EDISON activities on HTS and MgB_2

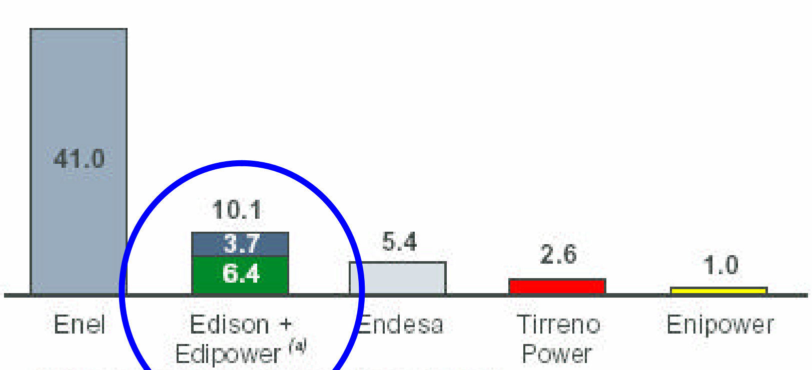
S. Zannella, Edison SpA

WAMS-2004
Workshop on Accelerator Magnet Superconductors
Archamps, 22-24 March 2004

EDISON

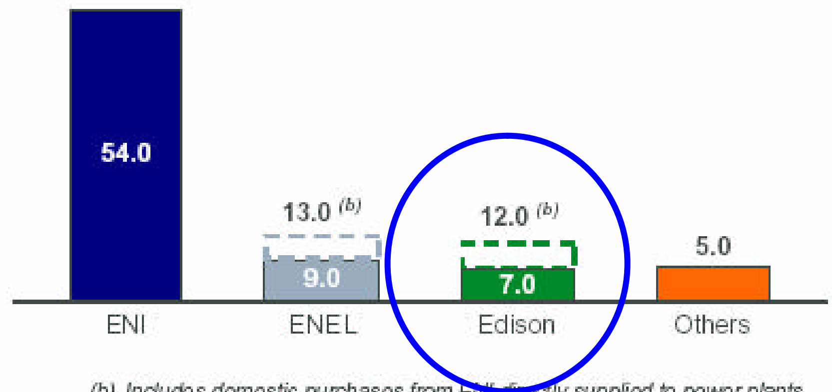
Edison today - the competitive position

2003 Electricity Installed Capacity - *Gw*



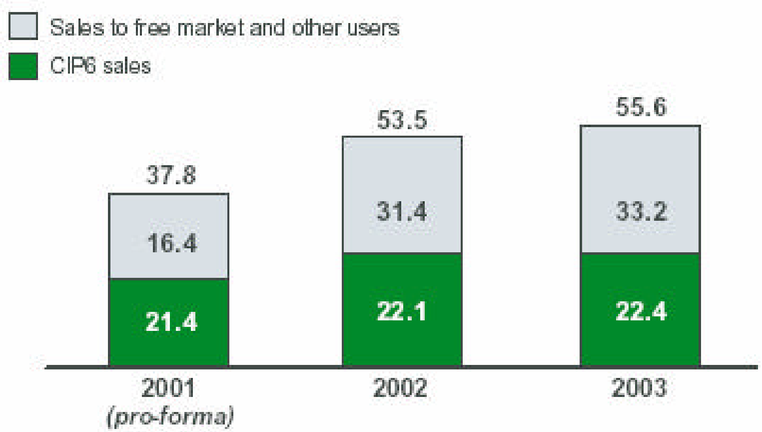
(a) Pro-quota EDISON through tolling agreement

2003E Gas Supply (production and import) – *bcm*



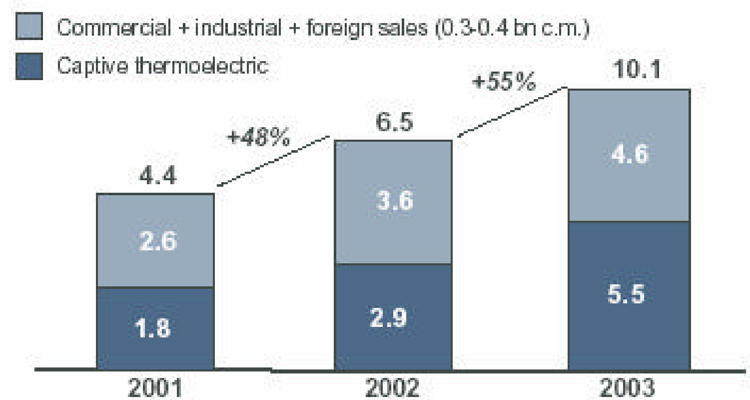
(b) Includes domestic purchases from ENI directly supplied to power plants

Electric Power sales *(TWh)*



Including 50% of Edipower sales starting from 2002

Natural Gas sales *(bn c.m.)*



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R&D Themes

- Hydrogen
- Fuel cells
- Sustenaible energy generation
- Distributed Generation
- Power Quality
- Superconductivity

EDISON

Superconductivity

Development of processes for innovative superconducting wires/bulks

- Y-123 coated conductors by thermal co-evaporation (partners: Europa Metalli Superconductors and CNR-IMEM)

- Bi-2212 electrodeposited tapes (CEA)

- MgB_2 bulks and wires (CNR-IENI)

Coated conductors by thermal coevaporation

Joint team: EDISON, Europa Metalli Superconductors,

CNR- IMEM.

Location: CNR-IMEM Laboratories (Parma, Italy).

Objective: Development of long Y-123 coated conductors with J_c> 200A/cm-width.

Work partially supported by CNR National Project (L. 95/95)

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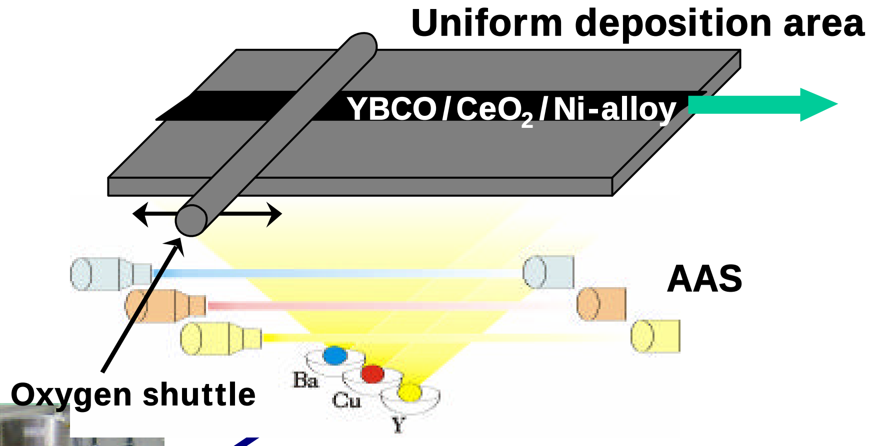
Thermal co-evaporation THEVA system for continuous production of coated conductors



- 20 x 20 cm^2 deposition area
- Production rate: 60 $nm.m^2/h$
- Continuous refilling of crucibles
- AAS for precursor rate control
- in situ oxygenation
- T < 700 °C in all phases of the process

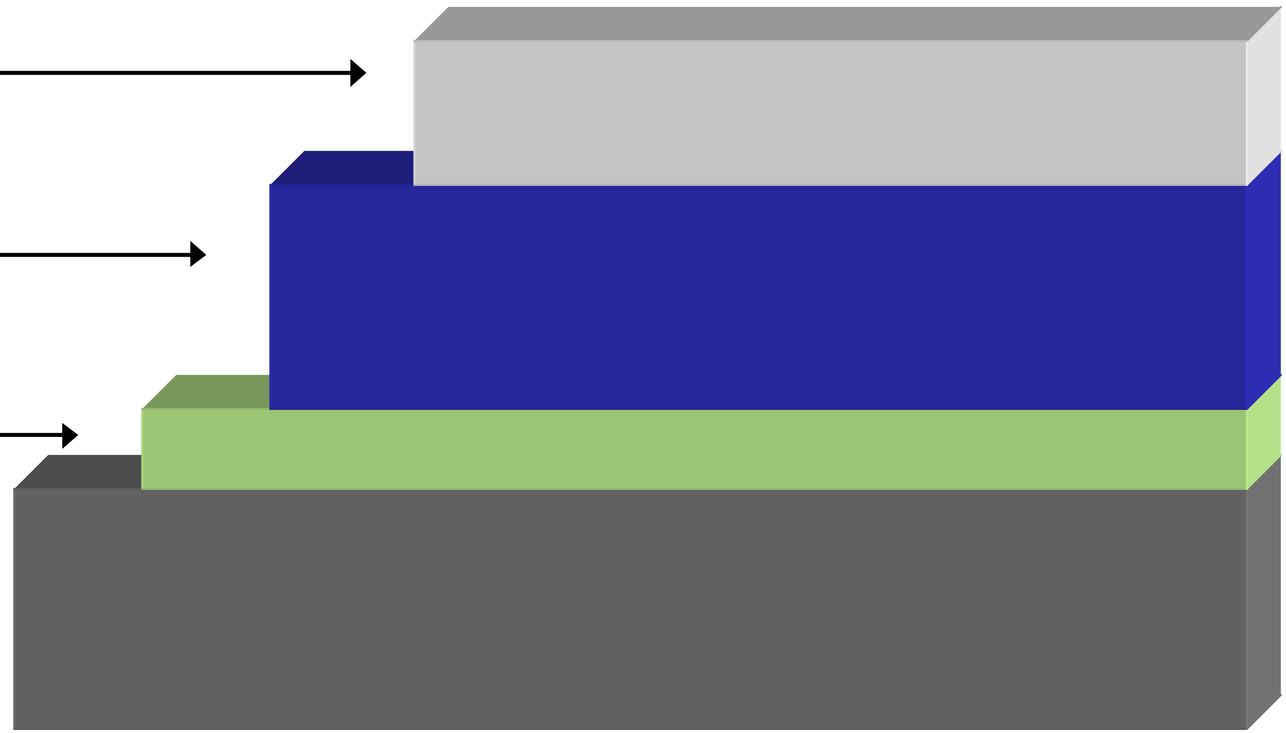
Multilayer architecture of Coated Conductor (CC)

