Some issues in HTS wire application

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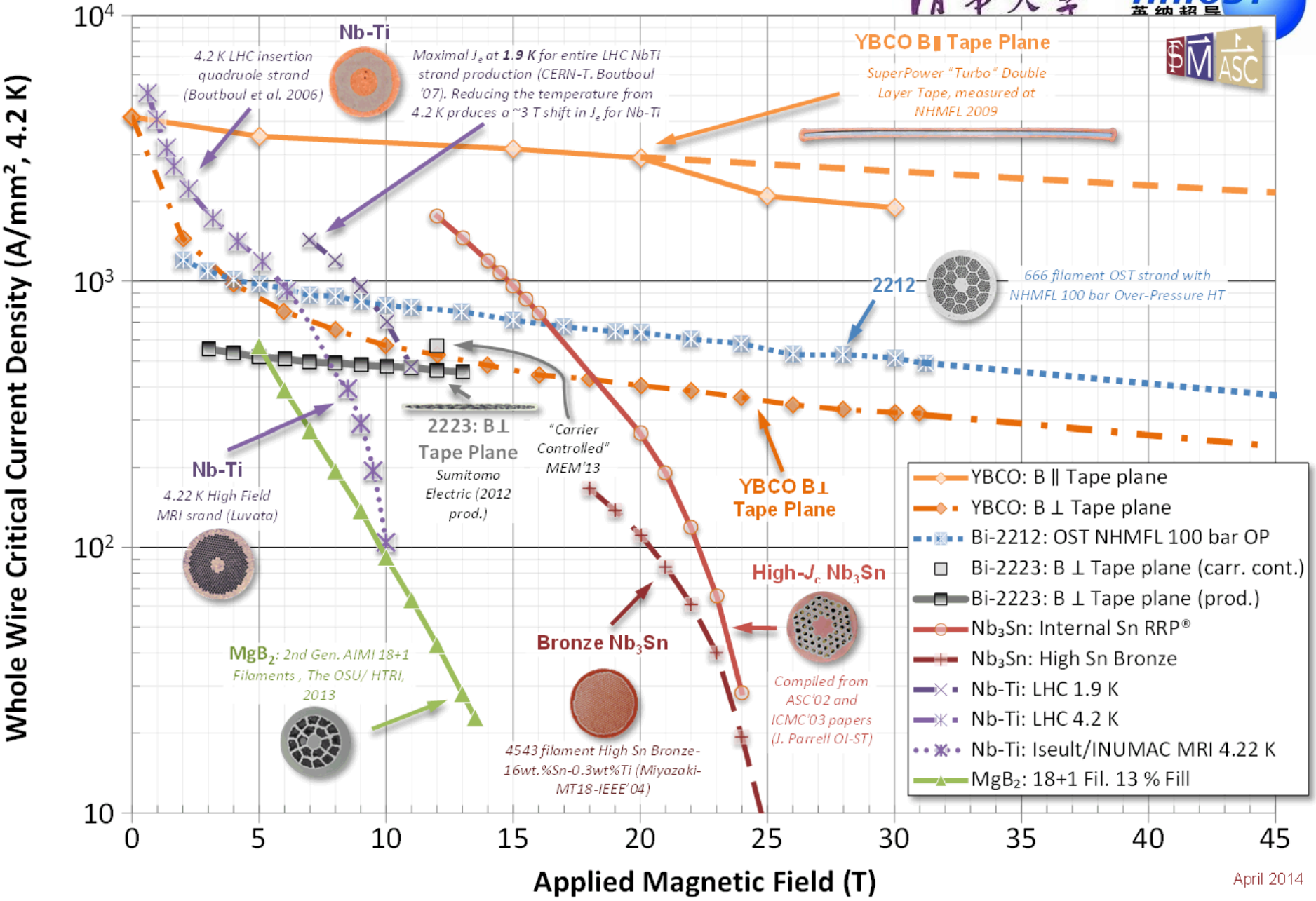
BSCCO wires, YBCO thin films, HTS rotating machines, Magnets, AC losses, Measurements,

Innova Superconductor Technology Co., Ltd. (InnoST)

Bi2223 tape and related application，

Bi2212 and MgB2 wire if need.


