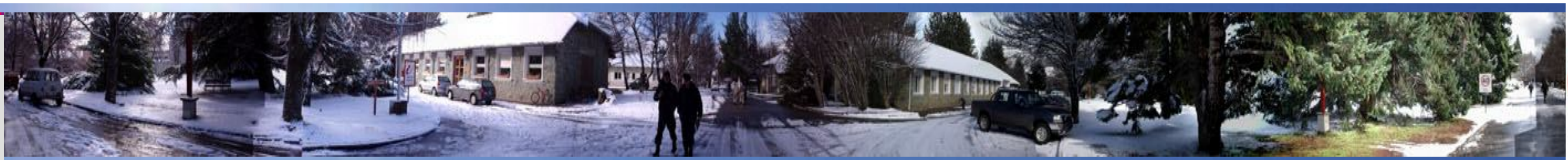
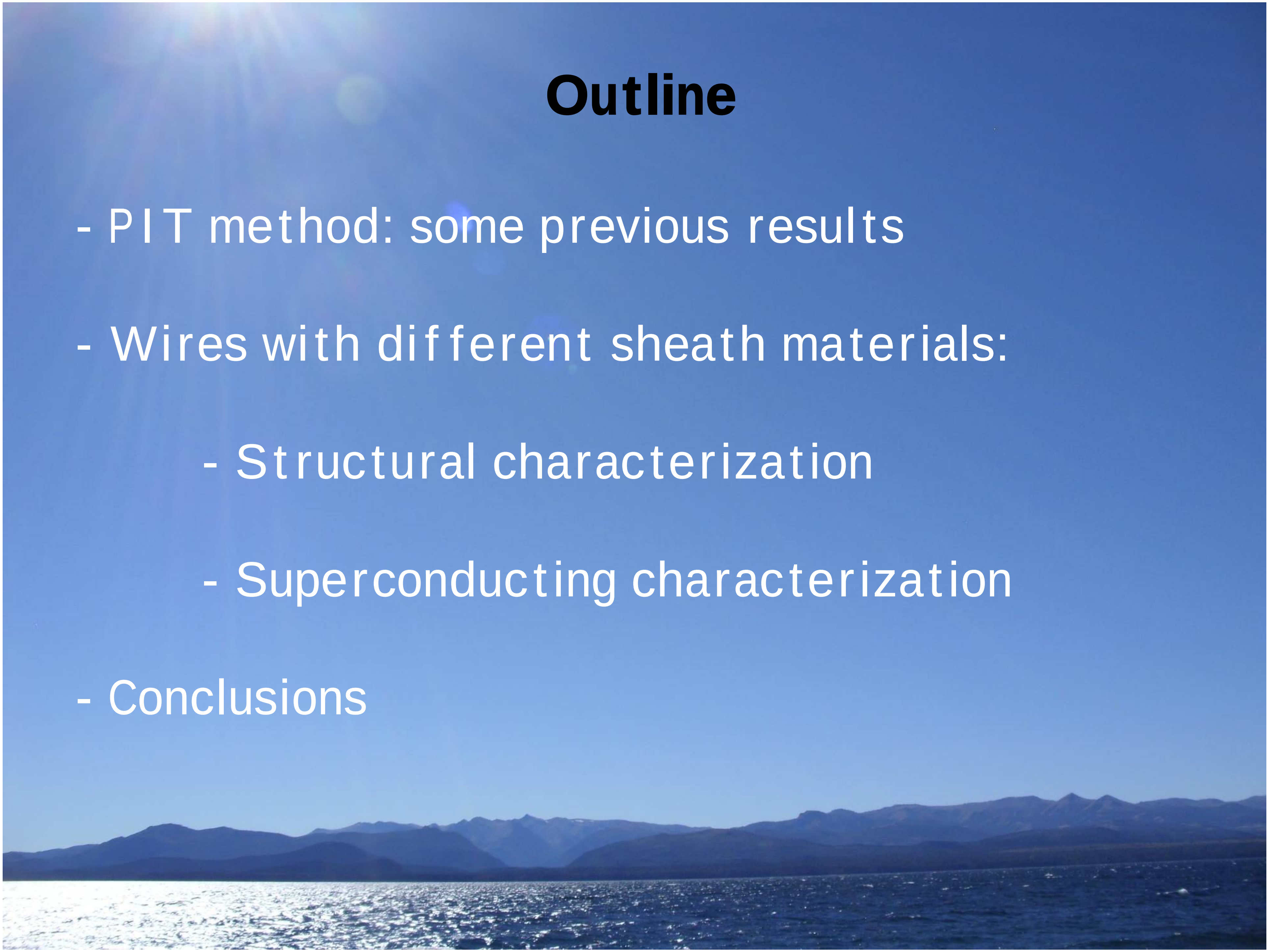


Enhancement of critical currents in wires of MgB_2 using different sheath materials

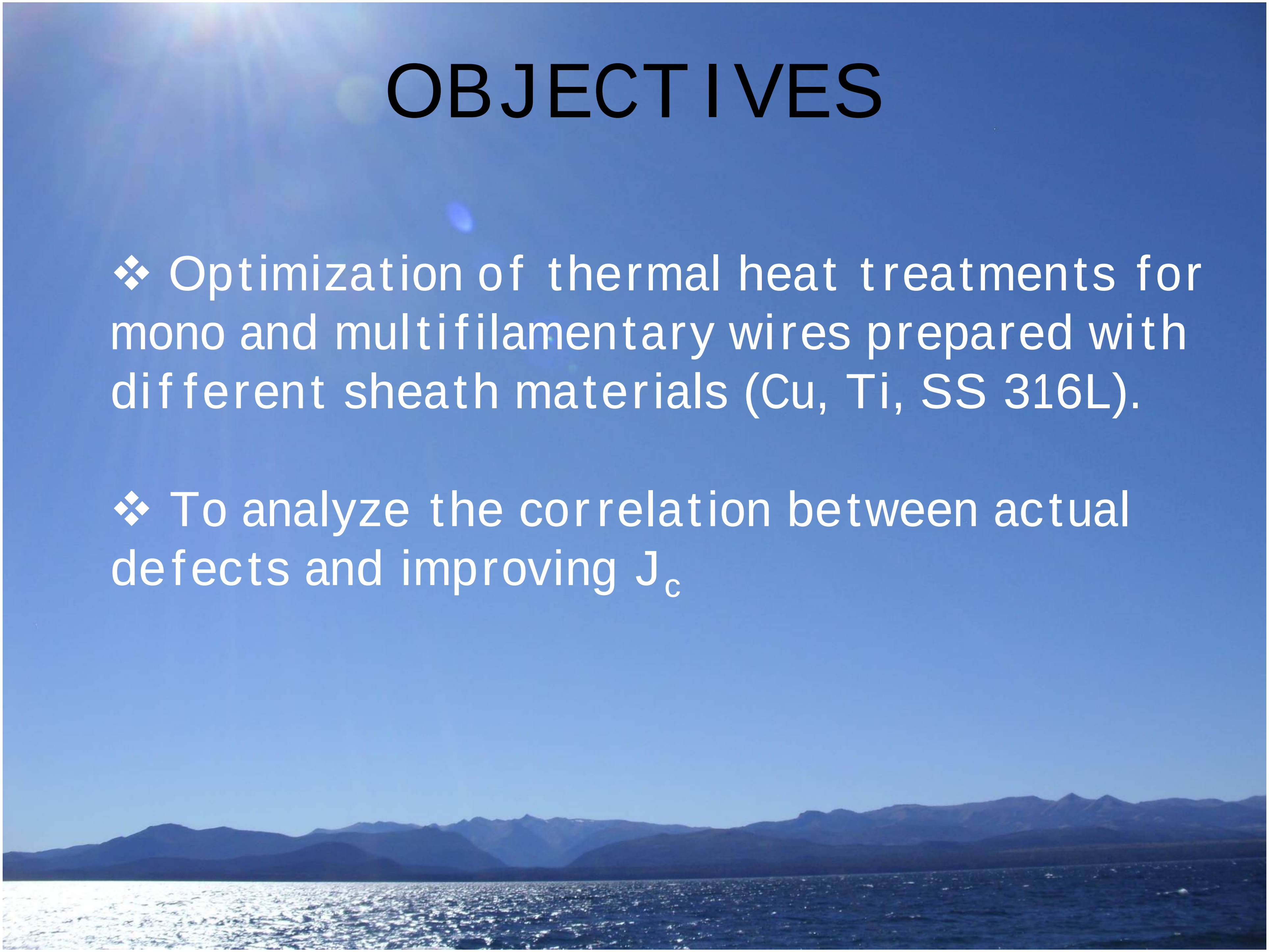
C. Sobrero, M. T. Malachevsky, A. Soldati, Adriana Serquis

Centro Atómico Bariloche, CNEA-CONICET, S.C. de Bariloche,
ARGENTINA



Outline

- PIT method: some previous results
- Wires with different sheath materials:
    - Structural characterization
    - Superconducting characterization
- Conclusions



OBJECTIVES

- Optimization of thermal heat treatments for mono and multifilamentary wires prepared with different sheath materials (Cu, Ti, SS 316L).

