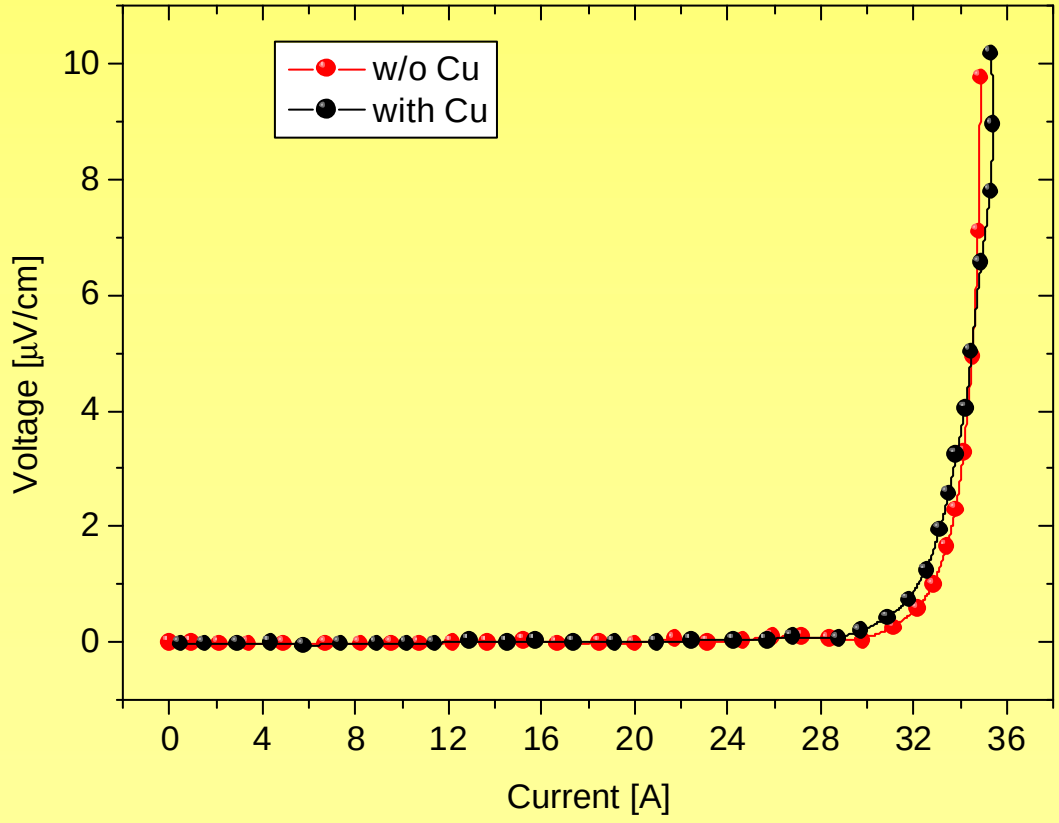
Copper does not diffuse to BSCCO as it happens in the resistive barrier case.

However, the barrier is not continuous as it was before heat treatment. CuO agglomerates in 1-5 µm particles.