Ag cap layer
1-2 mm

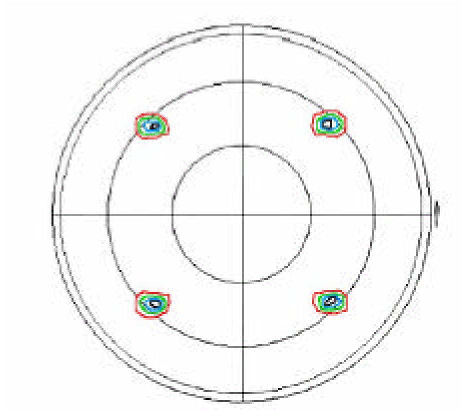
YBCO
1-2 mm

CeO_2 buffer layer
0.1 mm

RABiTS substrate
Ni, Ni-5at.%W
50-80 mm

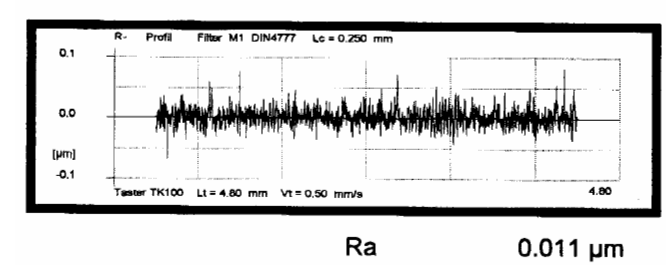


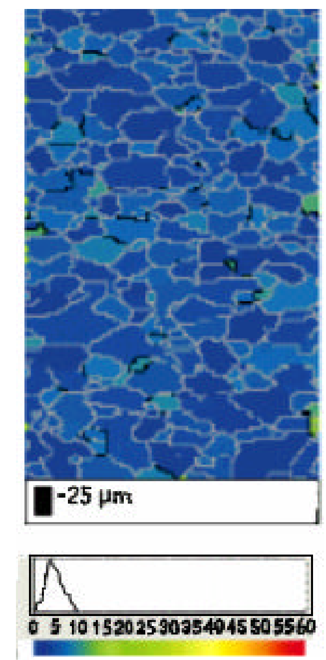
Textured tapes Ni e Ni-5 at.%W



(111) Pole figure

	In-plane $\Delta\phi$	*Out-of-plane* $\Delta\chi$
NiW	7.7°	7.7°





Supplier: IFW, Dresden (Germany)
thickness: 80 µm
width: 1 cm
Roughness R_a: < 15 nm

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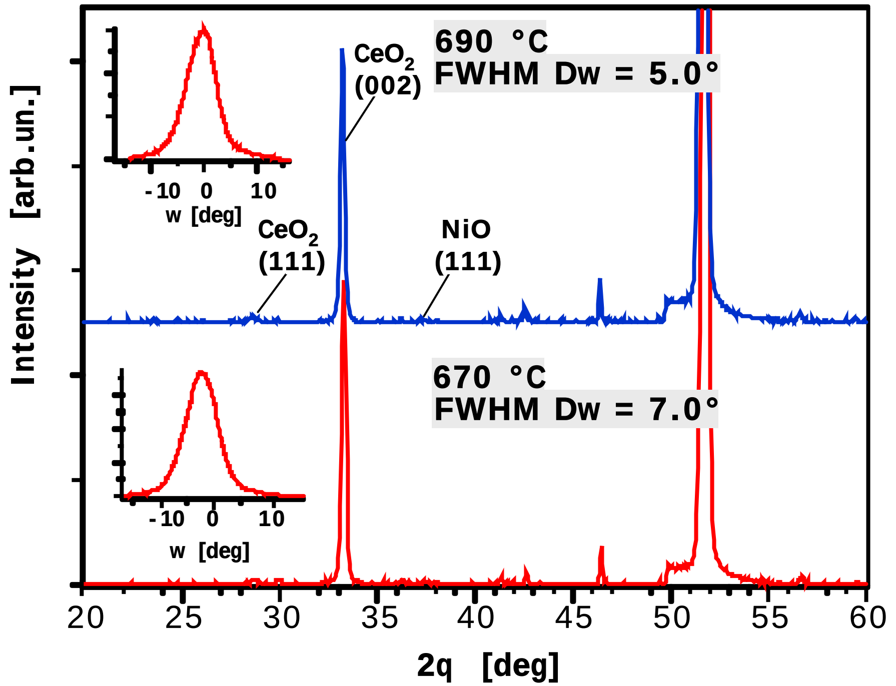
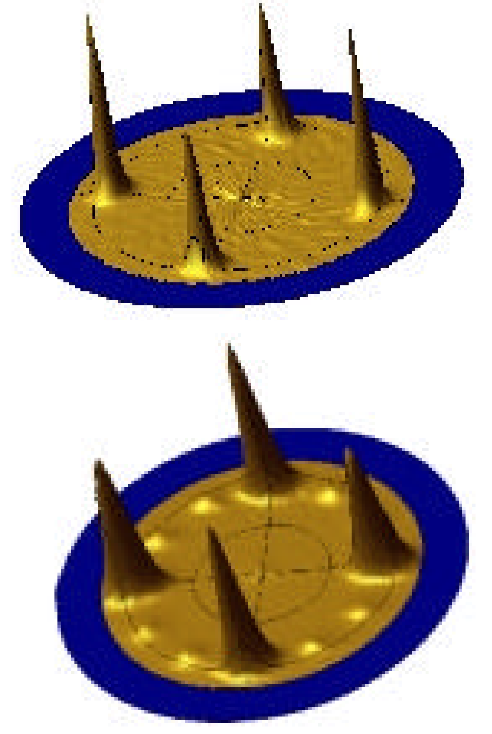
CeO_2 Buffer Layer

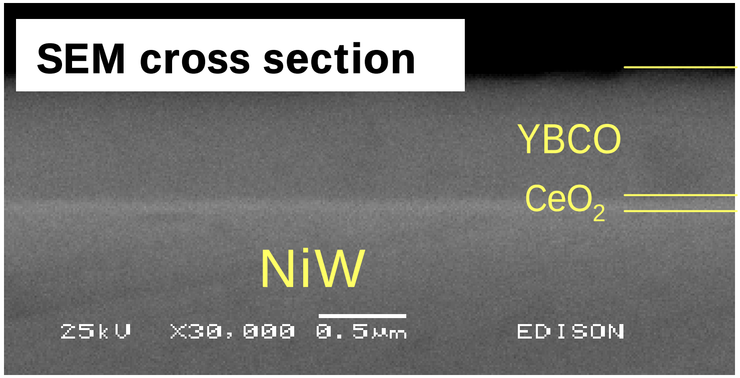




CeO_2 layer texture data

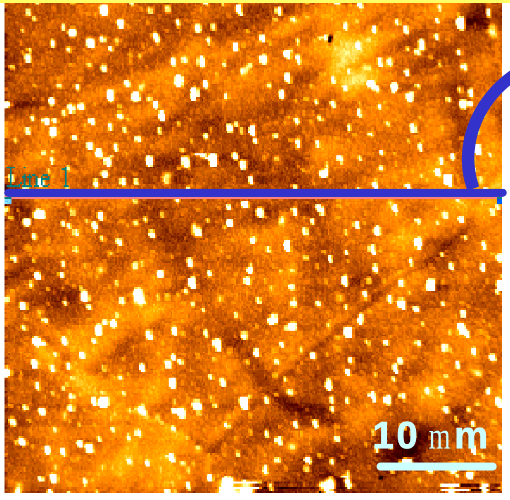
Substrate	Δφ *in-plane*	Δχ *out-of-plane*
Ni	5.8°	5.0°
Ni 5at.%W	6.0°	4.8°

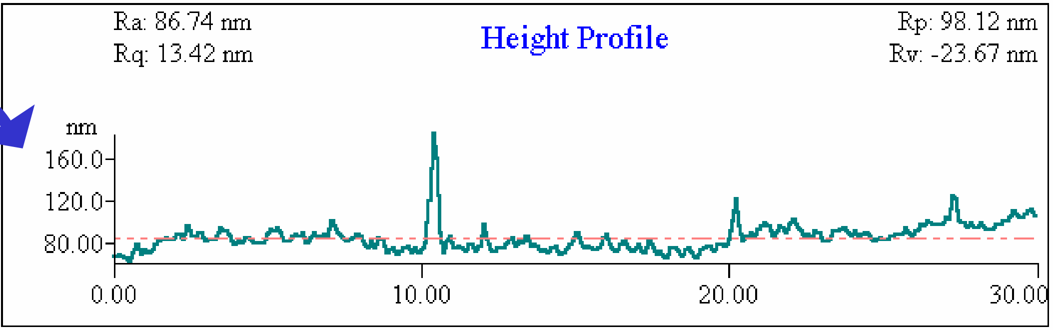
CeO_2 Buffer layer



- Uniform 100 nm thick CeO_2 layer;
- crack free surface
- Sharp interfaces.

AFM topography





average roughness:

$R_{av}(CeO_2) \approx 15$ nm

$R_{av}(NiW) \approx 12$ nm

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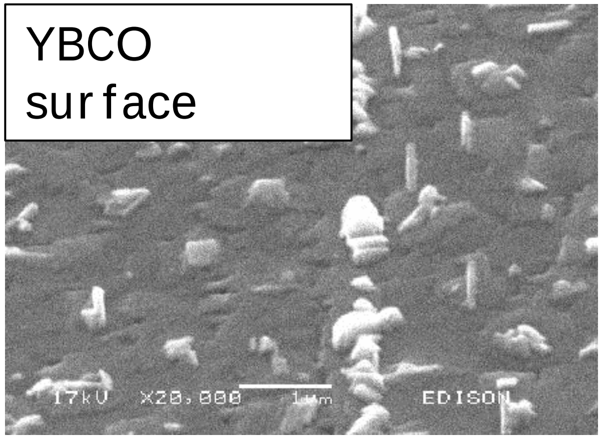
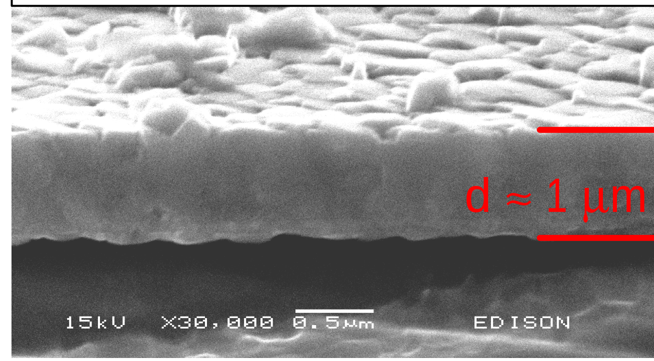
YBCO layer