- To analyze the correlation between actual defects and improving J_c

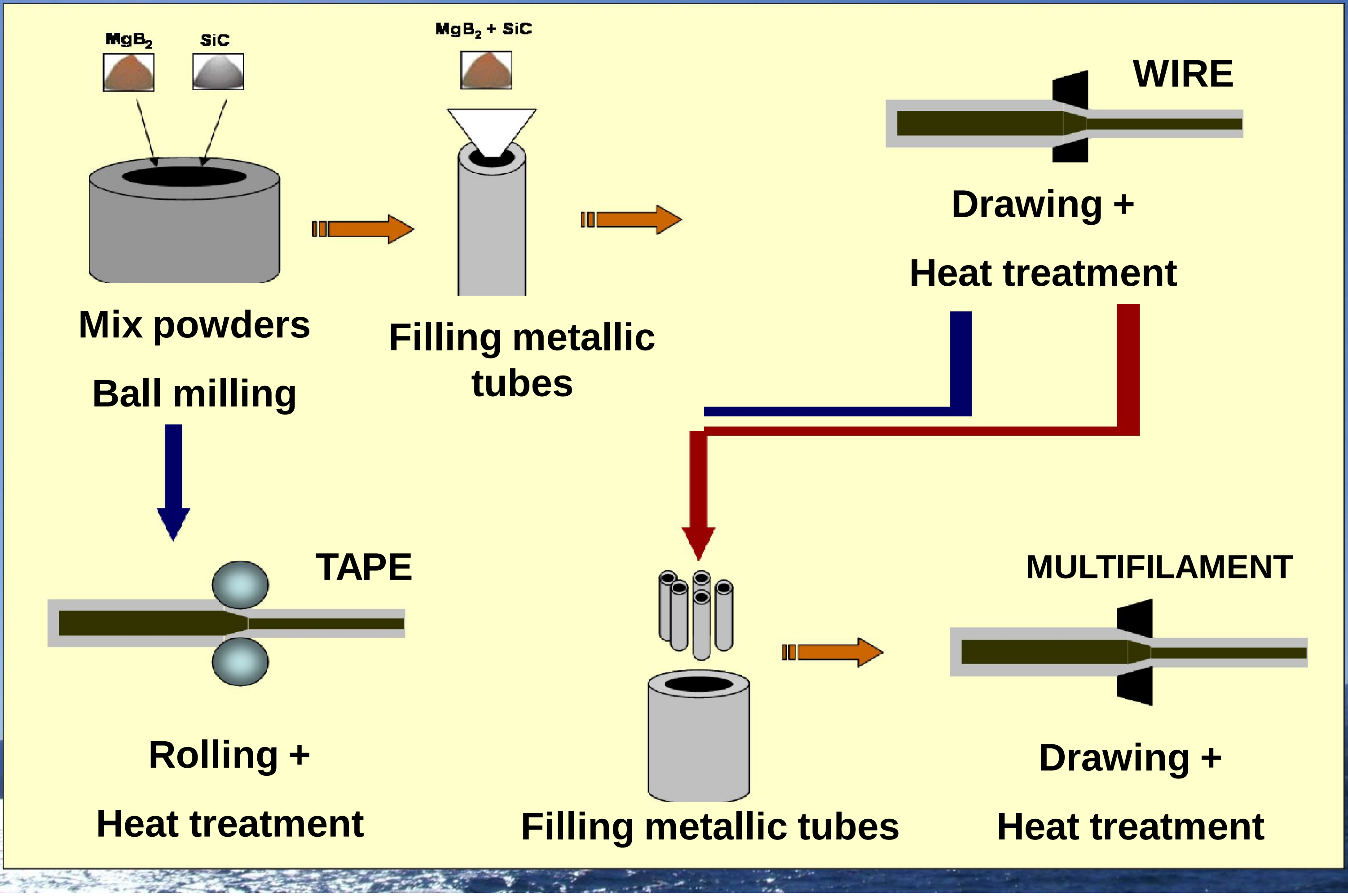
Process for PIT MgB2 wires - tapes

Ex-situ process:

- Stainless steel as sheath material
- MgB2 (Alfa Aesar) + 5 %at Mg excess
- MgB2 (Alfa Aesar) + 5 %at SiC
- MgB2 + ??

Annealings:

- Intermediate annealings at 500-900°C
- Final annealing: needed for removal o microcracks formed in the cold working



Mix powders

Ball milling

Filling metallic tubes

Drawing +

Heat treatment

Rolling +

Heat treatment

Filling metallic tubes

Drawing +

Heat treatment

Sheath
- SS,
- Ti,
- Ag
- Cu

Process for PIT MgB2 wires - tapes

Ex-situ process:

- Stainless steel as sheath material
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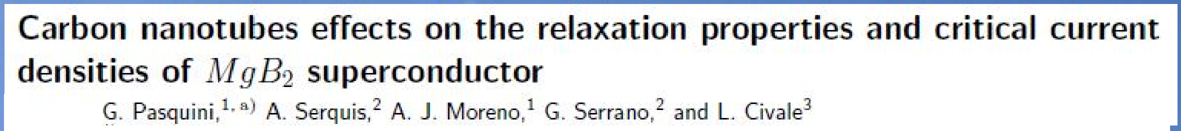

Carbon nanotubes effects on the relaxation properties and critical current densities of MgB_2 superconductor

G. Pasquini,[1, a)] A. Serquis,[2] A. J. Moreno,[1] G. Serrano,[2] and L. Civale[3]

Journal of Applied Physiscs (2013) in press.

Process for PIT MgB2 wires - tapes

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Annealings:

- Intermediate annealings at 500-900°C
- Final annealing: needed for removal o microcracks formed in the cold working

➢ Powder in Tube (PIT) method: desired performance (**J_c**) already achieved in a small scale by

- ✓ Optimization of post-annealings (R. Flukiger et al. [review: Physica C 385 (2002) 286]; G. Grasso et al. [Supercond. Sci. Technol. 16 (2003) 271; A. Serquis et al [APL 82 (2003) 1754]; A. Serquis et al [JAP 94 (2003) 4024]
- ✓ HIPing (Serquis *et al.* APL 82 (2003) 2847)
- ✓ Intermediate annealings Serano et al IEEE 15 (2005) 318
- ✓ doping with SiC (Dou *et al.* APL 81 (2002) 3419); Serquis et al IEEE 15 (2005) 3188; Serrano et al. JAP 103 (2008) 023907, Da Silva et l. IEEE Transactions on Applied Superconductivity 19 (2009) 2730-2734.

Sheath

- SS,
- Ti,
- Ag
- Cu

- Several intermediate heat treatments at high temperatures degrade the inter-grain critical current more than the increase in intra-grain J_c due to SiC addition
- Connectivity of MgB_2 core is a first order key parameter for obtaining good superconducting properties.

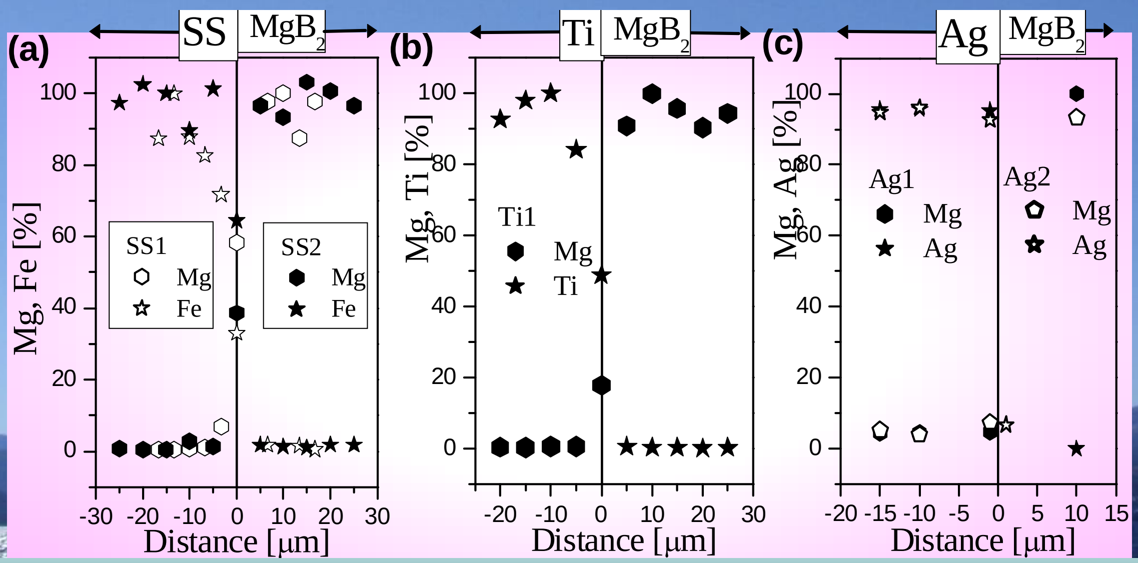
Effect of heat treatments for different sheaths

- Optimization of heat treatments suitable for each material

Sample	Sheath	Type of sample	External Size (mm)	Intermediate treatments quantity (N) and temperature (T)
SS1	stainless steel	tape	0.42 x 2.58	N = 4+ 2, T = 900°C
SS2	stainless steel	tape	0.35 x 2.85	N = 4+ 2, T = 600°C
Ti1	titanium	tape	0.35 x 2.5	N = 4 , T = 600°C
Ti2	titanium/copper	tape	0.62 x 3.1	N = 1 , T = 600°C
Ti3	titanium (wire) titanium/copper	multifilament tape	0.75 x 1.86	N =4+ 3, T = 600°C
Ag1	silver	tape	0.45 x 3.7	N = 8, T = 250 ºC
Ag2	silver	tape	0.75 x 2.7	N = 8, T = 250 ºC