Whole Wire Critical Current Density (A/mm², 4.2 K)
Applied Magnetic Field (T)
10⁴
10³
10²
10
0
5
10
15
20
25
30
35
40
45
Nb-Ti
4.2 K LHC insertion quadruole strand (Boutboul et al. 2006)
Maximal J_c at 1.9 K for entire LHC NbTi strand production (CERN-T. Boutboul '07). Reducing the temperature from 4.2 K prduces a ~3 T shift in J_c for Nb-Ti
YBCO B∥ Tape Plane
SuperPower "Turbo" Double Layer Tape, measured at NHMFL 2009
2212
666 filament OST strand with NHMFL 100 bar Over-Pressure HT
2223: B⊥ Tape Plane
Sumitomo Electric (2012 prod.)
"Carrier Controlled" MEM'13
Nb-Ti
4.22 K High Field MRI srand (Luvata)
YBCO B⊥ Tape Plane
High-J_c Nb_3Sn
Bronze Nb_3Sn
Compiled from ASC'02 and ICMC'03 papers (J. Parrell OI-ST)
MgB_2: 2nd Gen. AIMI 18+1 Filaments , The OSU/ HTRI, 2013
4543 filament High Sn Bronze-16wt.%Sn-0.3wt%Ti (Miyazaki-MT18-IEEE'04)
YBCO: B ∥ Tape plane
YBCO: B ⊥ Tape plane
Bi-2212: OST NHMFL 100 bar OP
Bi-2223: B ⊥ Tape plane (carr. cont.)
Bi-2223: B ⊥ Tape plane (prod.)
Nb_3Sn: Internal Sn RRP®
Nb_3Sn: High Sn Bronze
Nb-Ti: LHC 1.9 K
Nb-Ti: LHC 4.2 K
Nb-Ti: Iseult/INUMAC MRI 4.22 K
MgB_2: 18+1 Fil. 13 % Fill
April 2014

Outline

1. **Some basic properties of HTS materials**
2. **Anisotropy of HTS wires**
3. **Mechanical properties of HTS wires**
4. **Other issues**

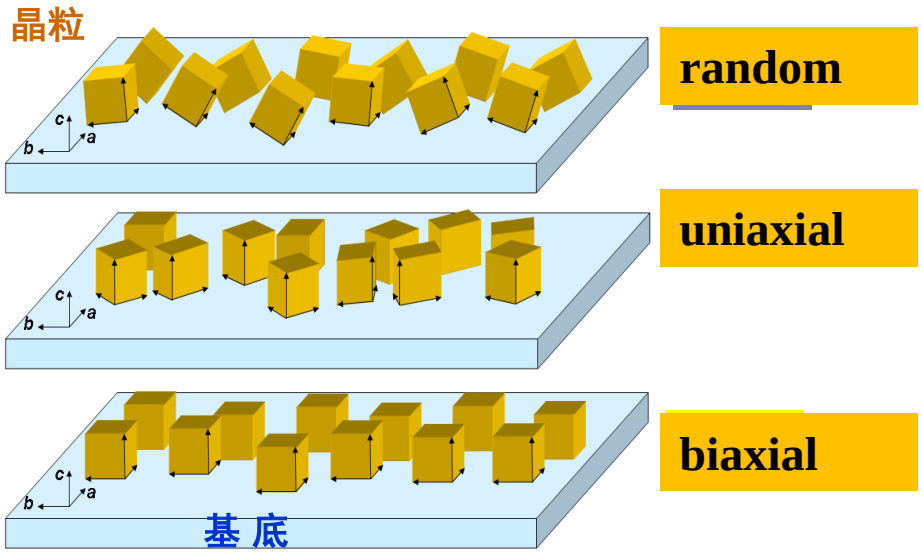
1. Some basic properties of HTS materials

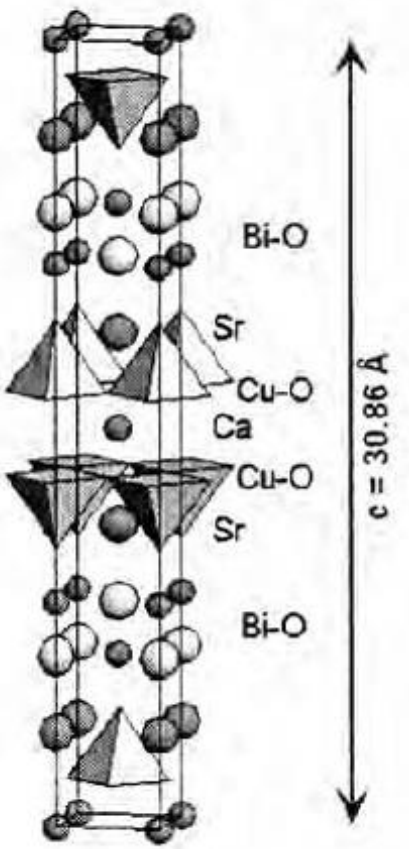
High T_c, H_c,

1. **Short coherence length, about one crystal lattice.**
2. **Layer structure**
   - **Connectivity,**
   - **Anisotropy**
3. **Ceramic oxides**
   - **brittle, cracks**

if we know, less difficulties.