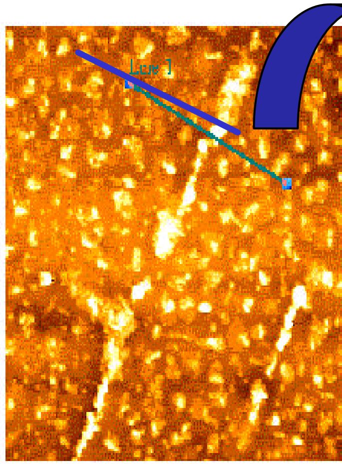
YBCO surface



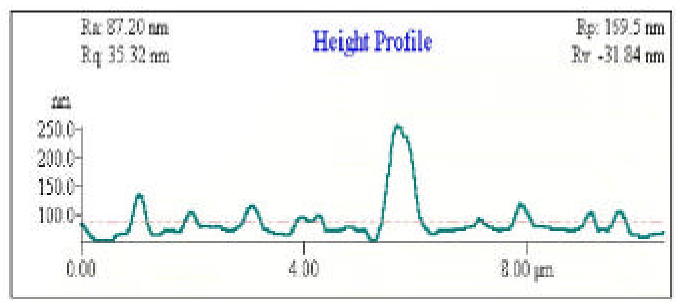
YBCO/ CeO_2 fracture



Dense YBCO layer and smooth surface



$R_{av} \approx 20$ nm



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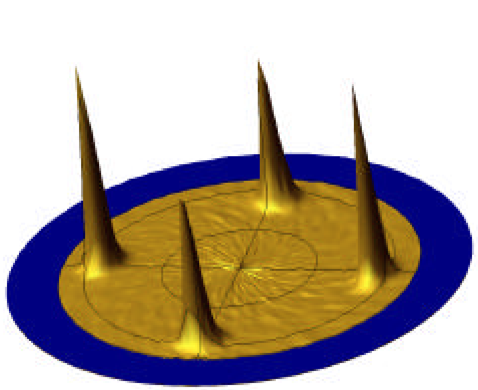
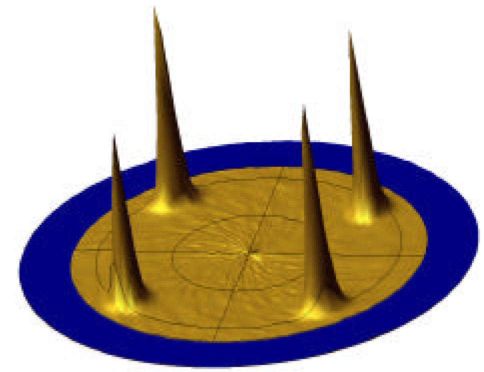
Y-123 texture



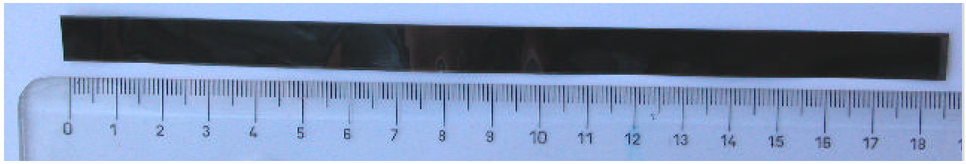
(111) CeO_2 pole figure



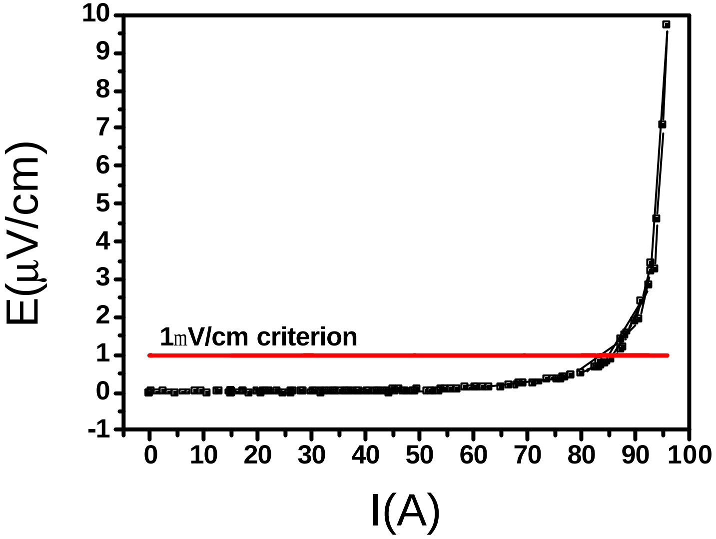
(113) YBCO pole figure

	FWHM Dc ***out-of-plane***	**FWHM** Dj ***in-plane***
NiW	8°	8°
CeO_2	4.8°	6°
YBCO	5.8°	6°

20 cm long Y-123 CC: transport properties

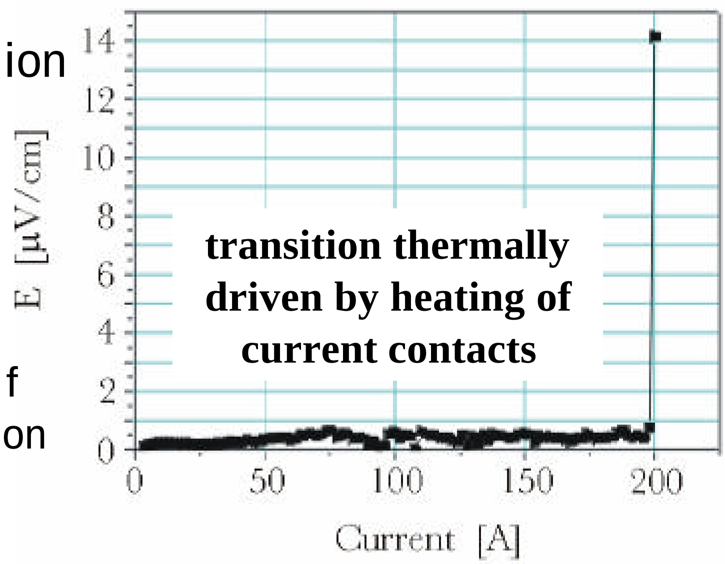


film width = 0.9 cm
YBCO thickness = 0.85 μm



Static deposition

Optimisation of YBCO composition



I_c/w = 94 A/cm-width

J_c = 1.1 MA/cm^2 @ 77 K, s.f.

I_c/w = 220 A/cm-width

J_c = 2.6 MA/cm^2 @ 77 K, s.f.

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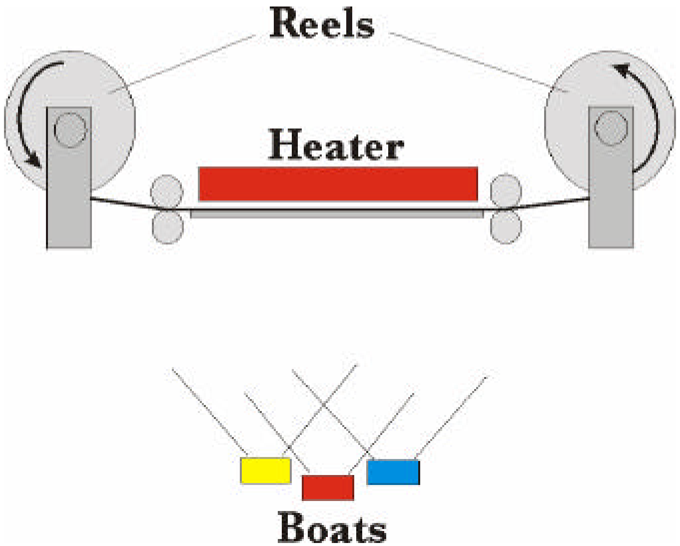
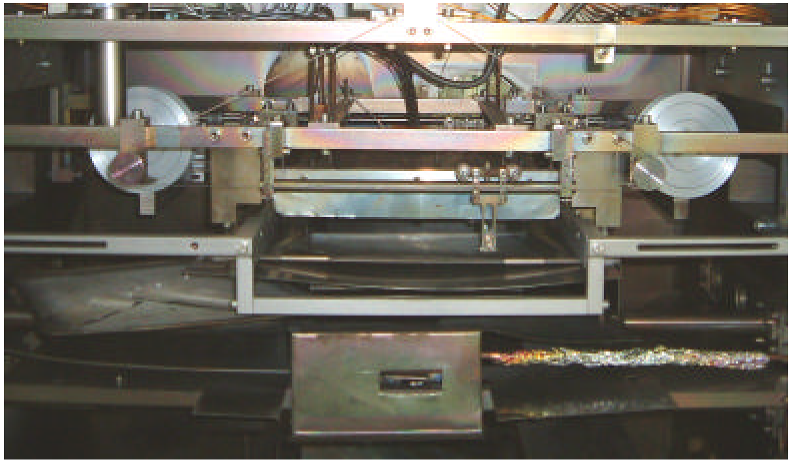
Continuous deposition of Y-123 CC's

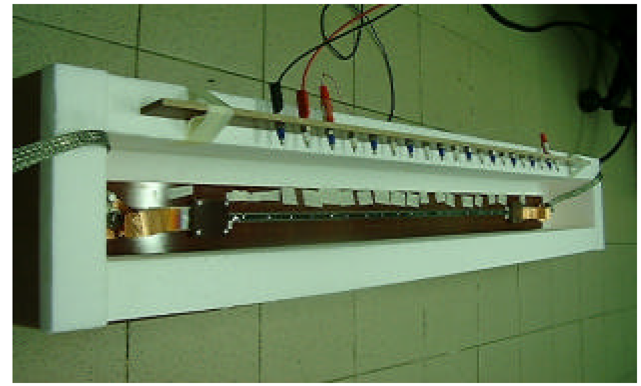




- Simple single-pass reel-to-reel system
- Tape speed: 0.2 - 0.4 m/h.