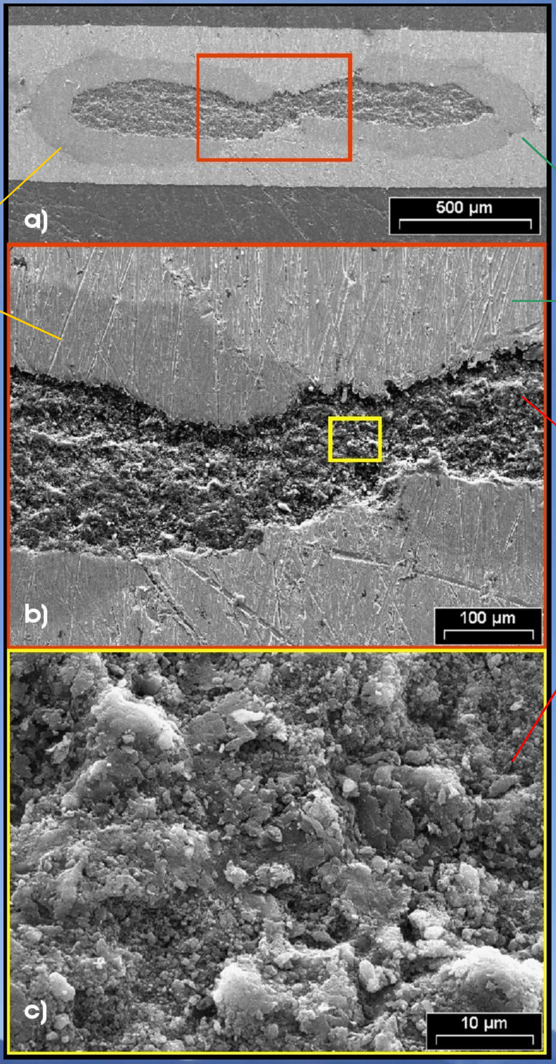
- **Diffusion?**

EDS analysis



M.T. Malachevsky et al IEEE Trans. on Appl. Superc.19 (2009) 2730-2734.

Composite sheaths microstructure



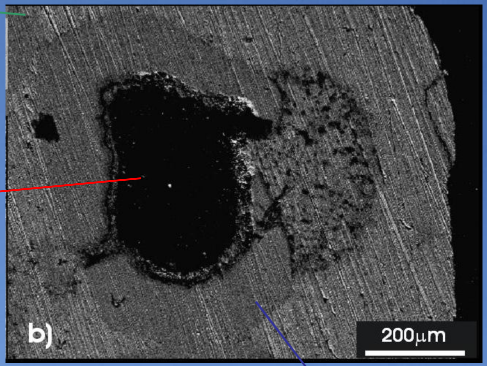
Ti

Cu

MgB_2

- **Multifilament**

(backscattered SEM micrograph)

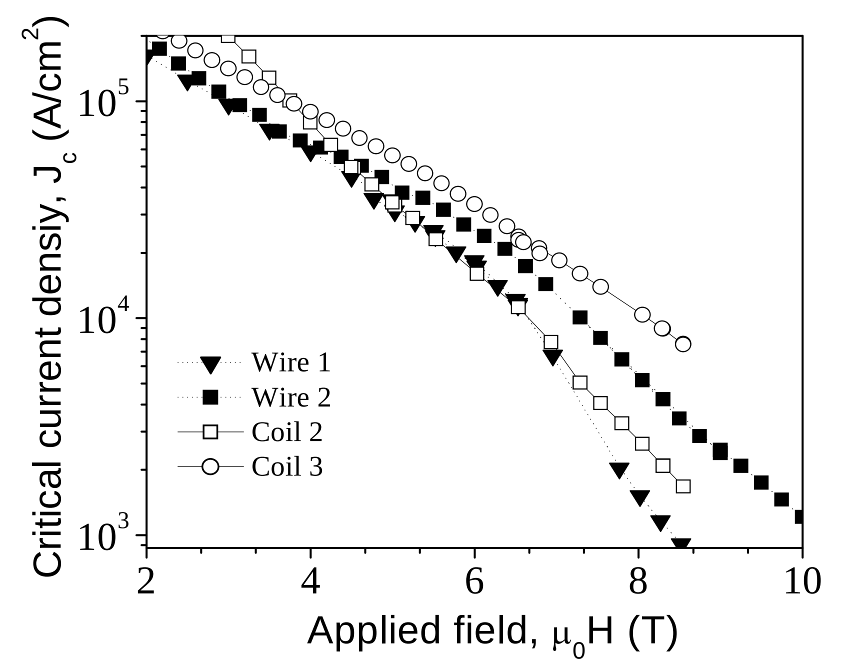


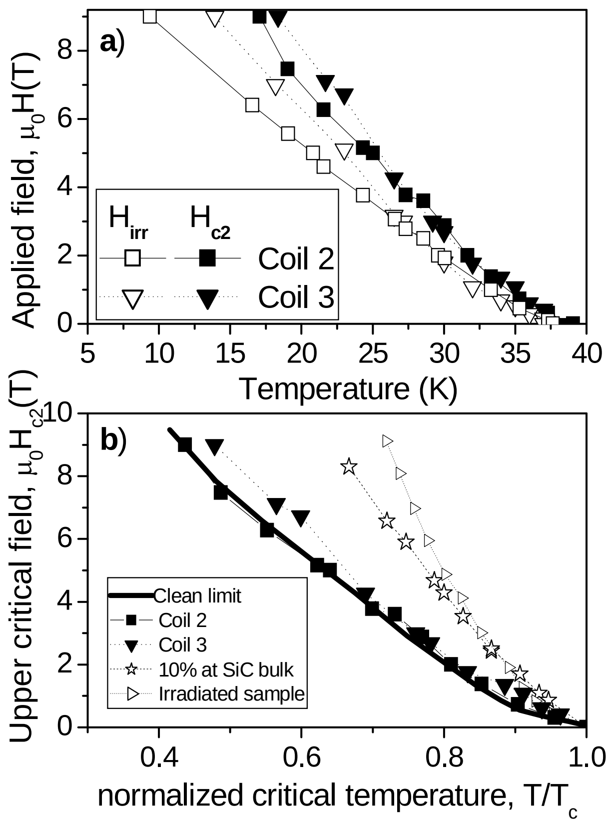
SS

Fast inter-diffusion of Mg/Cu when the barrier materials breaks (cold work with inadequate heat treatments)

Effects of SiC doping

☑ **Doping with SiC**
  - ☑ **Variations in H_{c2} y H_{irr}**
  - ☑ **Variations in J_C**





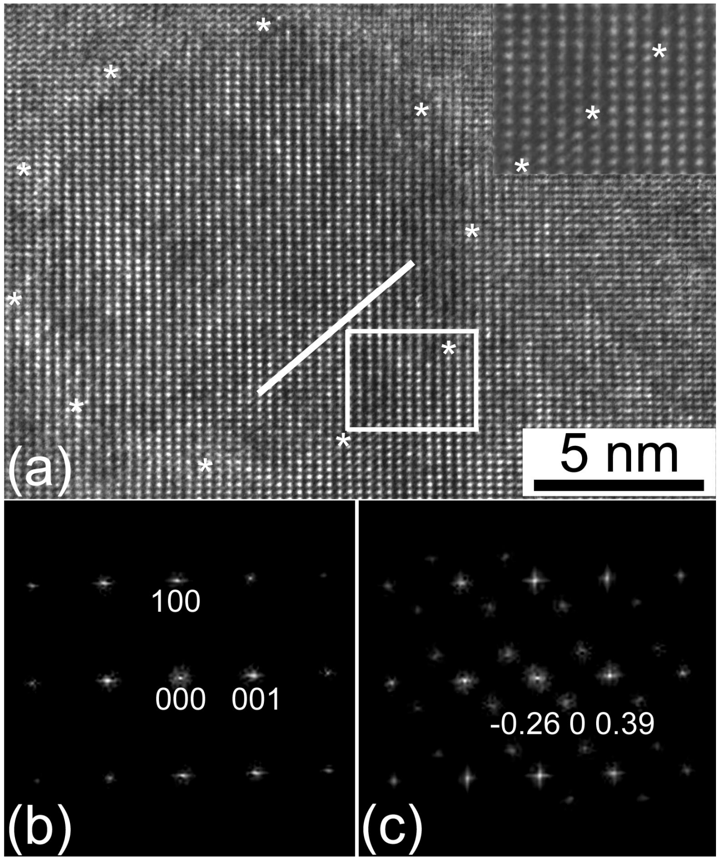
Optimization of critical currents in MgB_2 wires and coils