2. Anisotropy of HTS wires





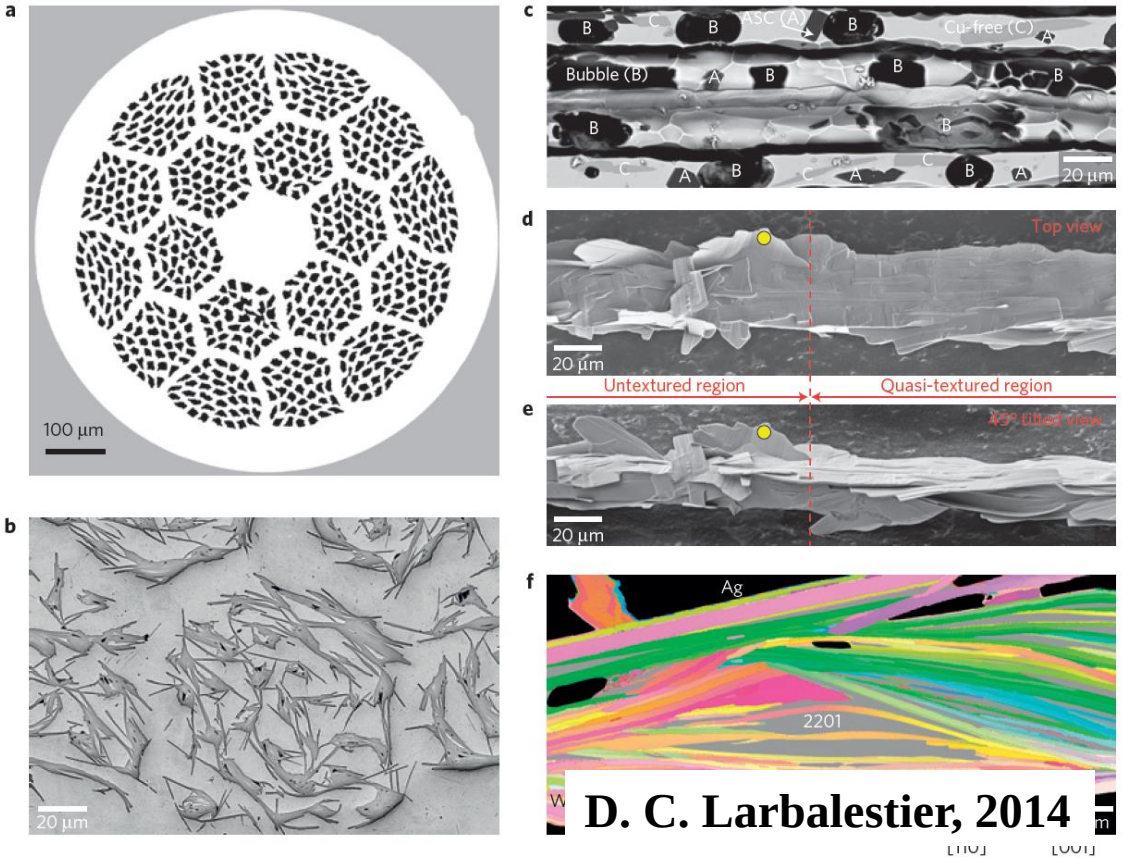
Grain boundary, grain alignment,

Uniaxial： Bi2212, Bi 2223

Biaxial： Re123

Bi-2212 round wire

Uniaxial filaments random orientated in the cross section area.

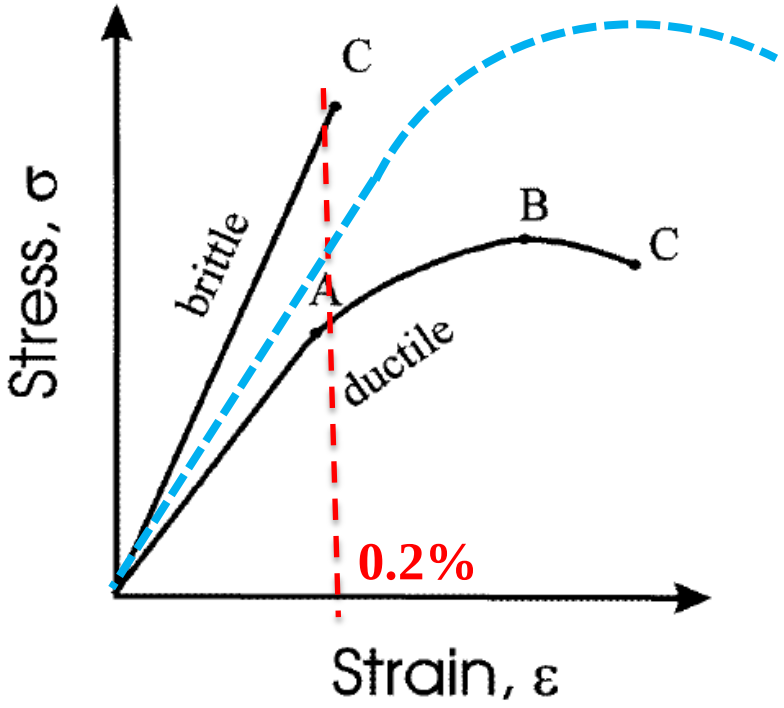


D. C. Larbalestier, 2014

If Re-123, Bi-2223 tapes narrow enough: round cable.

No foundamental but only techincal problems.