20 cm long CC: J_C=1.8 MA/cm^2

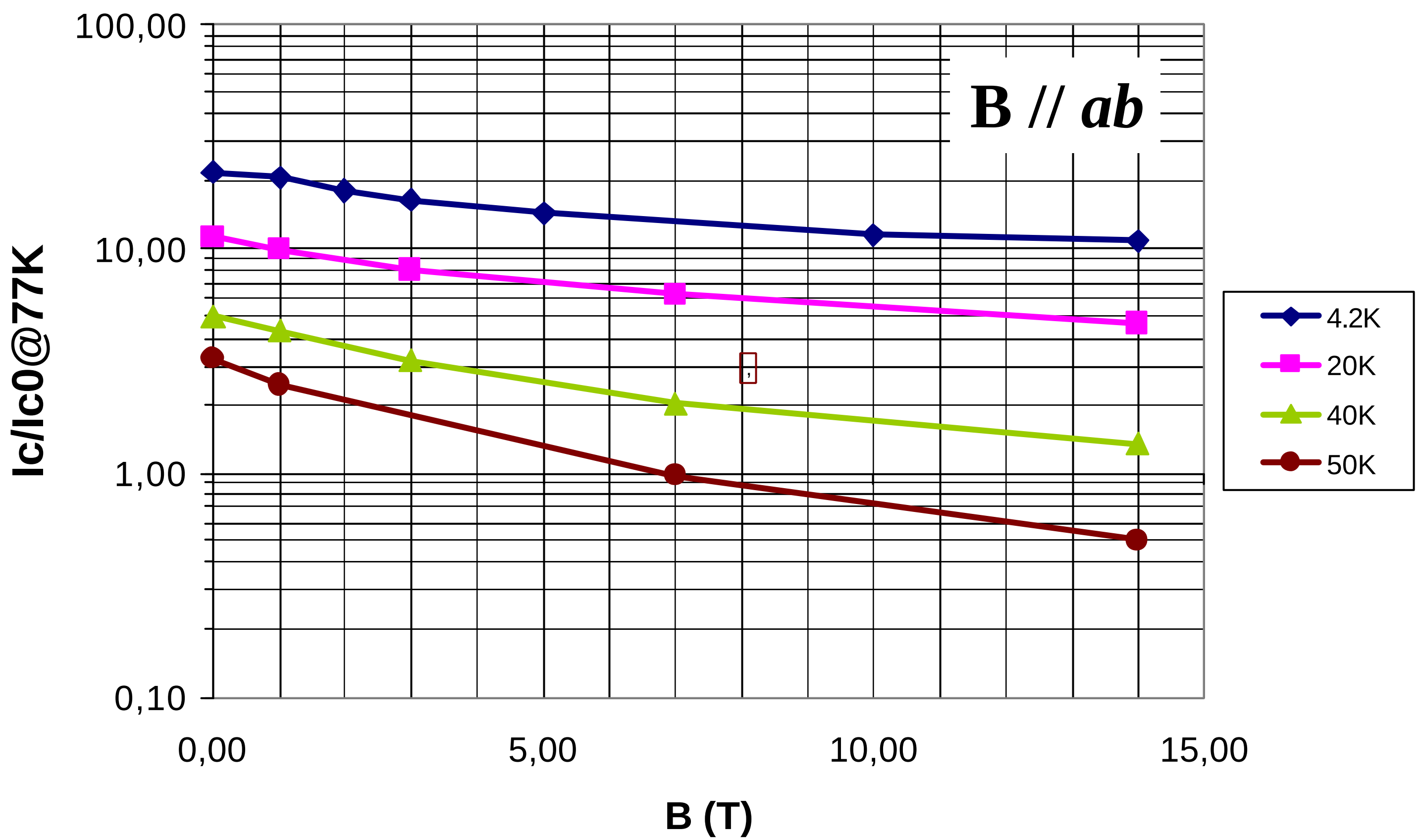
Continuous deposition of CC's



1 meter long CC: J_c=1-2 MA/cm^2

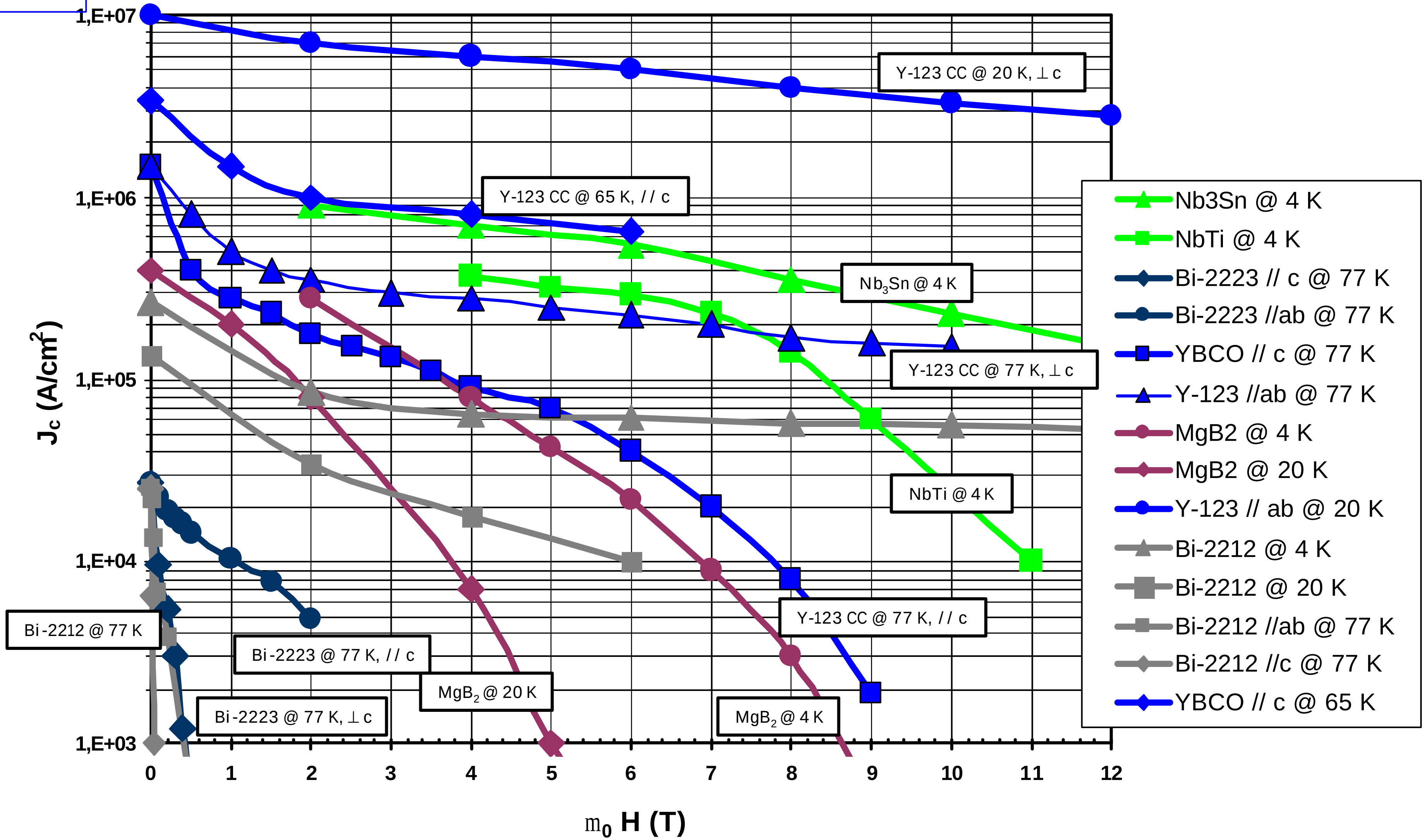
Next goal: 3 m long CC with I_c > 200 A/cm-width by 2004.

J_c vs B at low temperature



D. Uglietti, Département de Physique de la Matière Condensée, Université de Genève

J_c (B)



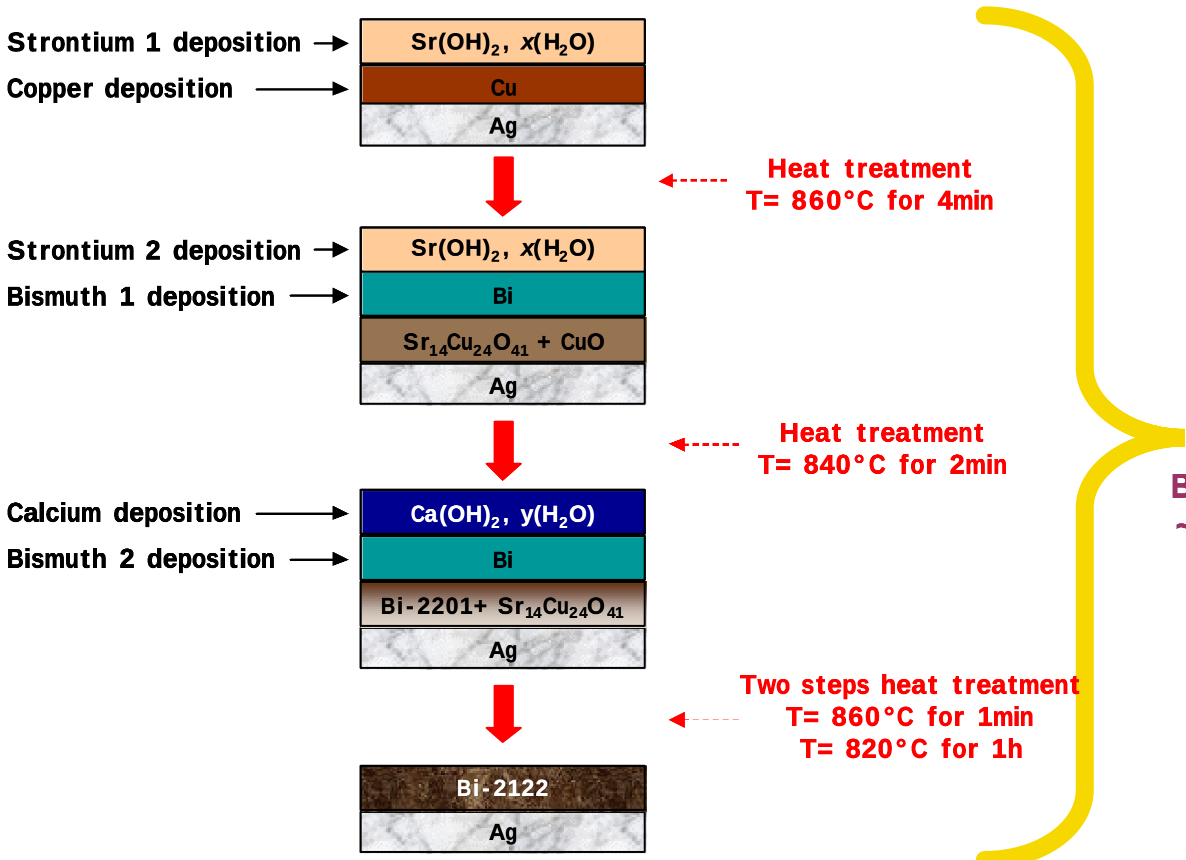
1,E+07
1,E+06
1,E+05
1,E+04
1,E+03
Jc (A/cm2)
0 1 2 3 4 5 6 7 8 9 10 11 12
m0 H (T)
Y-123 CC @ 20 K, ⊥ c
Y-123 CC @ 65 K, / / c
Nb3Sn @ 4 K
Y-123 CC @ 77 K, ⊥ c
NbTi @ 4 K
Y-123 CC @ 77 K, / / c
Bi-2212 @ 77 K
Bi-2223 @ 77 K, / / c
MgB2 @ 20 K
Bi-2223 @ 77 K, ⊥ c
MgB2 @ 4 K
Nb3Sn @ 4 K
NbTi @ 4 K
Bi-2223 // c @ 77 K
Bi-2223 //ab @ 77 K
YBCO // c @ 77 K
Y-123 //ab @ 77 K
MgB2 @ 4 K
MgB2 @ 20 K
Y-123 // ab @ 20 K
Bi-2212 @ 4 K
Bi-2212 @ 20 K
Bi-2212 //ab @ 77 K
Bi-2212 //c @ 77 K
YBCO // c @ 65 K