Critical currents of tape with Cu layer

- Identical to those of the conductors not subjected to the Cu deposition

19-filament tapes of 0.24 x 3.0 mm and 24% BSCCO filling factor

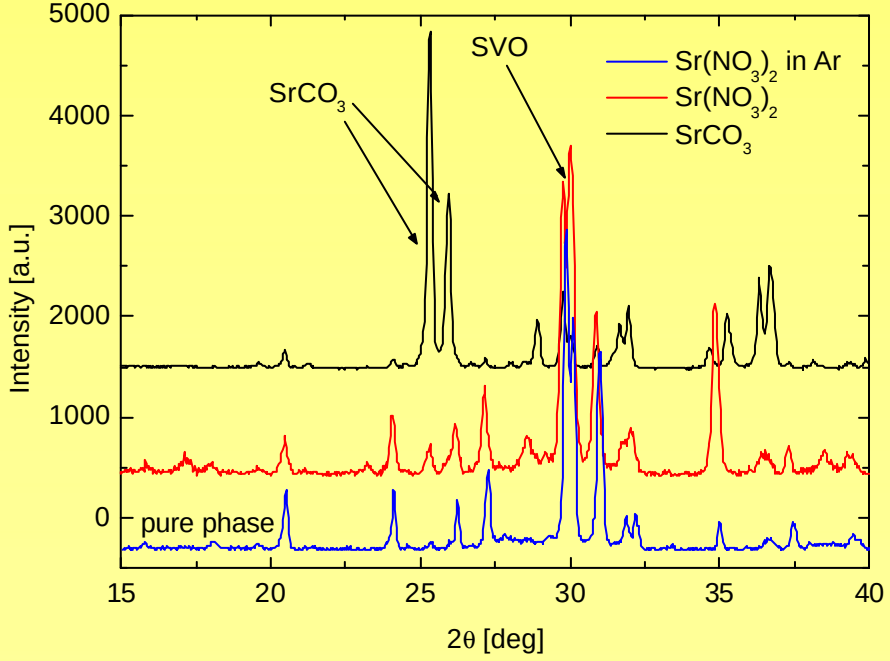


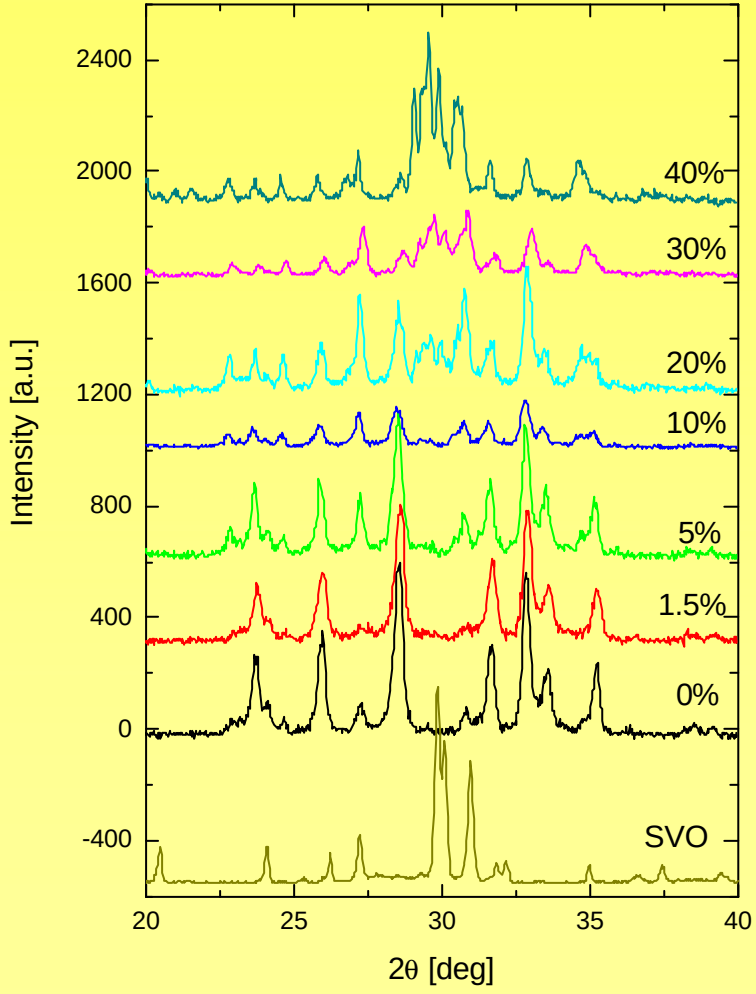
Introduction of oxide diffusion barriers

- Different compounds have been studied for their compatibility with Bi-2223 phase formation