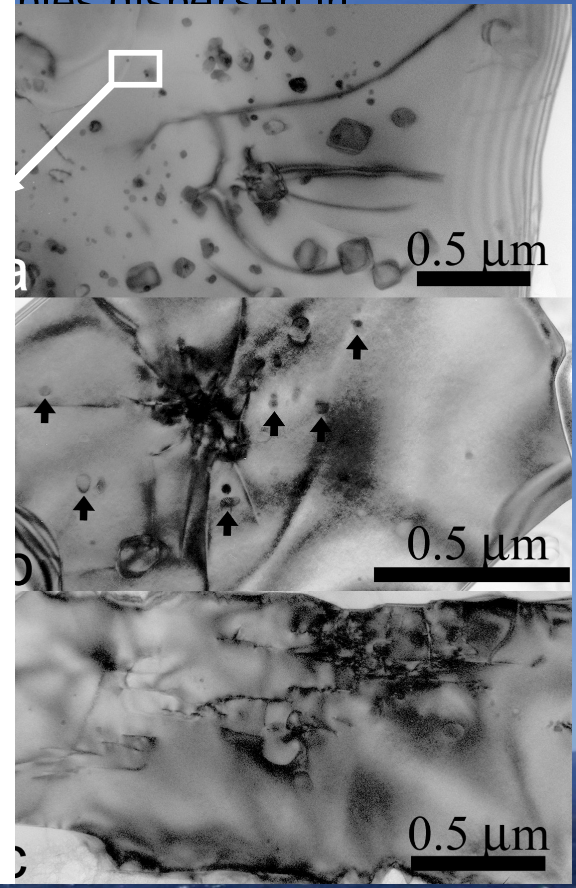
A. Serquis, L. Civale, D. L. Hammon, G. D. Serrano and V. F. Nesterenko

(IEEE Transactions in Aplied Supreconductivity 2005)

Intragranular critical currents in **bulk** samples

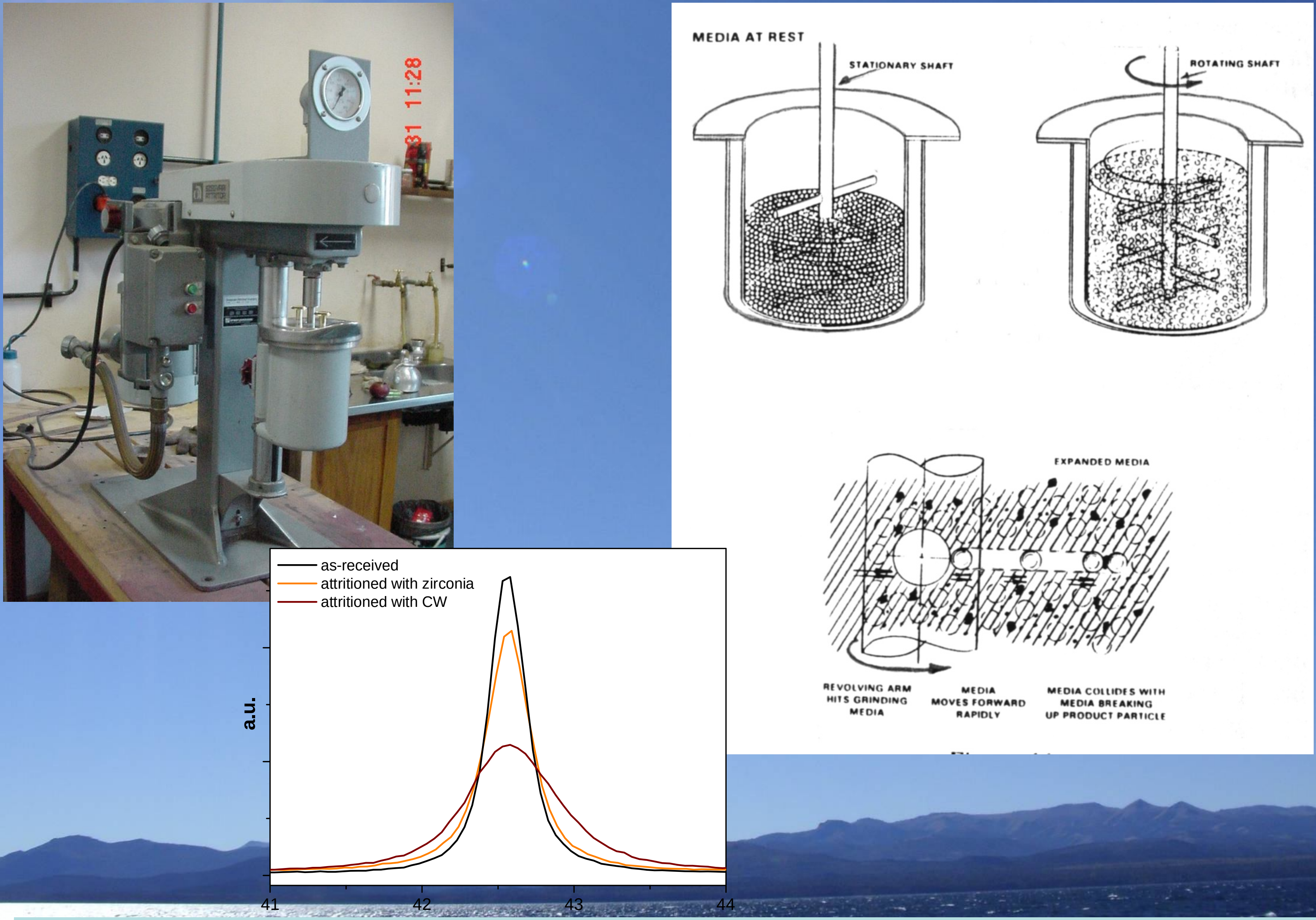
- **Presence of $Mg(B,O)_2$ precipitates: X.Z. Liao *et al* APL 92, 351(2002)**
- Samples sintered with different parameters
- ples dispersed in





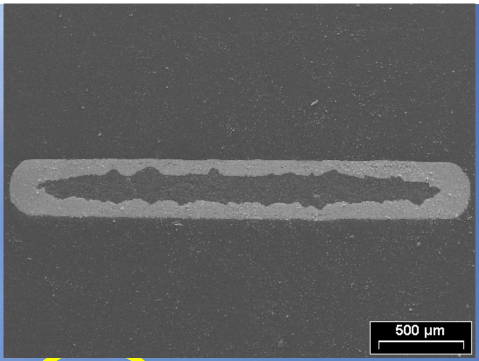
H (Oe)

Atrition milling: reducing initial particle and crystallite size

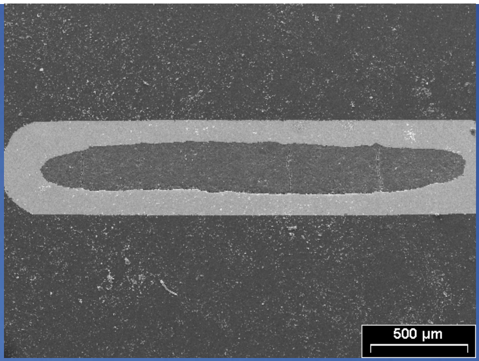


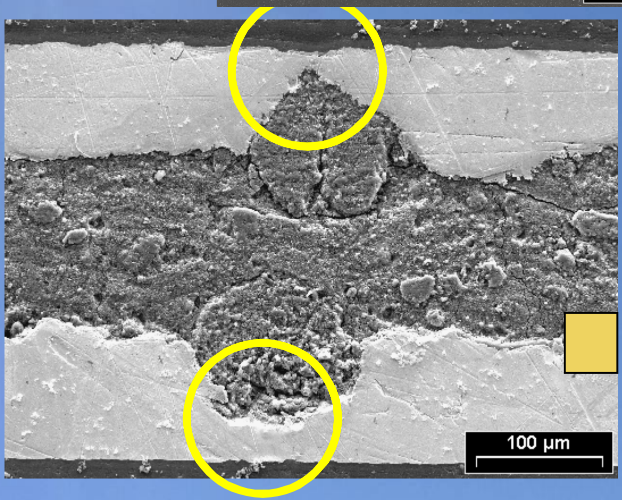
M.T. Malachevsky et al IEEE Trans. on Appl. Superc. 19 (2009) 2730-2734