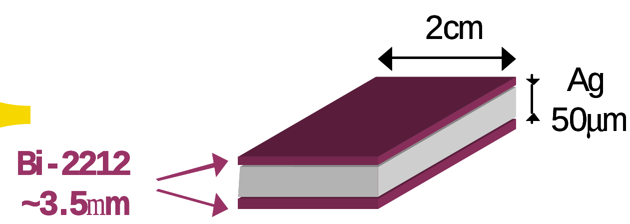
Bi-2212 electrodeposited tapes

- No-vacuum, fast and low-cost technique.
- Silver substrate without buffer layer
- Goal: scale-up of the electrochemical process, optimized on short samples, to a pilot plant for production of long Bi-2212 long tapes by a continuous electrochemical process
- Suitable also for Y-123 deposition (J_c=10 kA/cm^2 @ 77 K on untextured Ag substrates)

EDISON

Sequential electrodepositions

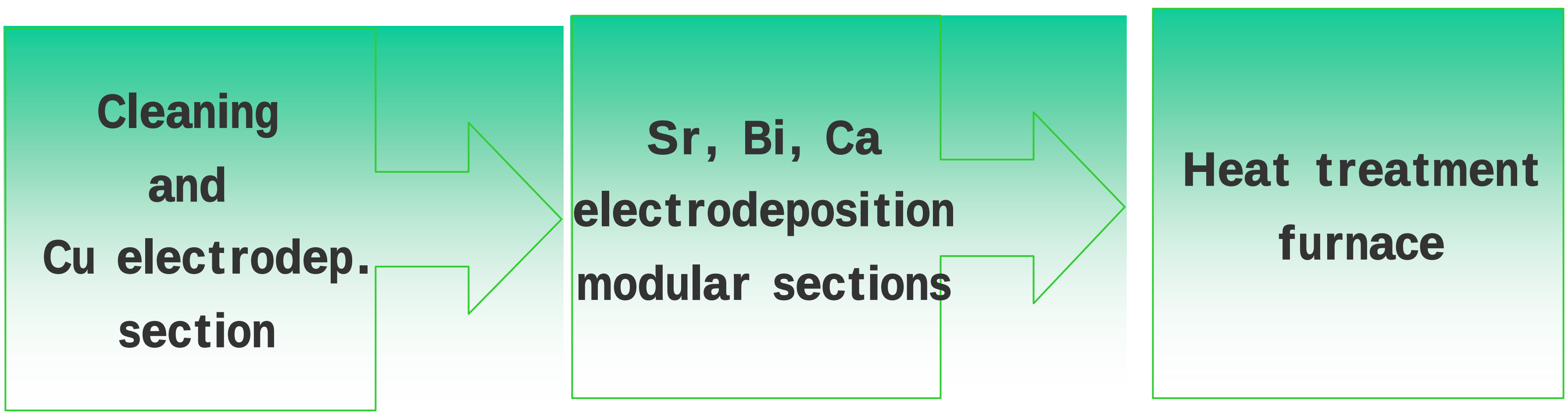




Cooperation with ENEA for substrates alternative to Ag

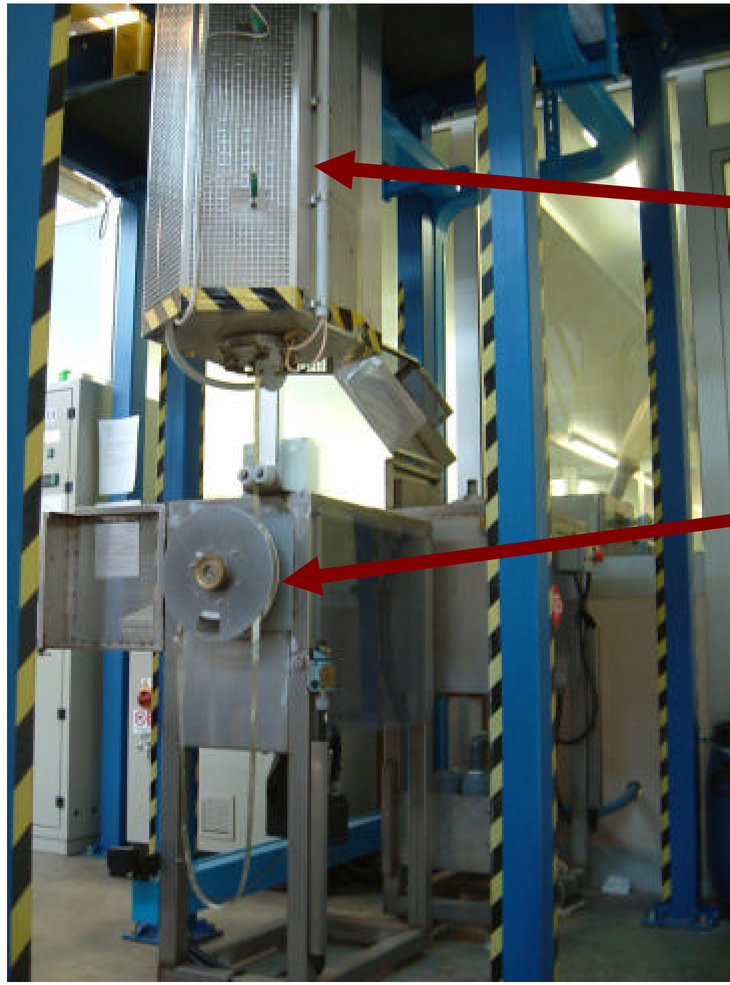
EDISON

Block diagram of pilot plant



Pilot plant
Modular Electrodeposition Section

Heat treatments furnace



Vertical tubular furnace

Unwinding reel

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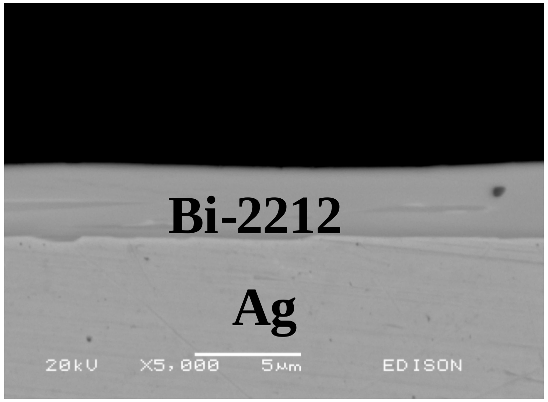
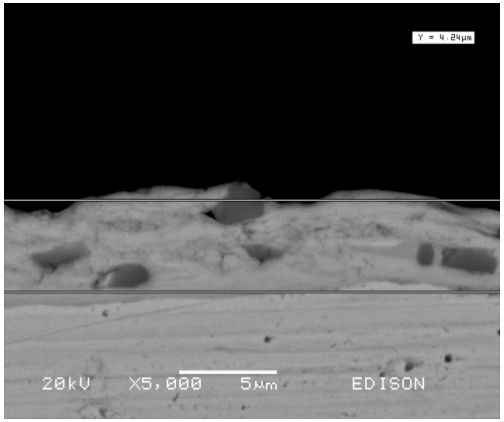
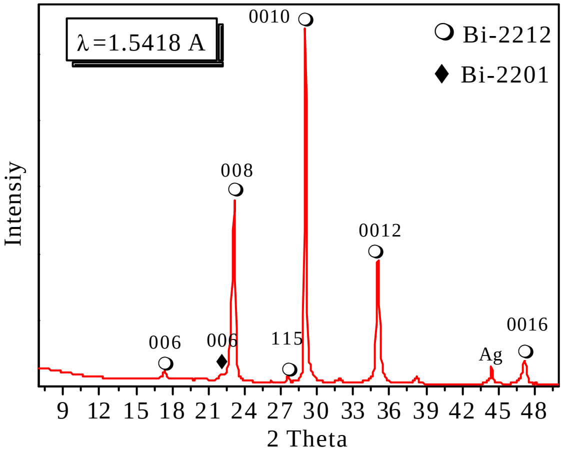
Electrodeposited Bi-2212 tapes







Best quality Lab sample

pilot plant tape

lower density

small size secondary phases

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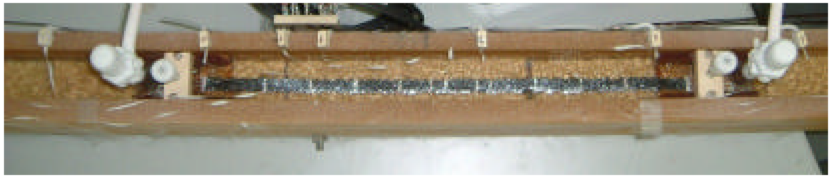
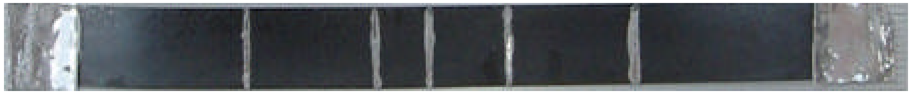
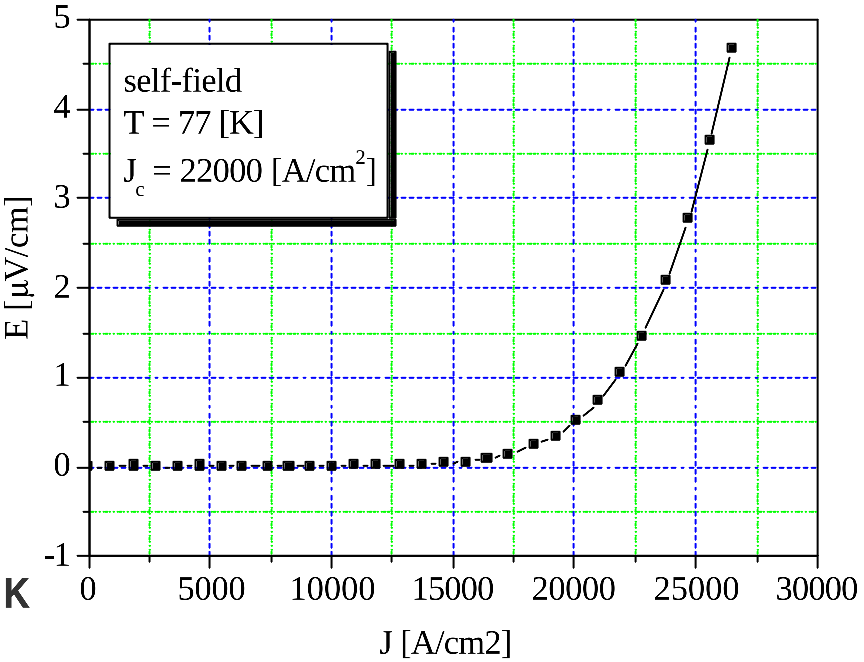
Electrical performances