Maeda barrier compound $Sr_6V_2O_{11}$

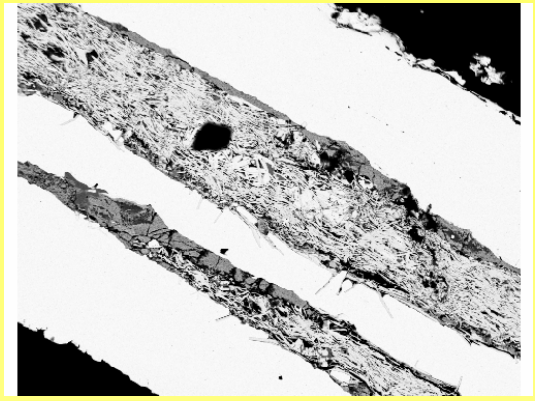
found optimal conditions for reaction (700C in Ar)



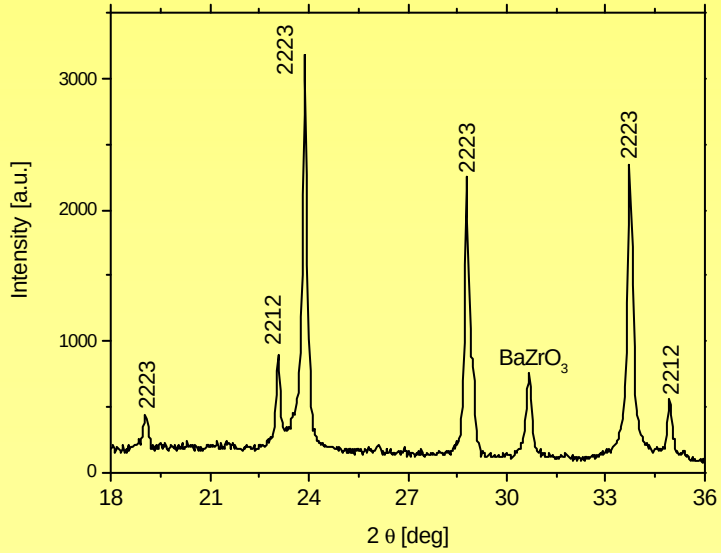


Bi-2223 does not form in presence of SrVO!

Flukiger materials for barrier



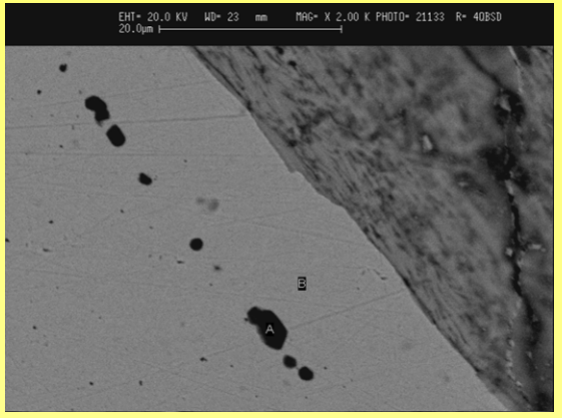
- The reaction with 2223 is modest
- Tapes have been made with the diffusion barrier in direct contact with 2223