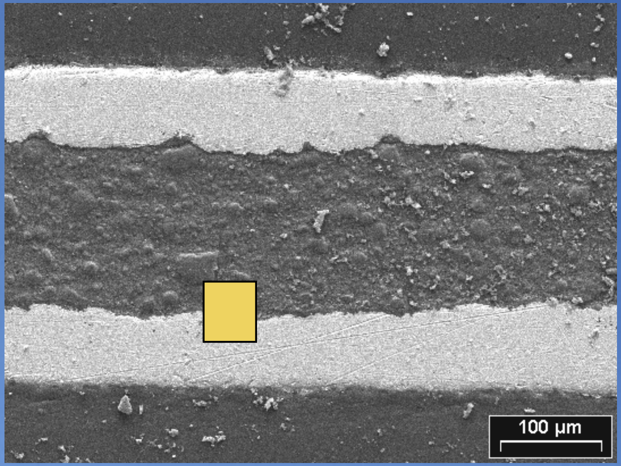
Zr balls

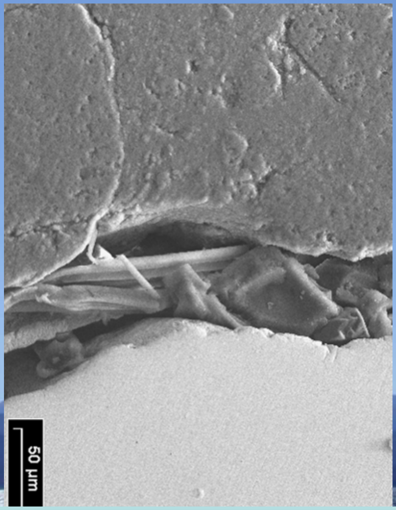


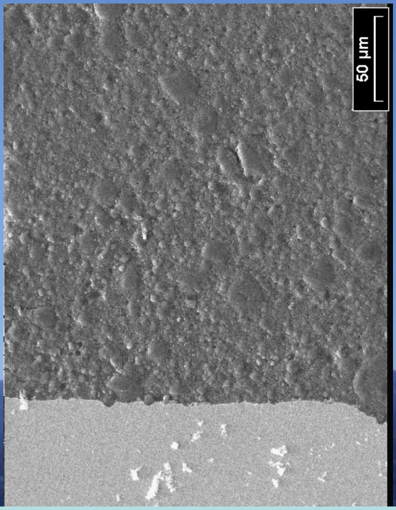
CW balls











M.T. Malachevsky et al IEEE Trans. on Appl. Superc. 21 (2010) 2676 – 2679

Molido con circonia

Molido con acero inoxidable

Molido con carburo de tungsteno

Powder	D [nm]	ε_g x 10^{-3}	T_c [K]
Z	27	0.6	38.4
SS	27	1.10	38.3
WC	17	4.25	38.2

D = tamaño de grano
ε_g= microdeformación (dislocaciones)
Tc = temperatura crítica

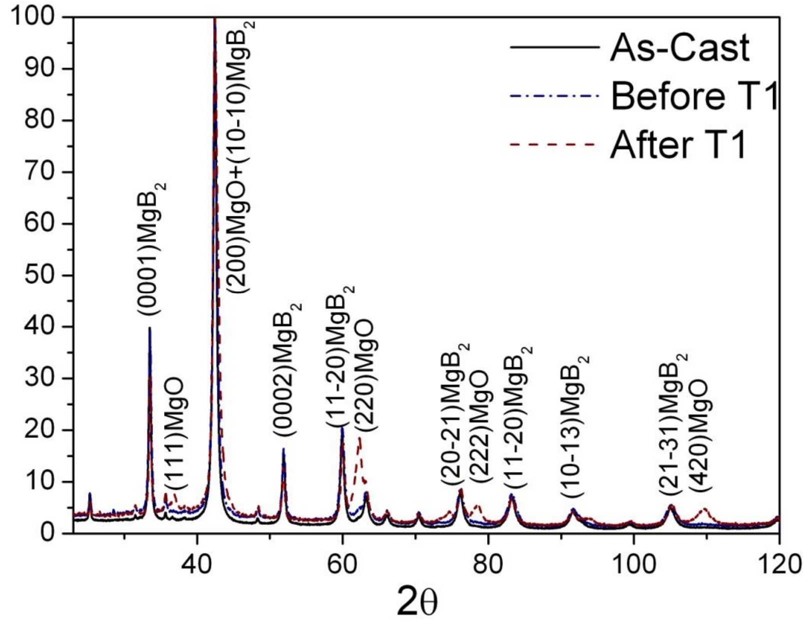
Results

Wires preparation:

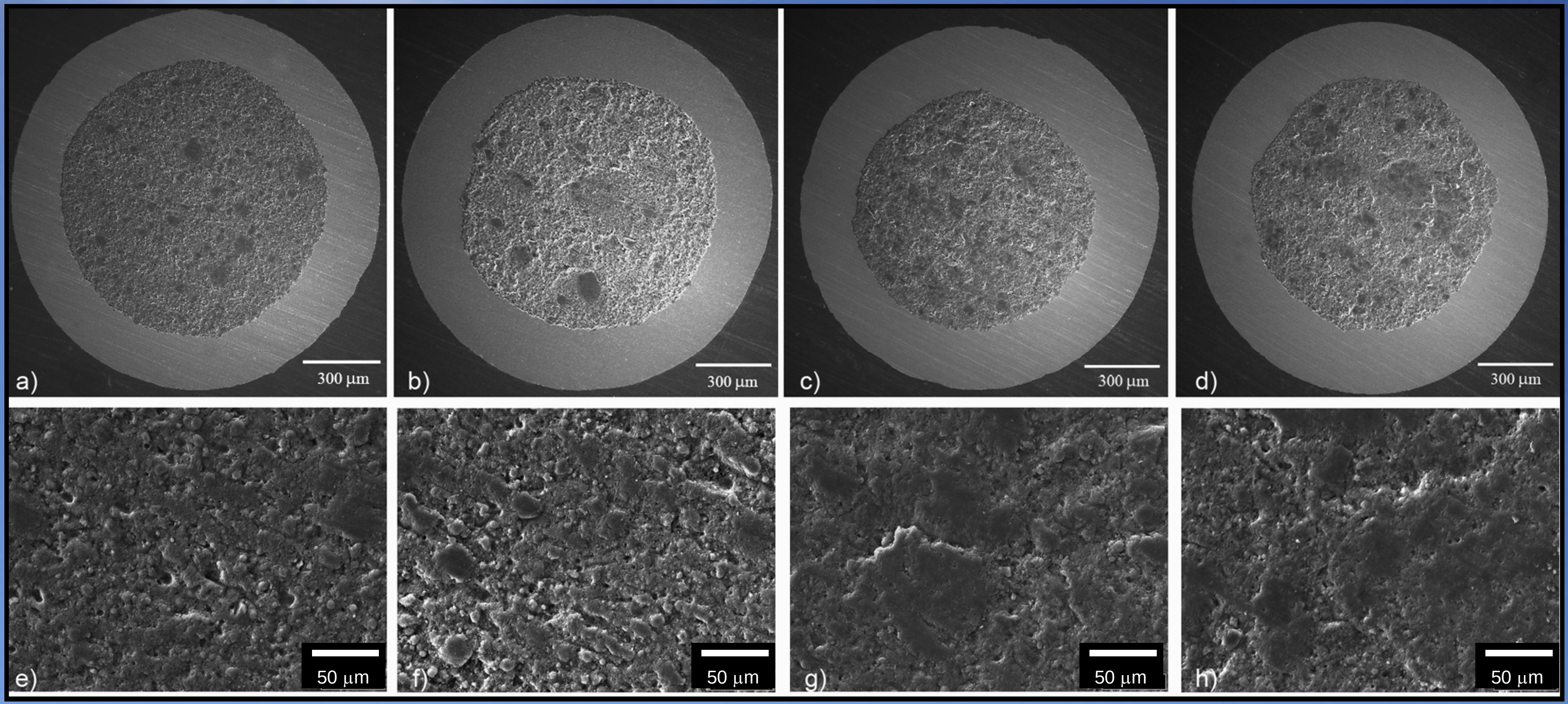
- ✓MgB2 milled with WC balls
- ✓Sheath materials
- ✓Intermediate treatments
- ✓Final annealing

XRD Characterization:

- ✓*Rietveld analysis*
- ✓*Presence of MgO: crystal size ~7-8 nm*

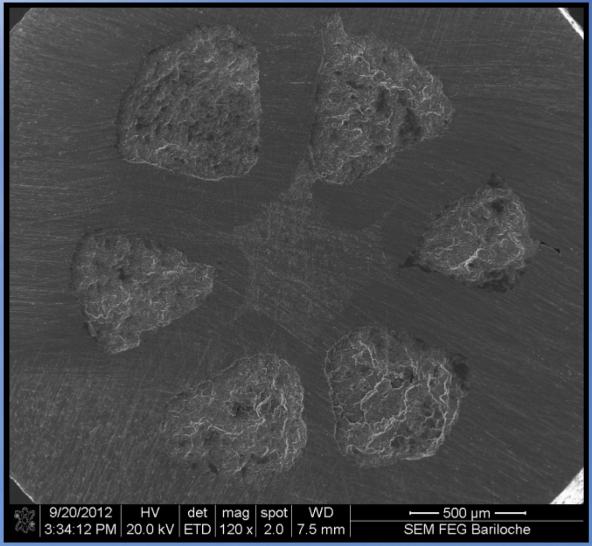


Sample	a (Å)	c (Å)	Strain XRD	Cristal Size XRD (nm)	R-Bragg
Powder	3.087	3.524	62	115	3.36
SS	3.086	3.523	70	91	2.38
SST1	3.083	3.526	45	58	3.4
CuT1	3.085	3.526	44	76	2.95