J_c transport measurement





20x2 cm long sample J_c > 25 kA/cm^2 @ 77 K

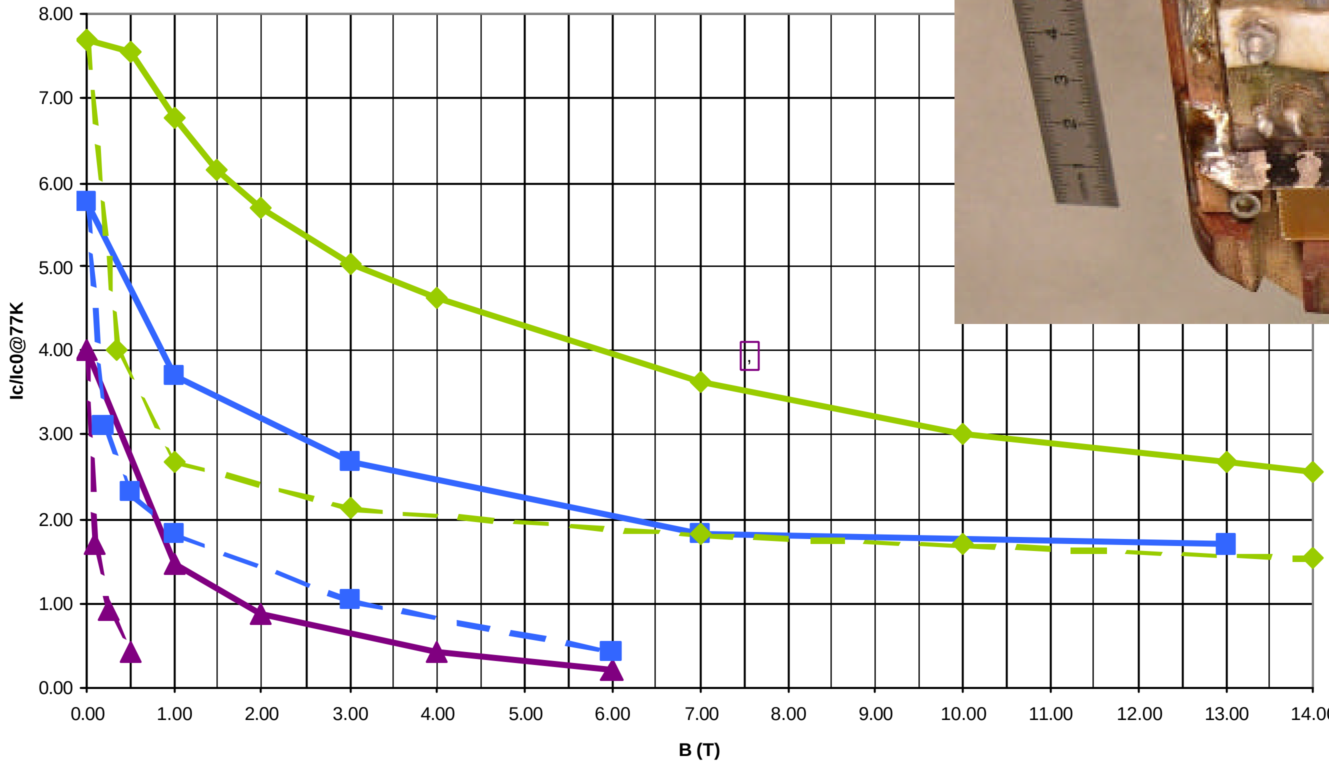
100x2 cm long sample J_c > 15 kA/cm^2 @ 77 K cut from 20 m of electrodeposited tape

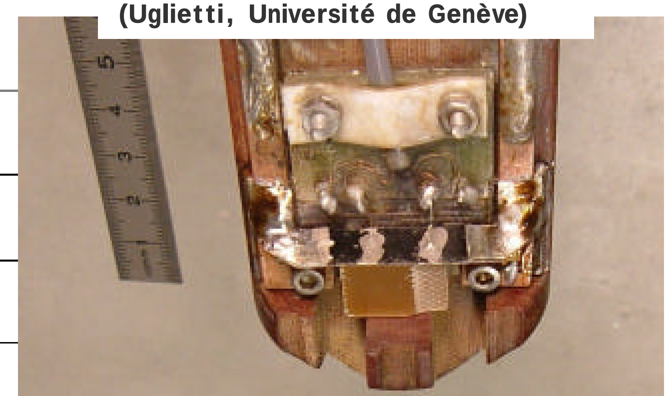
Next goal: 10 m, 20 kA/cm^2 by 2004 (end of funded national project)

EDISON

Critical current vs magnetic field

(Uglietti, Université de Genève)





EDISON

High density MgB_2 by Reactive Liquid Infiltration (RLI)

"in situ" process by the following reaction:

Mg (liquid) + B(powders)

Temperature (750 °C – 1000 °C)

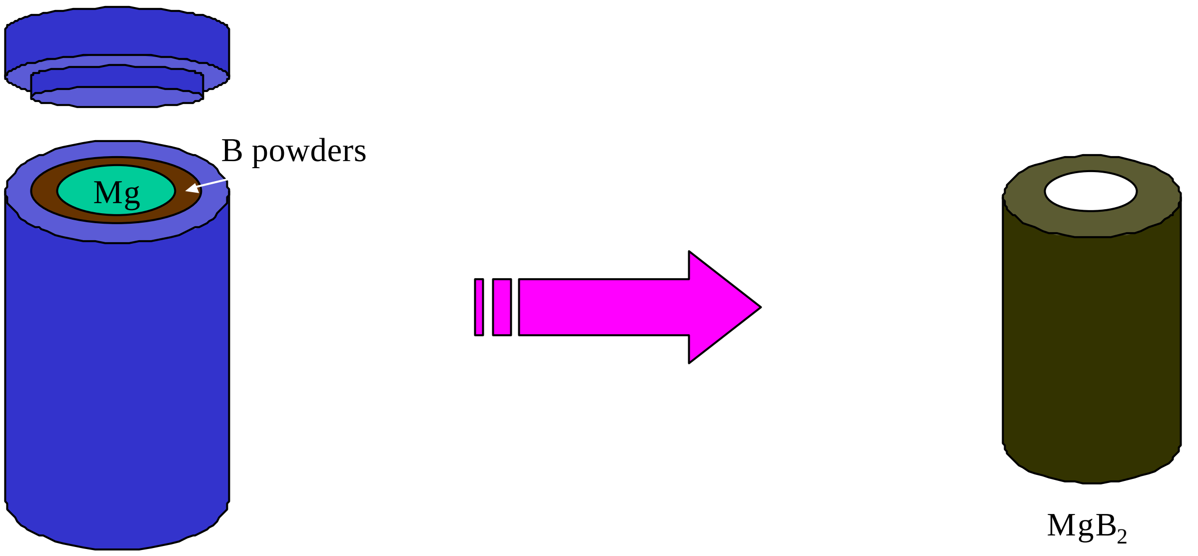
Pressure (> 1 atm)

MgB_2 ($\rho > 0.9\rho_{th}$)

EDISON

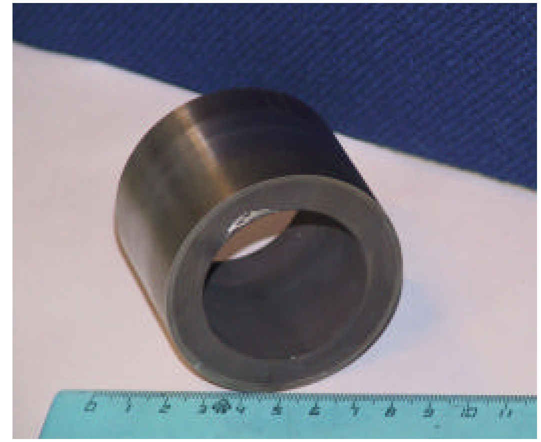
Bulk MgB_2 manufacturing

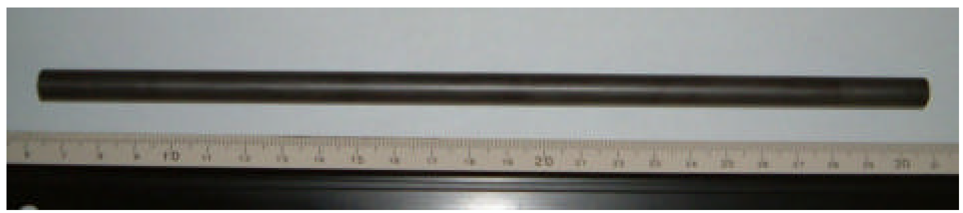
The reaction is performed in a sealed stainless steel container and the final shape resembles the shape of the B preform.



EDISON

Bulk MgB_2 Manufacts





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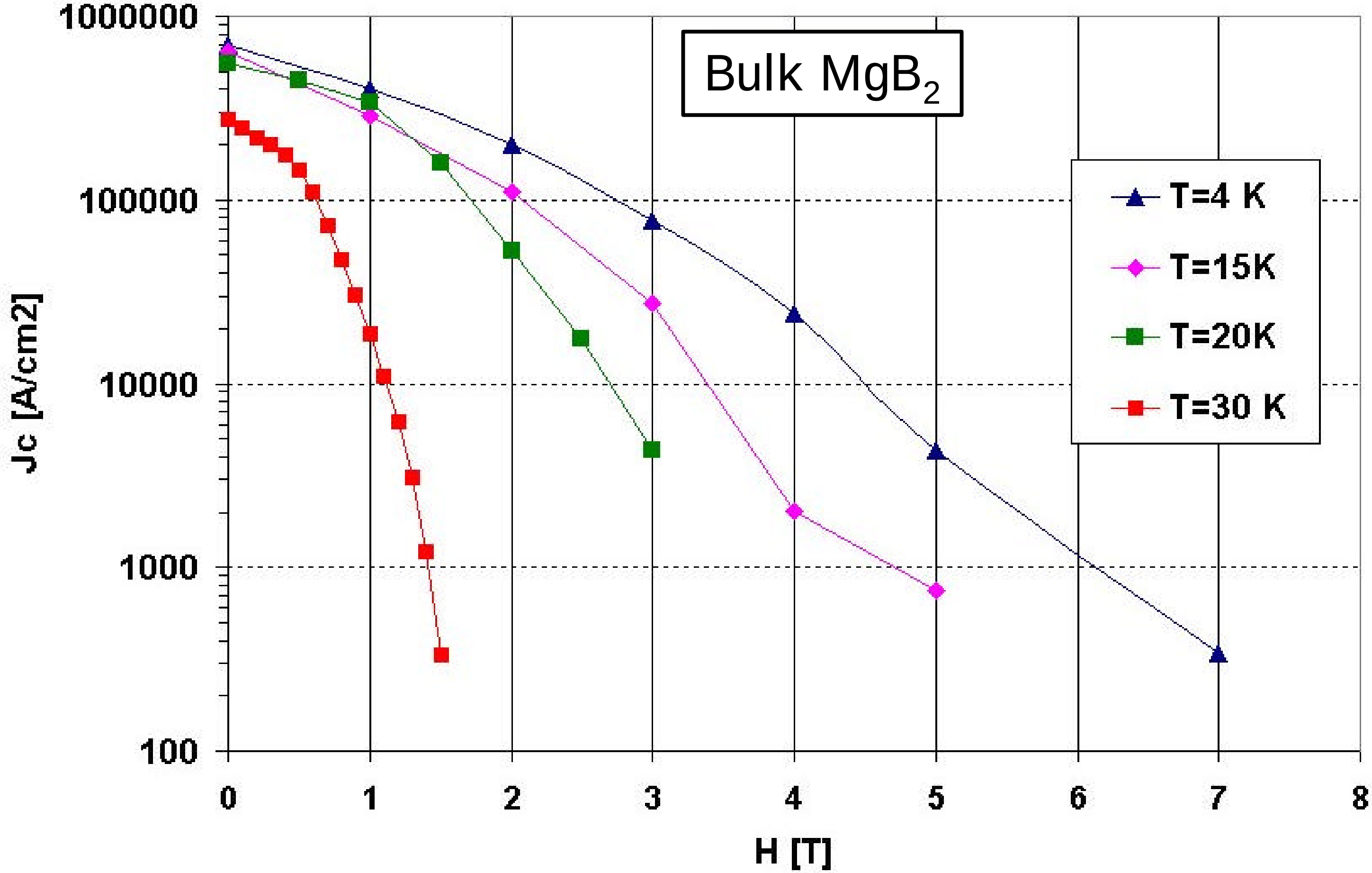
Benefits of the RLI technology