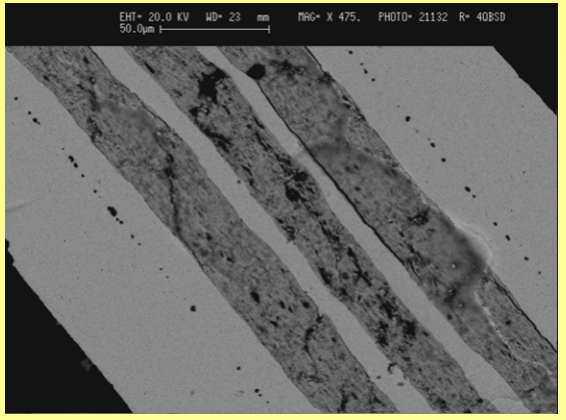


2% AgO has been added to BSCCO

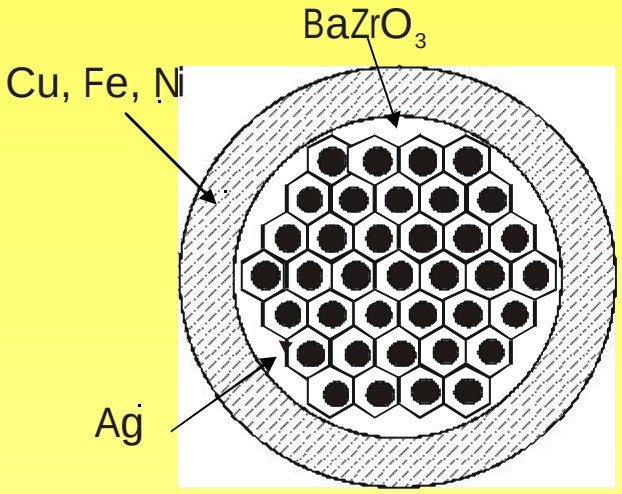
J_c decreases from 15 kA/cm^2 to 12 kA/cm^2 measuring from the tape end to the tape center (40 cm long sample)