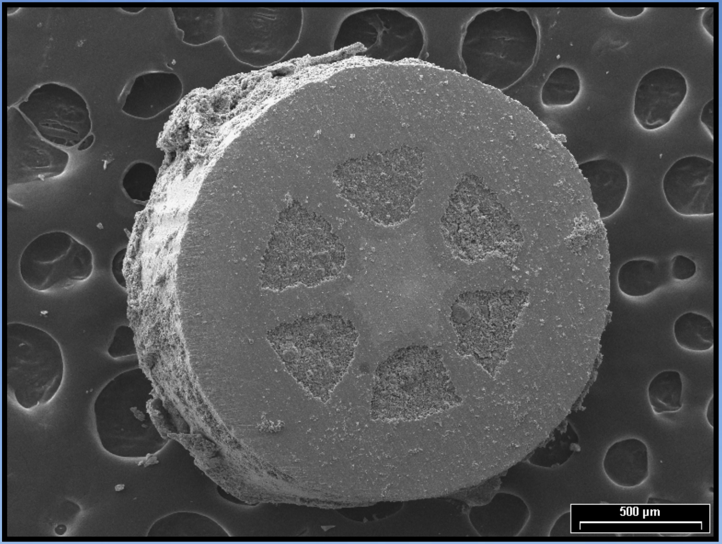


SEM of wires cross sections

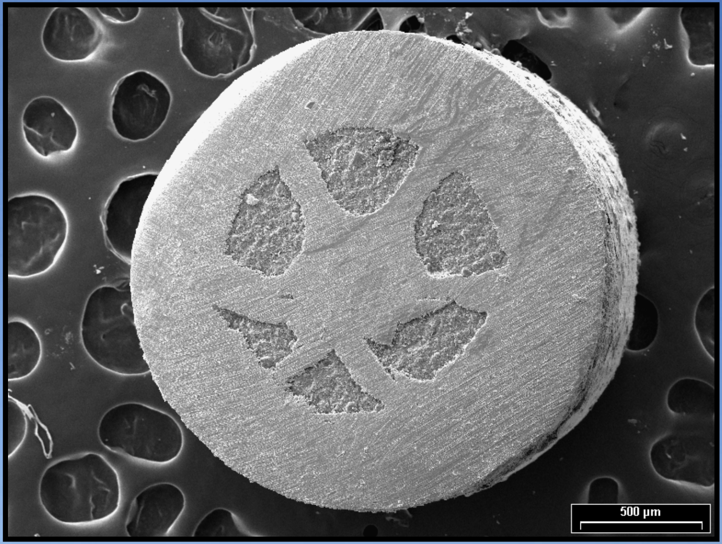
a) Cooper
b) Titanium
c) Stainless Steel 316L
d) Stainless Steel 316L (MgB2 + SiC)



SS 316L



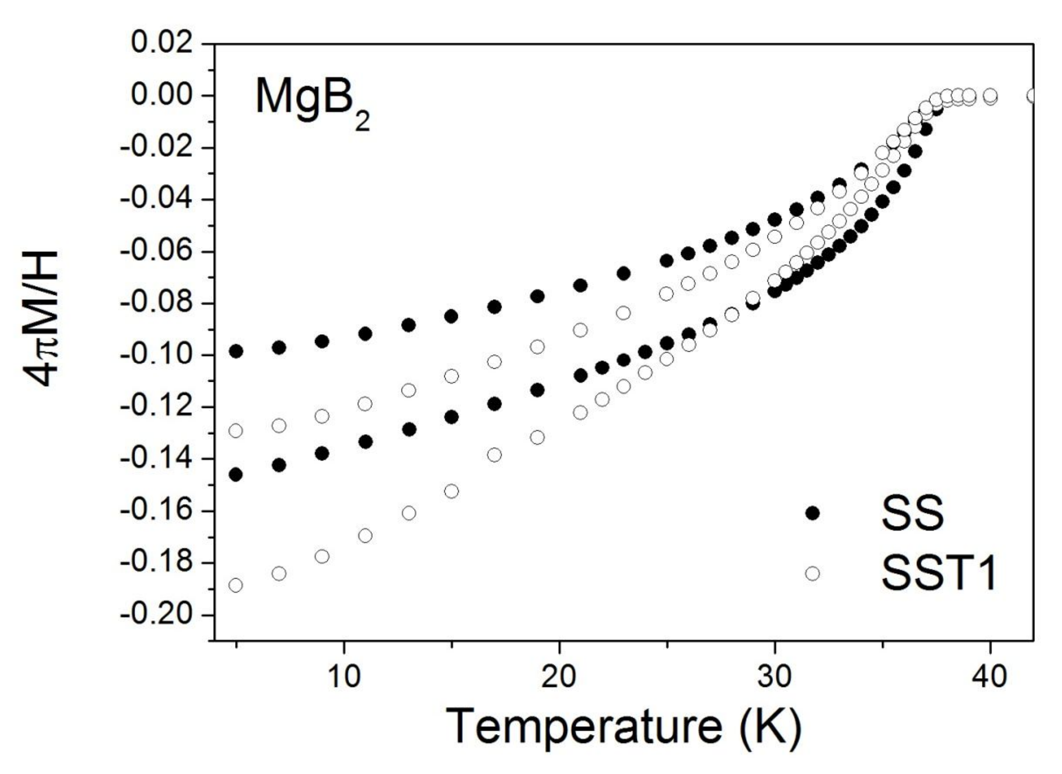
Titanium



Cooper

Superconducting properties: T_c

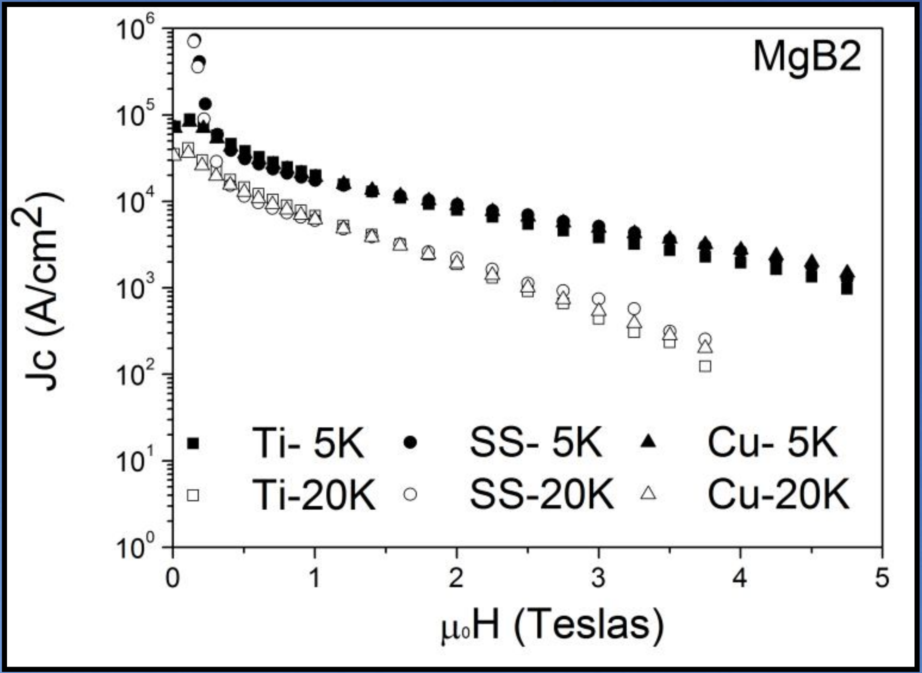
- Slightly below 38 suggests strain [A. Serquis et al Appl. Phys. Lett. 79, 4399 (2001)]

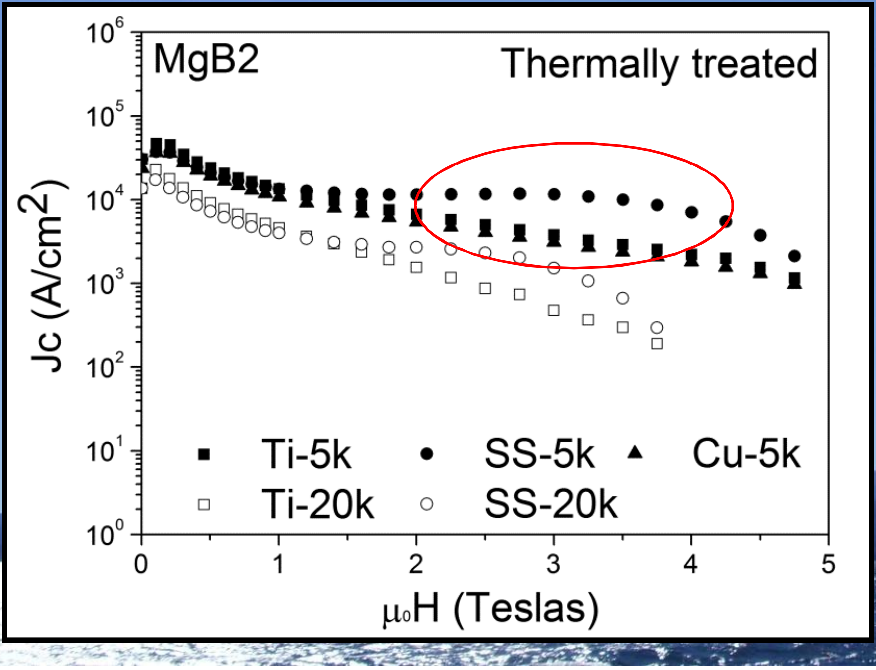


Superconducting properties: J_c

As-made wires

- ❖ Intermediate treatments: 500°C for Cu and Ti and 550°C for SS
- ❖ Slightly difference for samples before final heat treatment (even for Cu)





Wires after the final annealing

- ❖ Final annealing at 800°C during one hour under Ar atmosphere
- ❖ Particular improvement for SS: Matching field for defects?