3. Mechanical properties of the HTS wires



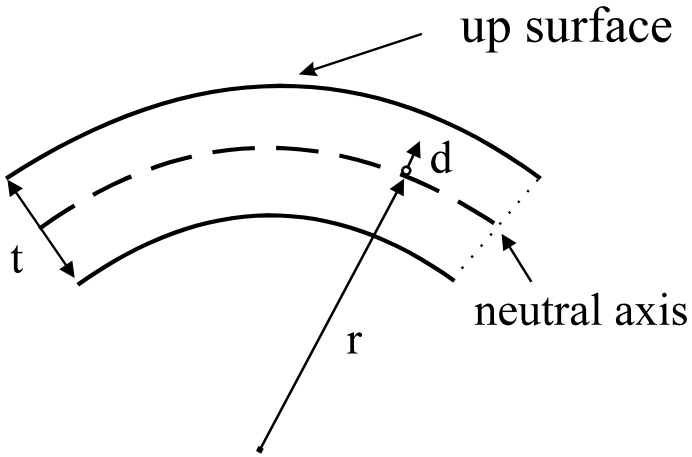
For HTS materials,

the critical tensile strain

is about 0.2% .

The 0.2% strain is the most important number when consider the mechanical properties of the HTS wires and the magnets!

Bending strain of the HTS wires



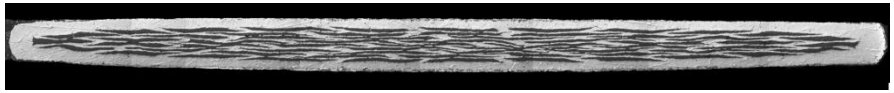
Bending strain
ε_b=d/r=t/2r=0.2%

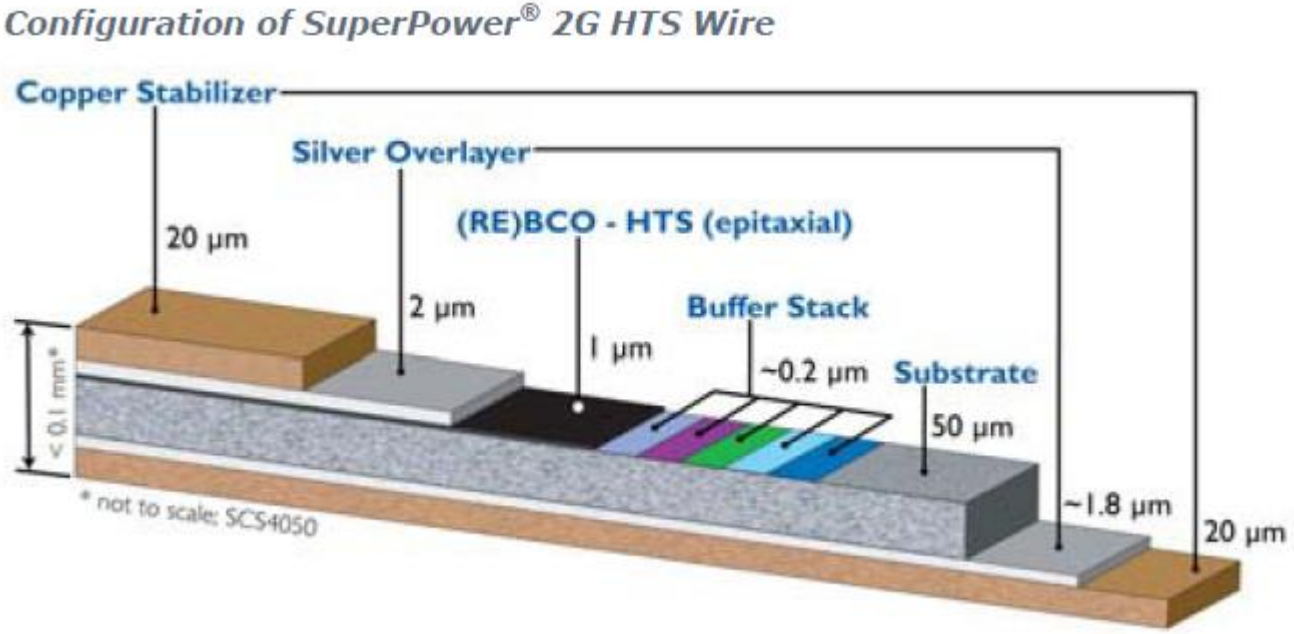
d: distance between the local point and the neutral axis.

If wire thickness=0.2mm,

Then the bending diameter:

2r=0.2mm/0.2%=100mm





Bending strain=d/r=0.2%,

d=50+20-(20+50+20)/2=25µm

r=25/0.2%=12.5mm

If the REBCO is in the center, r=about 1mm. Suitable for any coil

But….

For a Bi2212 wire

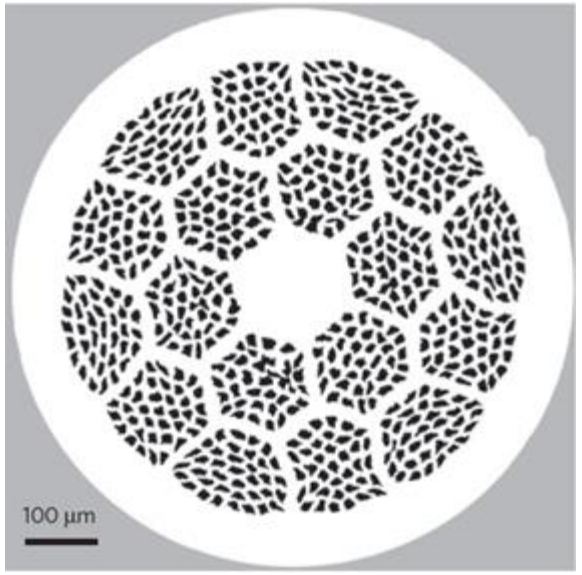
t=0.8mm,

t(Bi2212)=0.65mm

Bending diameter

2r=0.65/0.2%=325mm

W&R should be used;



The strength of Bi2212 tape

400 MPa

Problems in cooling (temperature cycling)

Delamination problem--- do not talk hear

The thermal expansion coefficient (x10^{-6}/K, not very precise)

Ag: 20.5 , HTS: 11, stainless steel: 15.