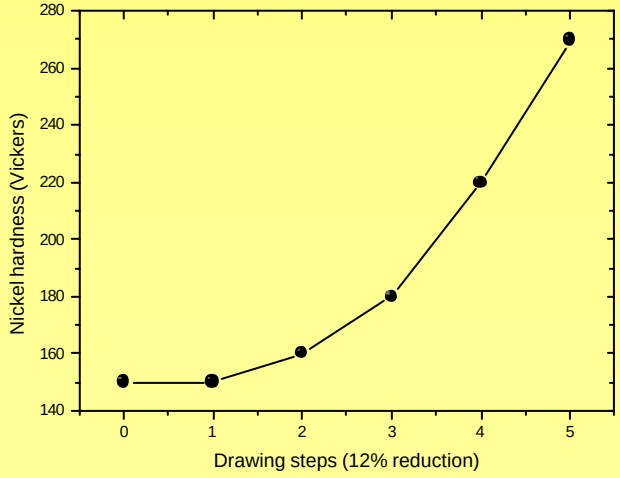
Metallic barriers are not effective



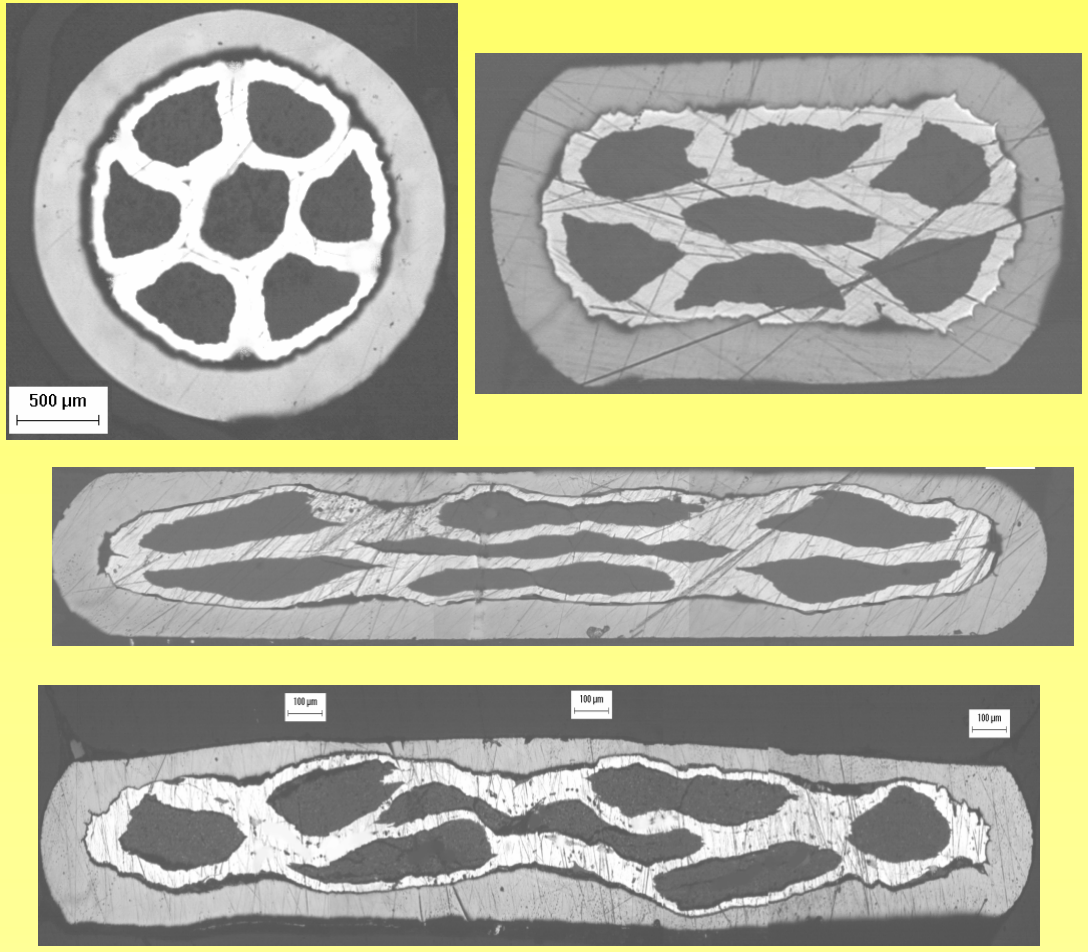


Multifilamentary tapes with outer Ni-sheath





Cold working to be controlled to limit Ni-hardening

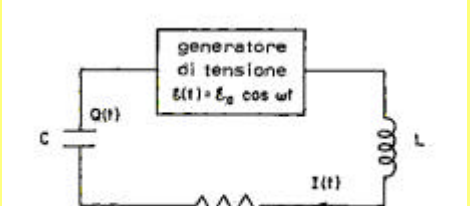


No reaction between Bi-2223 and Ni.
Difficult to measure transport properties
XRD reveals about 60% 2223 phase with AgO addition

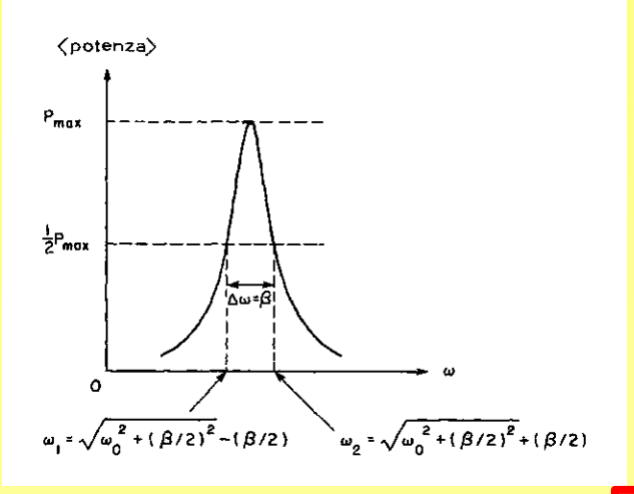
High frequency application of modified Bi-2223 tapes

The resistance of an antenna is given by two terms:
Ohmic Resistance R_Ω and Radiation Resistance R_R