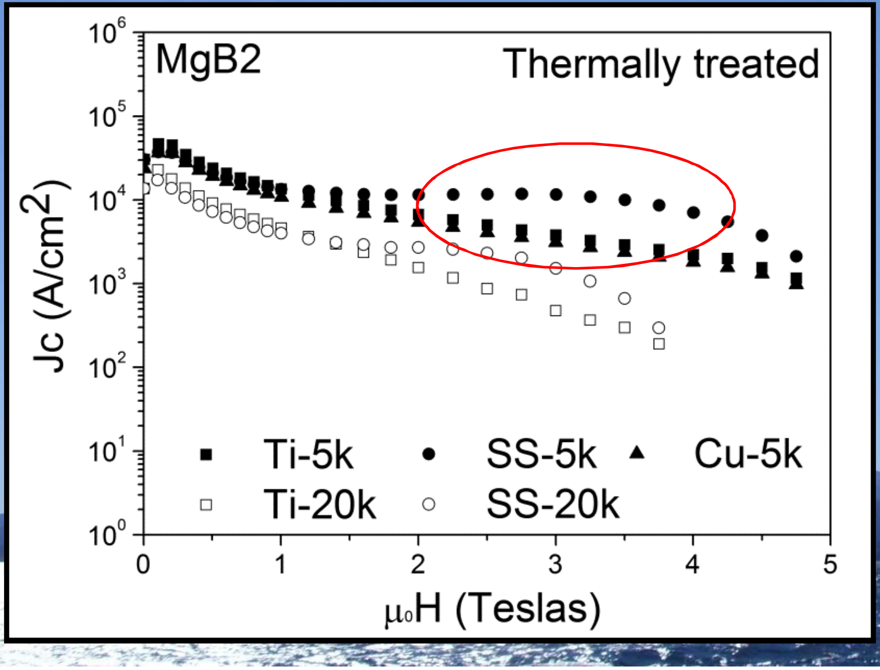
Superconducting properties: J_c

Matching field

❖Vortex distance = 1,075 (ϕ_0/B)^1/2

a (2T) ~ 35 nm, a (3T) ~ 29 nm,

Sample	T_c [K]	J_c (5K, 3T) [A/cm^2]	J_c (20K, 3T) [A/cm^2]
Cu	37.8	0.49	0.054
Ti	37.8	0.38	0.044
SS	37.8	0.51	0.074
SSSiC	37.3	0.58	0.081
CuT1	37.9	0.31	_
TiT1	37.9	0.38	0.047
SST1	37.5	1.15 x 10^4	0.151



Wires after the final annealing

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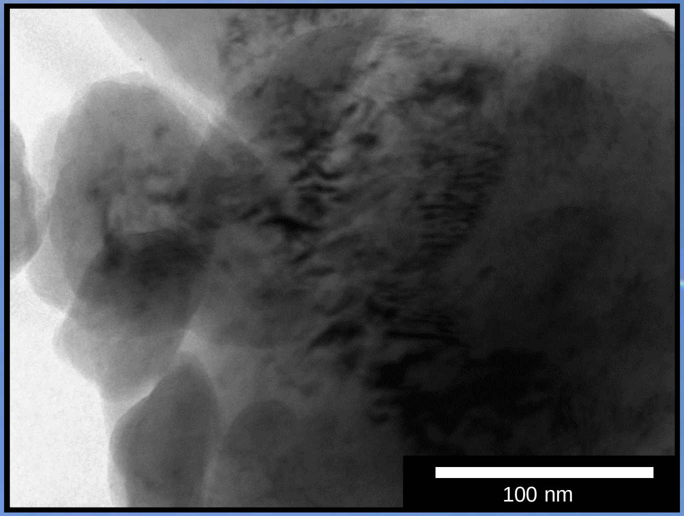
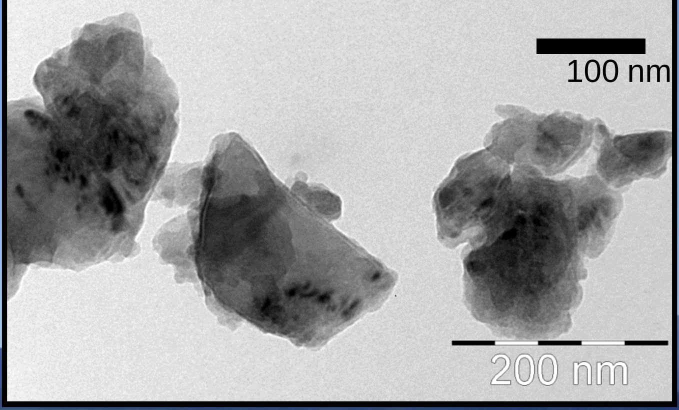
❖ Particular improvement for SS: Matching field for defects?