Cooling down from room temperature to 4K, the strain deference

Bi-2212/ Ag is about 0.2% .

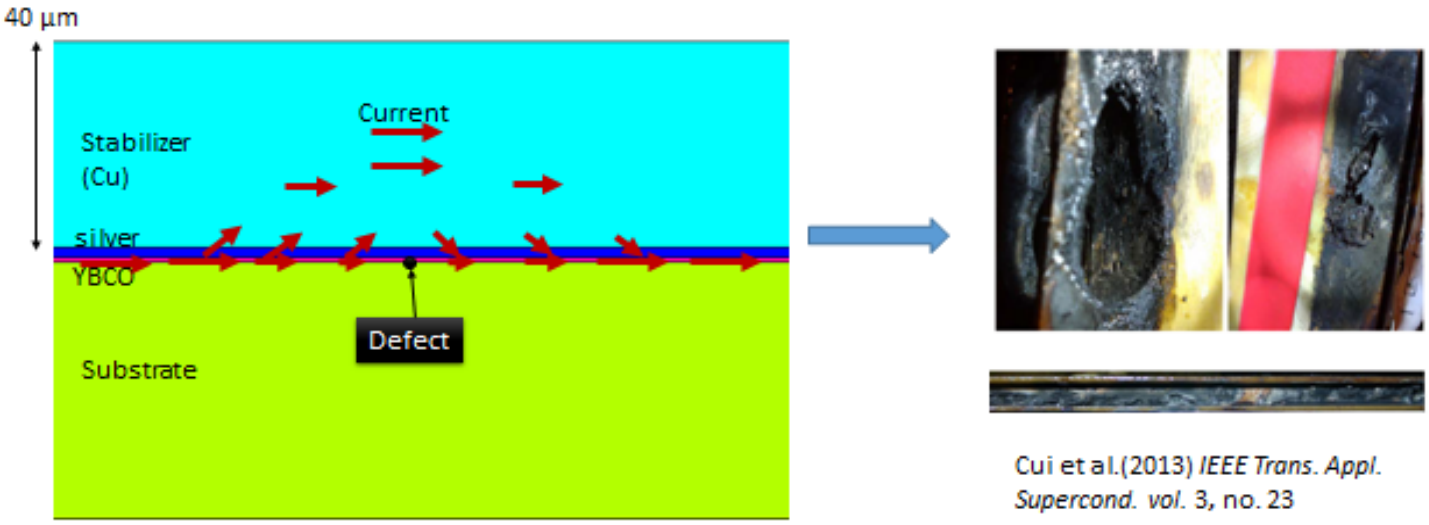
Re123/SS is about 0.1%.

Ag is soft but steel is strong.

Cracks in the superconducting layer might develop during thermal cycling.

HTS ceramic → defects

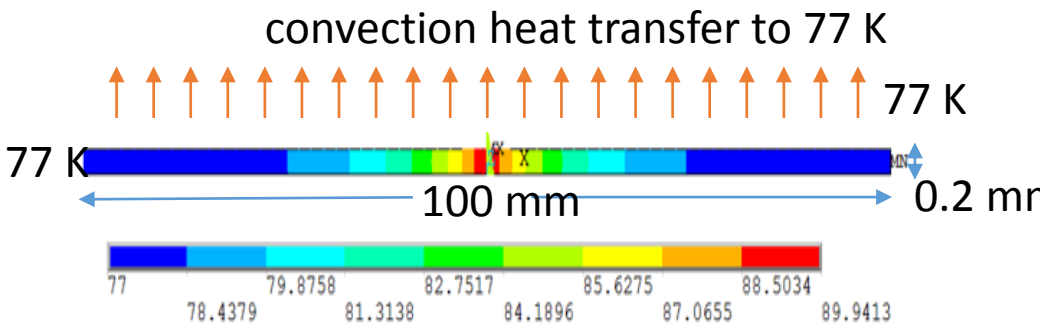
Instability in HTS coils caused by the tape defects