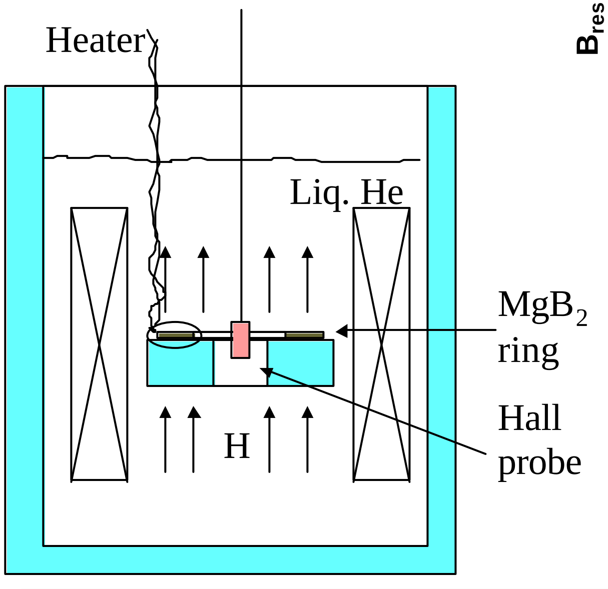
- High density products with a low pressure process.
- Large and thick sample manufacturing.
- Valid for bulk and wires.

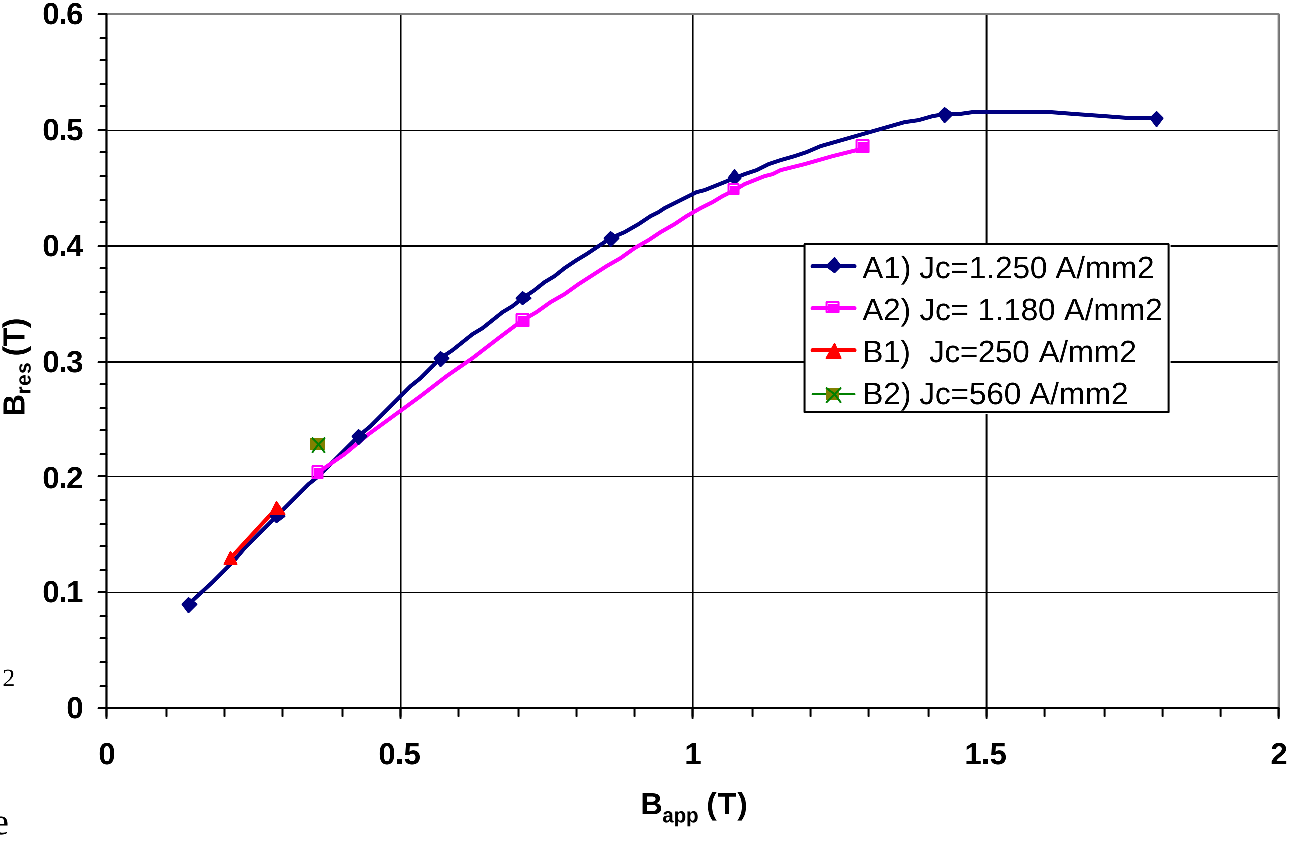
Magnetic critical current density



Trapped Magnetic Field

MgB_2 hollow disk , 1 mm thick (ϕ_{int}/ϕ_{ext}=25/46 mm)

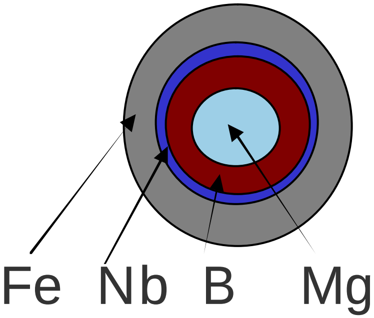


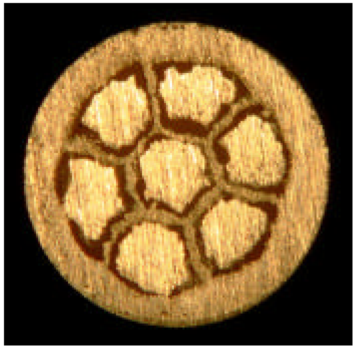


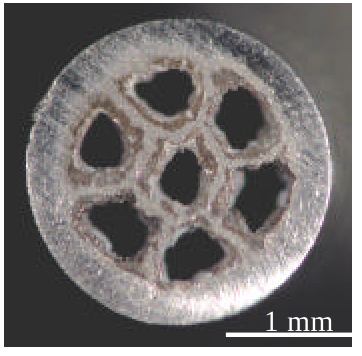
EDISON

Hollow wire manufacturing

- Cold working of a composite billet ,
- Assembling many billets for multiwire manufacturing
- Clamping the terminals
- Thermal treatment



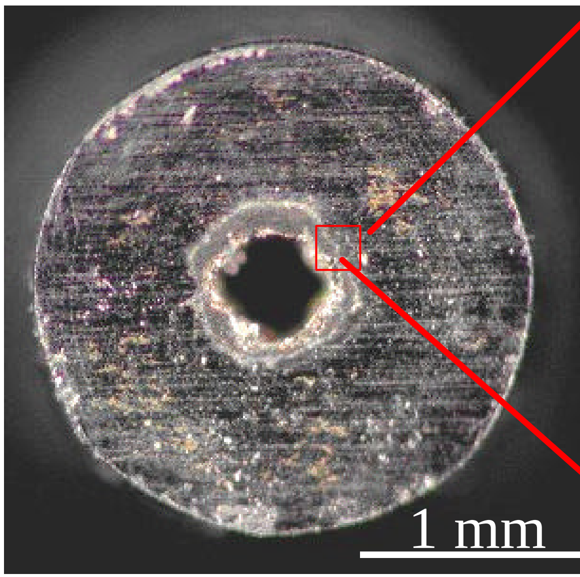

a)

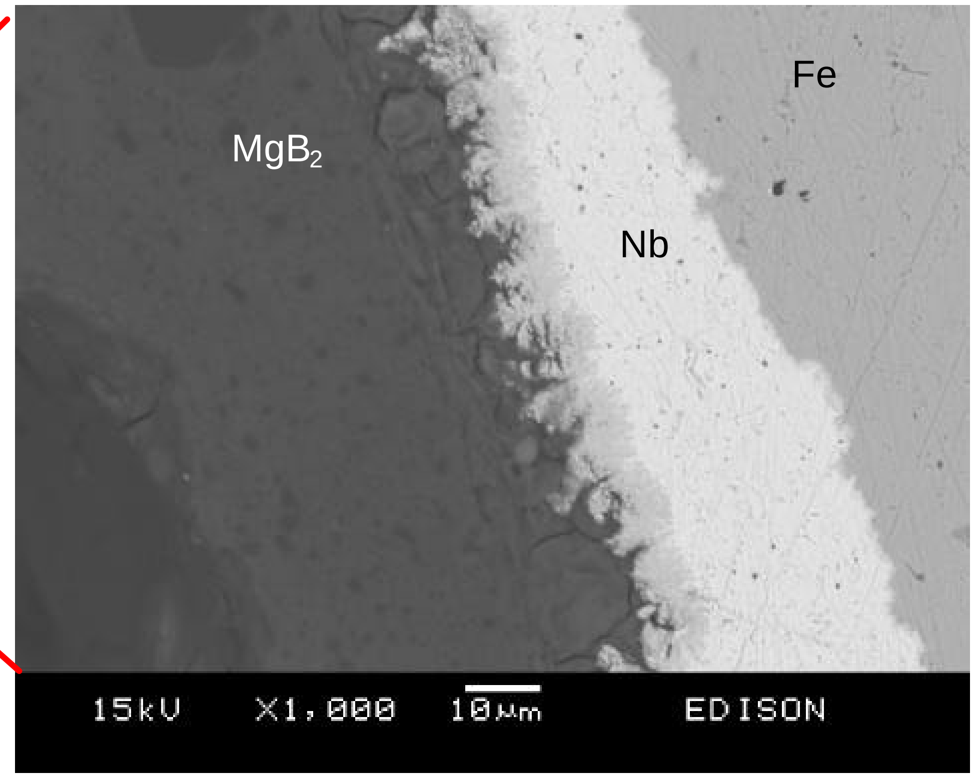


b)