TEM : before final TT

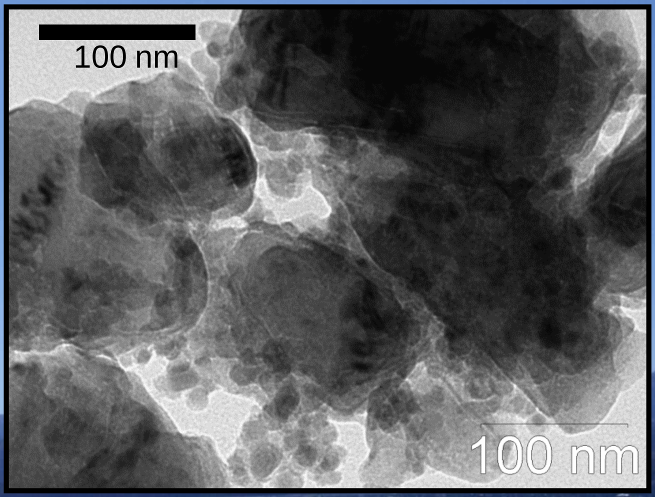


Initial MgB2 after milling

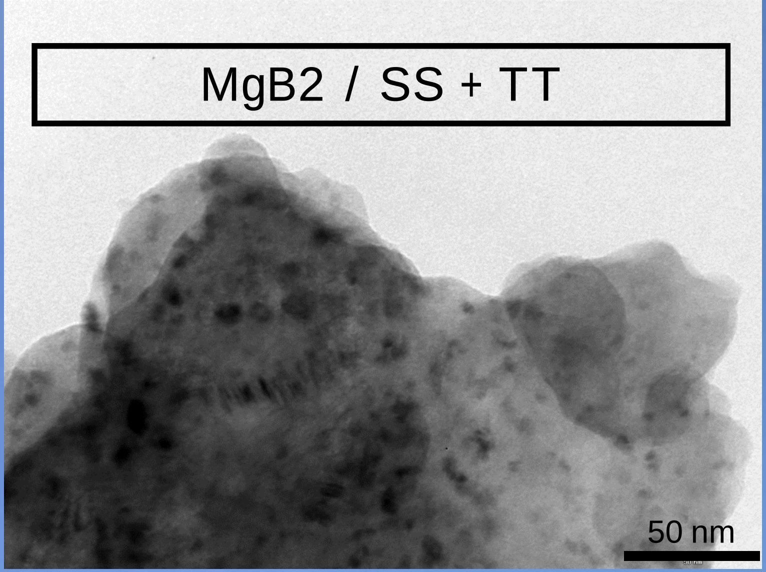
MgB2 I SS

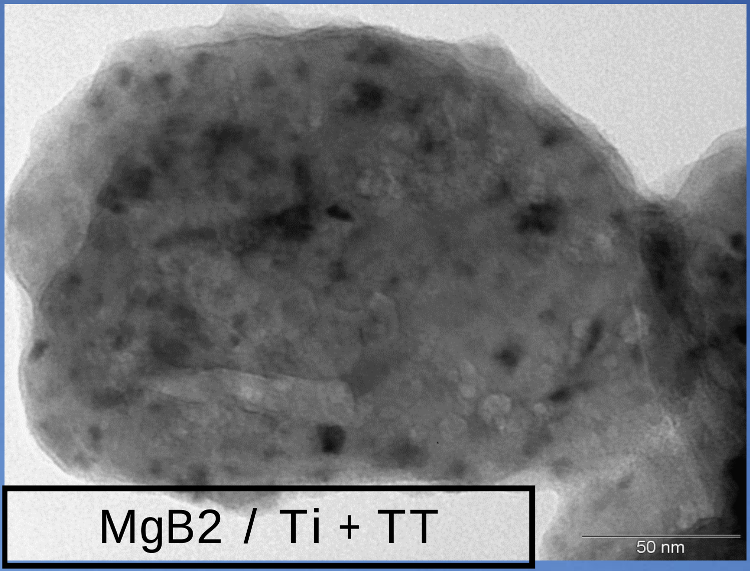


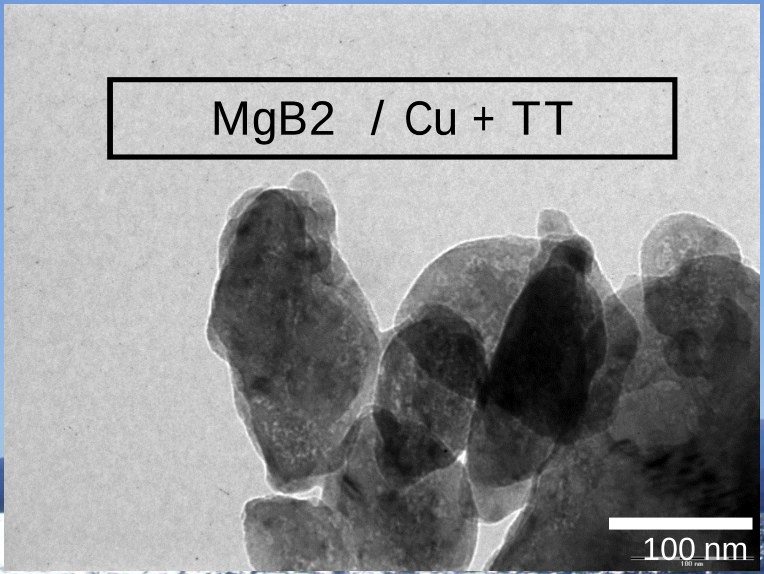
MgB2 + SiC / SS

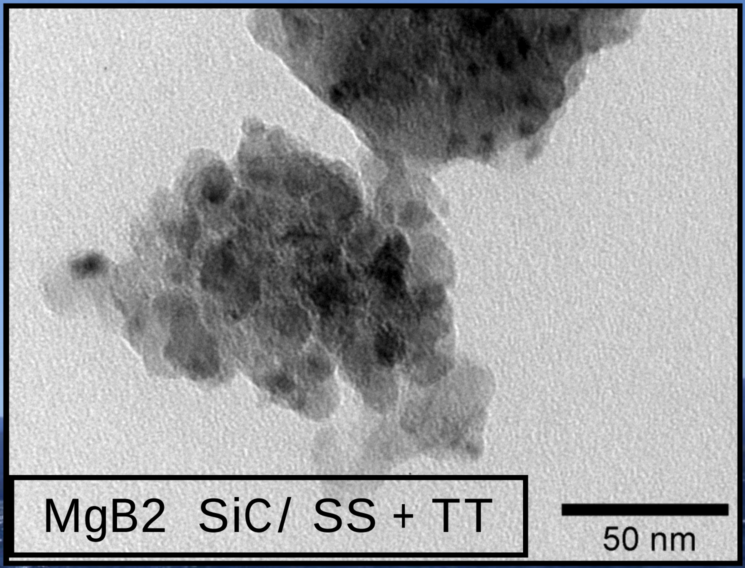


TEM: after final TT

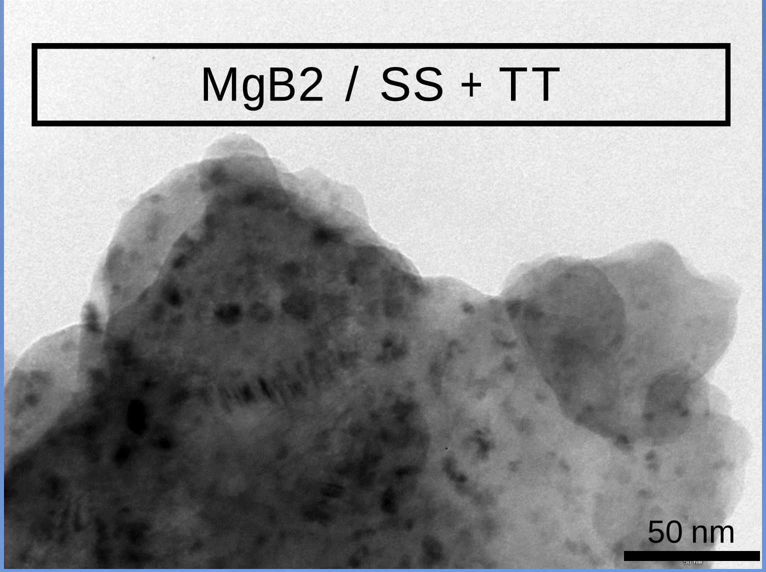

MgB2 / SS + TT

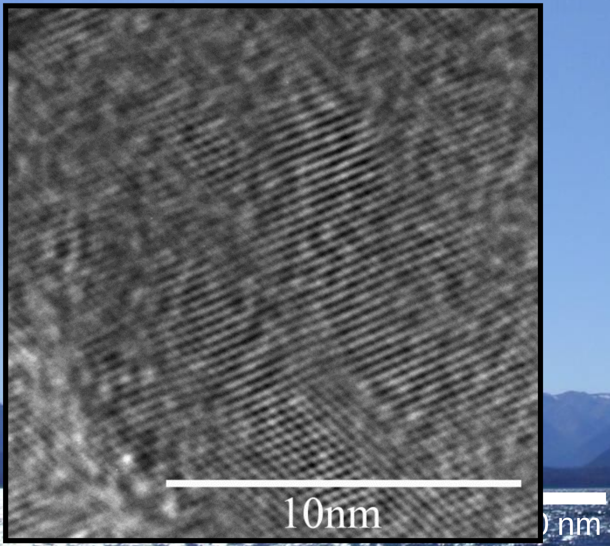

MgB2 / Ti + TT


MgB2 / Cu + TT


MgB2 SiC/ SS + TT

TEM: after final TT





- Vortex distance = 1,075 (ϕ_0/B)^1/2

a (2T) ~ 35 nm, a (3T) ~ 29 nm,

Mg(B, O)2 ?

Conclusions

- ✓ PIT with different sheath materials and appropriated intermediate thermal treatment (SS, Cu, Ti)
- ✓ Final treatment at 800 C is detrimental for Cu but beneficial for SS
- ✓ Possible presence of $Mg(B,O)_2$ precipitates with a density that corresponds to a matching field between 2 and 3 T

Work in progress

- ✓ Transport measurements
- ✓ Current transfer length
- ✓ New MgB_2 powder preparation method from boron mineral

11th European Conference on Applied Superconductivity
September 15-19 2013 - Genova, Italy
Eucas 2013

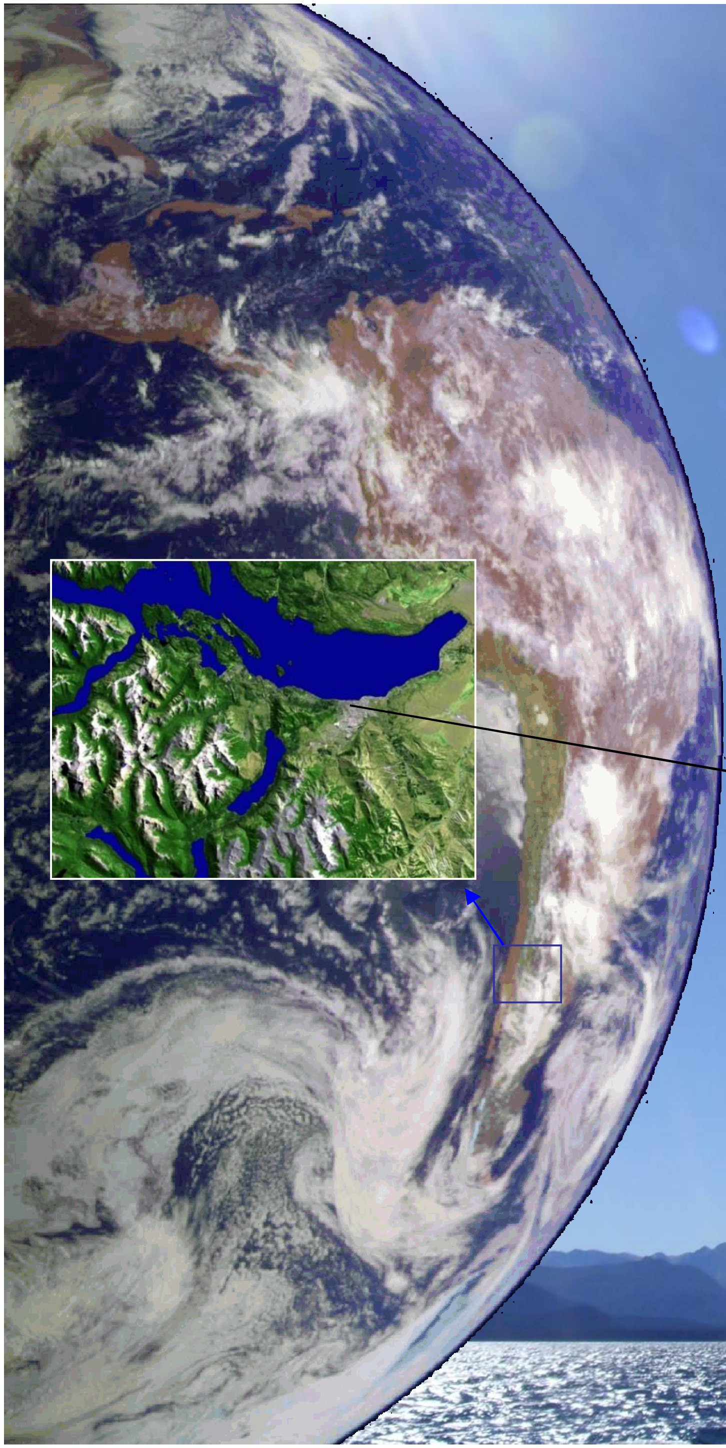
Thanks

18/06/13 ANB :: Imágenes de la nevada - Diario online

1 / 14 (foto lector Christian Platero)

QUESTIONS?

aserquis@cab.cnea.gov.ar



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