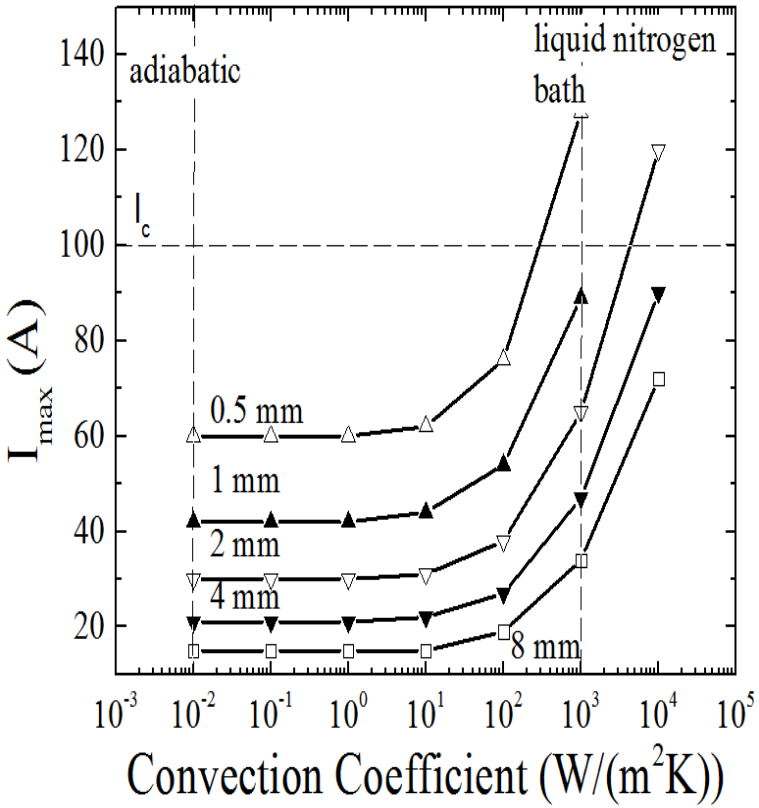
Cui et al.(2013) *IEEE Trans. Appl. Supercond. vol.* 3, no. 23

Quenching or melting?

For a single tape in different thermal condition



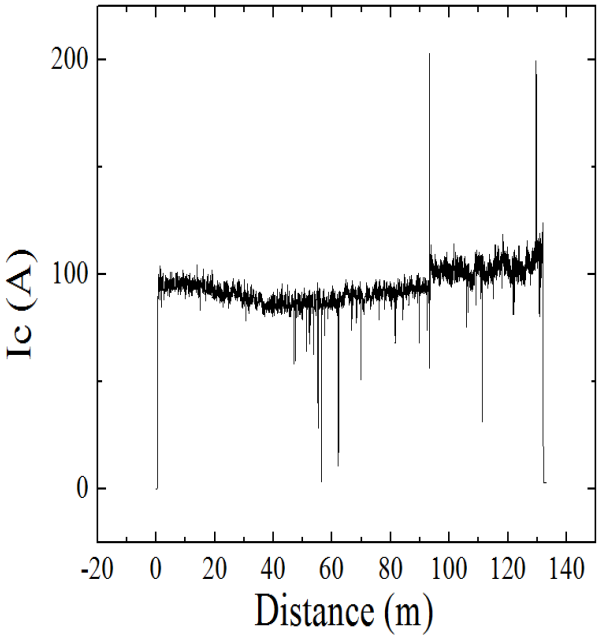
Temperature distribution for a single tape with a de



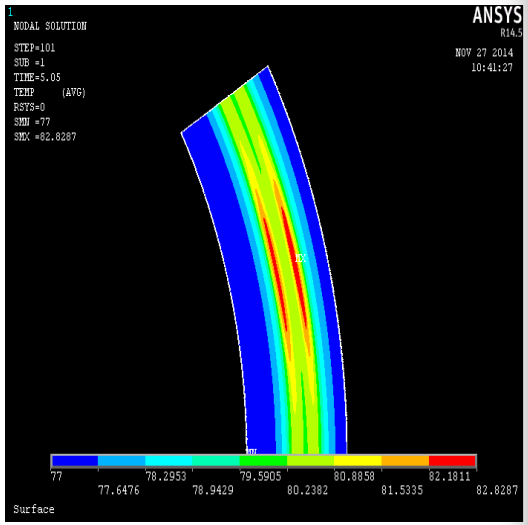
The maximum current to keep the temperature below 92 K