If antenna size $\ll \lambda$ then $R_\Omega \gg R_R$

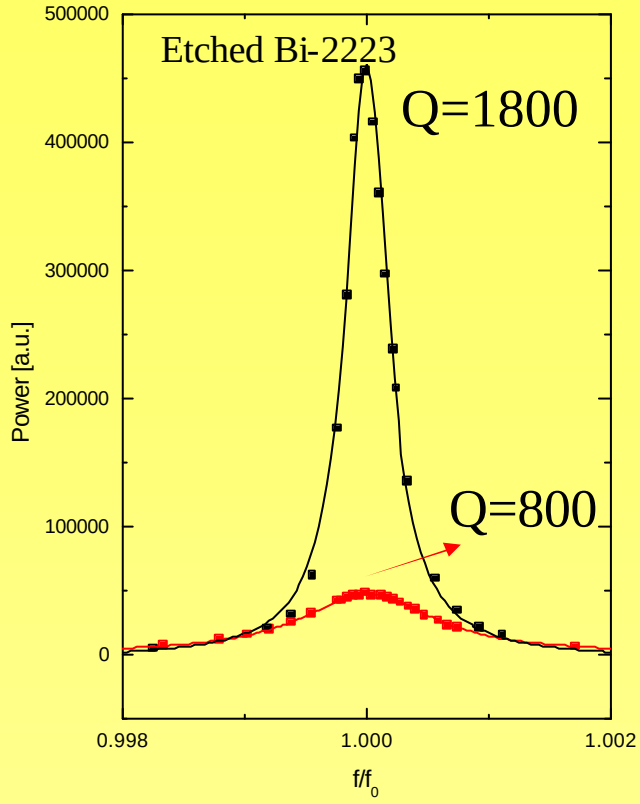


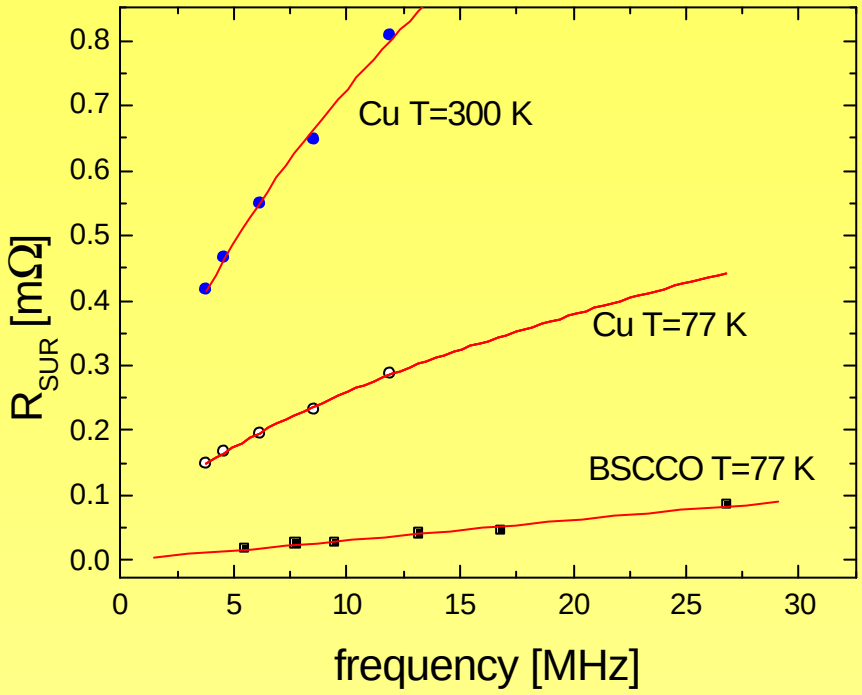
$$\omega_0 = \frac{1}{\sqrt{LC}}$$



$$Q = \frac{\omega_0 L}{R} = \frac{\omega_0}{\Delta\omega}$$

$$\frac{S}{N} \propto \sqrt{Q} \quad \Rightarrow \quad \frac{S}{N} \propto \frac{1}{\sqrt{R}}$$





$R_{SUR}(8MHz)$ {
- 20μO BSCCO at 77K
- 220μO Cu at 77K
- 570μO Cu at 300K

$$\frac{S}{N} \propto \frac{1}{\sqrt{R_{SUR}}}$$

improves by {
- **3** compared to Cu at 77 K
- **5** compared to Cu at 300 K

Conclusions

- The I_c performance level of industrial Bi-2223 tapes is already outstanding
- Cost of the conductor, AC losses, and mechanical properties still need strong improvements
- Replacement of the silver sheath can be solved in different ways
- Application of silver replaced conductors can be envisaged as low-loss RF wires