Optical micrographies of the cross sections of a 7-filament multiwire:
a) precursor wire, b) annealed superconducting wire

MgB_2 Monofilamentary wire





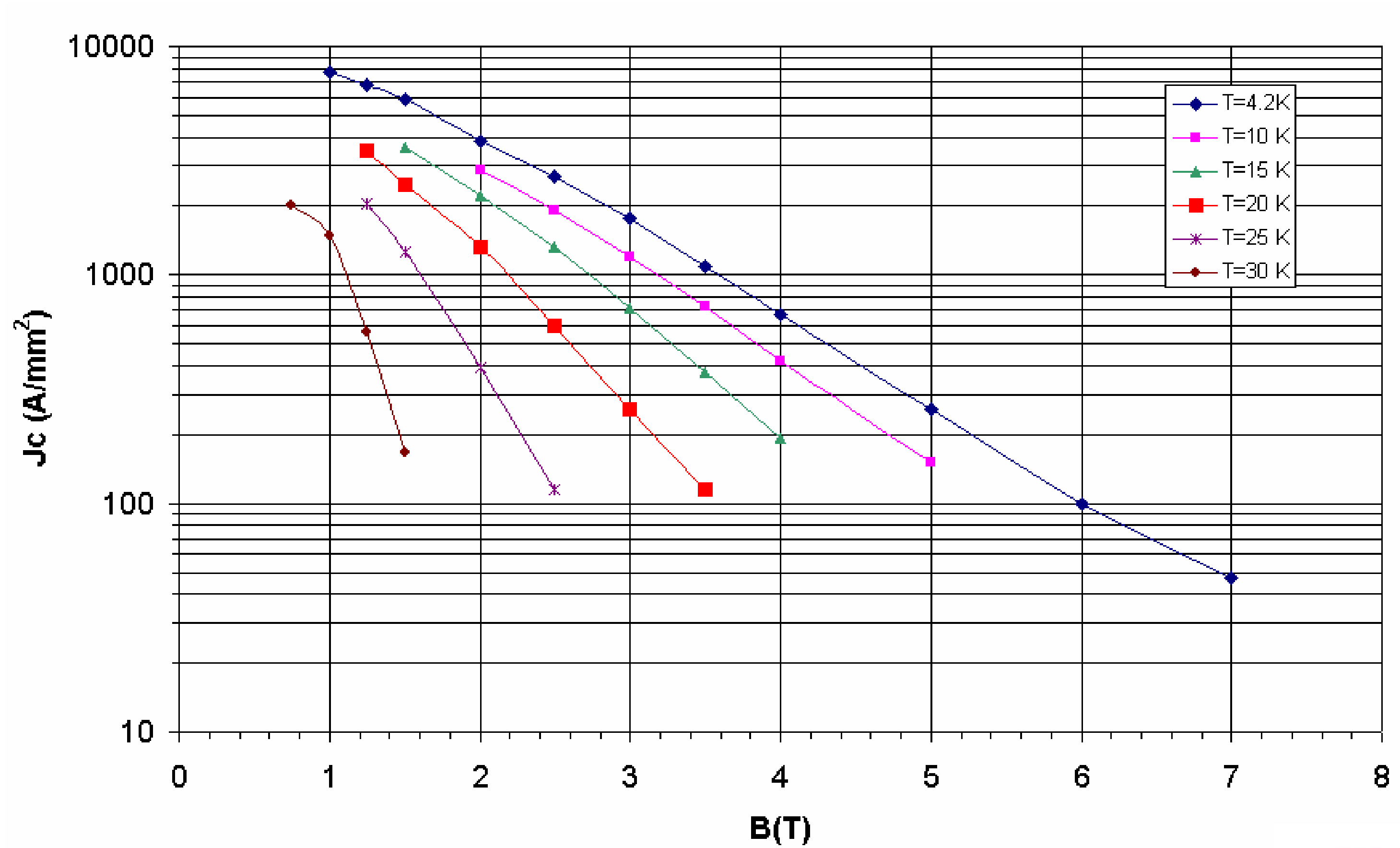
Optical cross section
cross section

Backscattered electrons

EDISON

J_c (B) of MgB_2 monofilamentary wire

(A_{SC}= 0.1 mm^2, A_{tot}=1.23 mm^2)



Bruzzone, EPFL-CRPP, Villigen

EDISON

n-factor

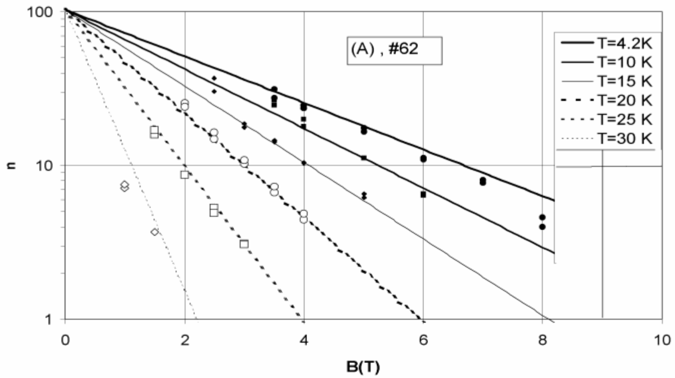
The n-factor for different specimens are interpolated according to the following relation:

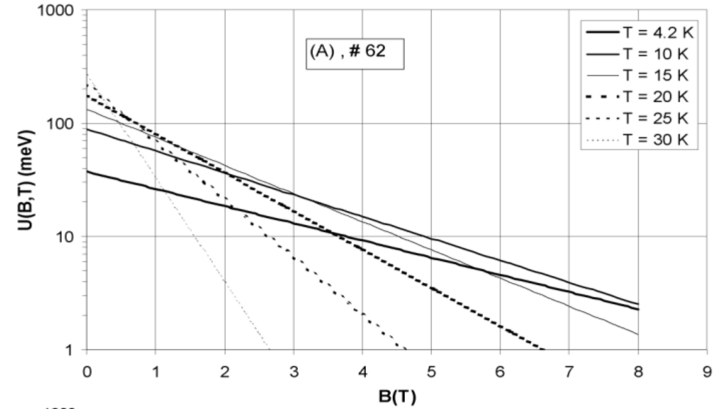
$$\mathbf{n(B,T) = n_o \exp(-aB/(1-T/T_c)^{b})}$$

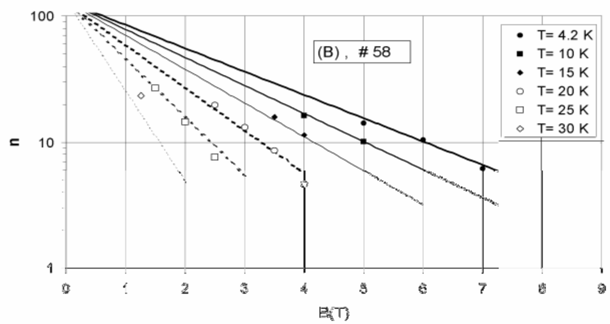
parameters n_o, α, β determined by fit of the exp. values

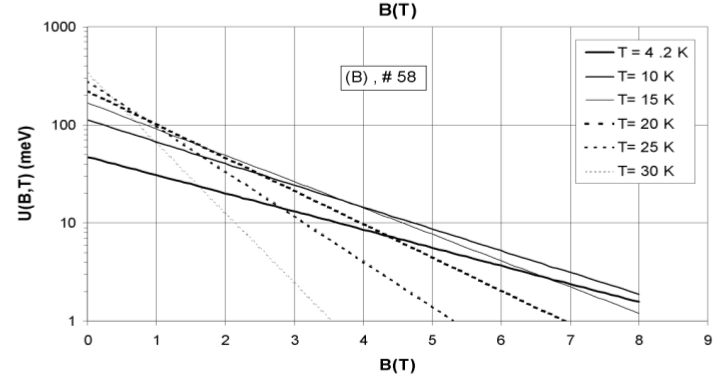
MgB_2 Samples	n_o	a (1/T)	b
(A) - Bulk (#62)	103	0.30	1.33
(B) -Monofilament wire (#58)	130	0.38	1.00
(C) -7-filaments wire (#40A)	37	0.145	1.33

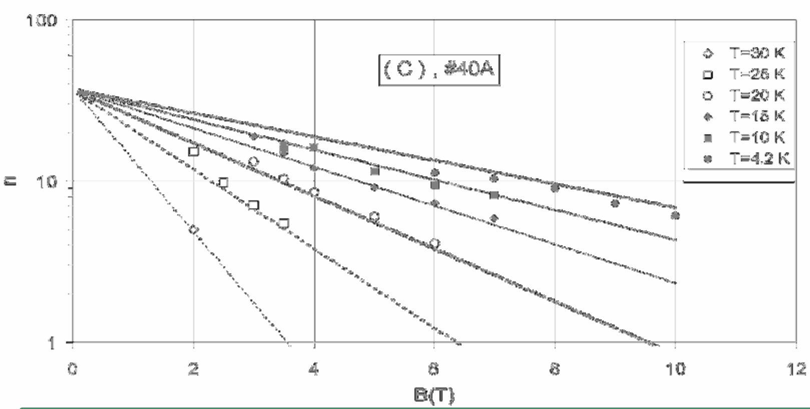
n-factor and flux flow activation energy

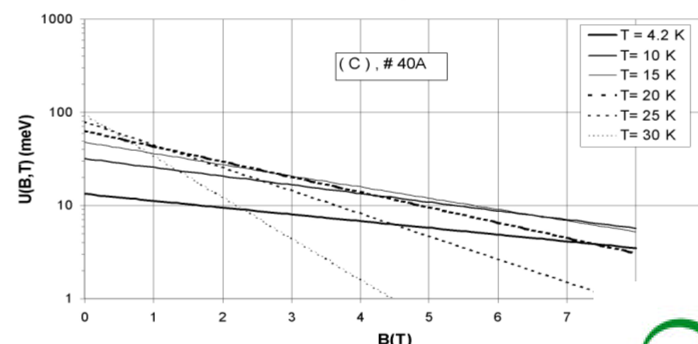












EDISON

MgB_2

- MgB_2 is potentially interesting for applications at intermediate magnetic fields and intermediate temperatures (< 20 K).

- The high potentiality of MgB_2 to reach rapidly a wide market is related to the low prospectic costs of raw materials and of the manufacturing process.