How to Prevent

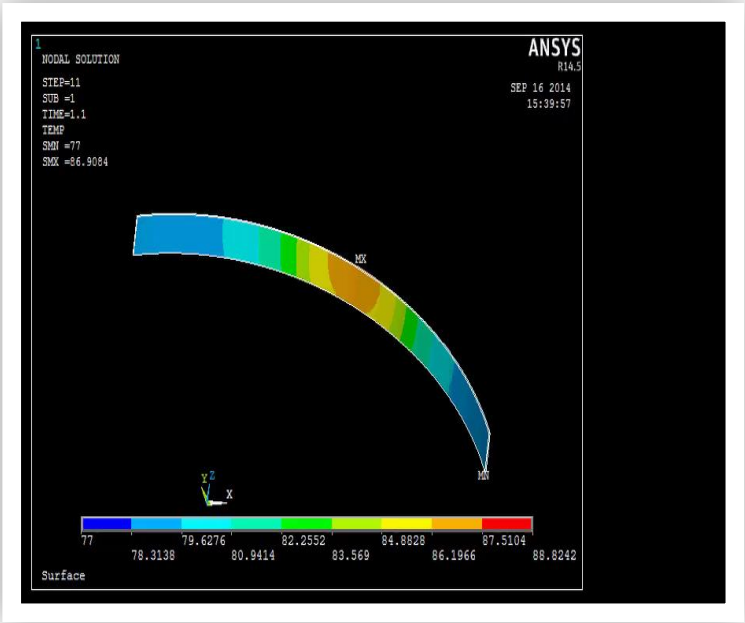
1. Continuous measurement



2. Detailed coil measurement



3. Setting the current limit based on the thermal condition



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4. Other issues

- **Superconducting properties will depend on the oxygen content ,**
- **influence by temperature.**
- **< 300 ° C could be safe.**

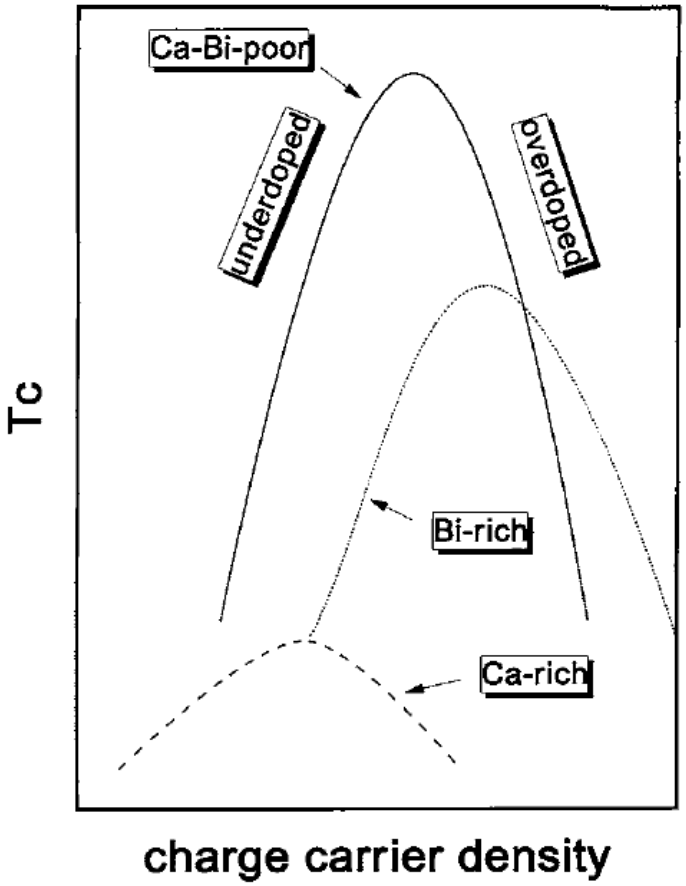
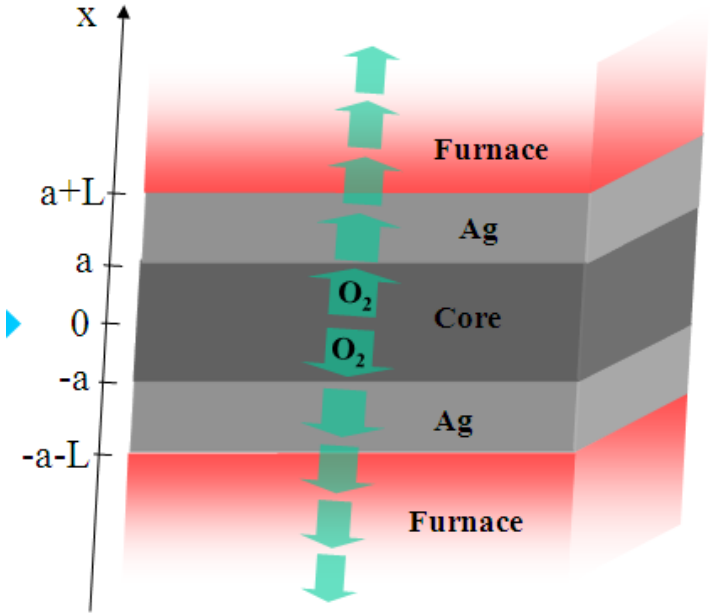
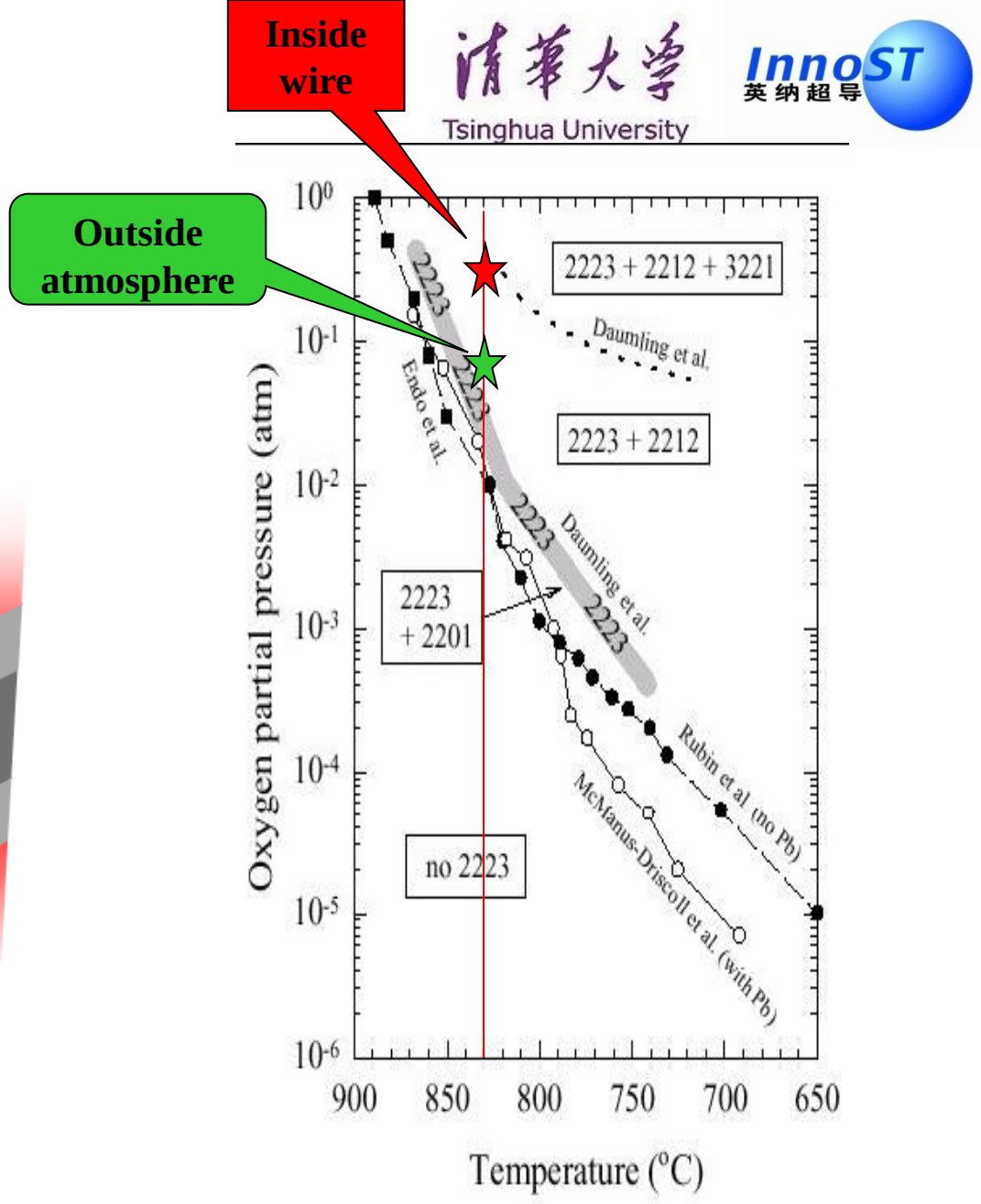


Figure 11. T_c versus the charge carrier concentration of Bi-based superconductors.

P. Majewski, 1997

Bi-2212 usually is W&R





J. Parrell, 1996.

Summary

1. HTS short coherence length, layer structure, ceramic oxide.
2. Connectivity, anisotropy, brittle, cracks.
3. Critical strain of 0.2% is important.
4. Defects in PIT/Ag wires and Re-123 tape.
5. HTS are the materials for high field application.
6. Some technical problems should be solved before making the big magnets.

Thanks!

Bi-2223 tapes for Delivery

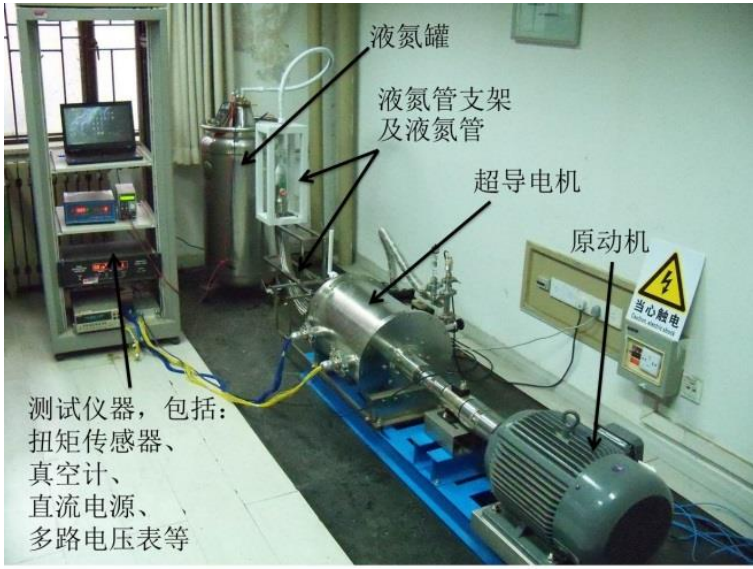
HTS coils for motor

Coils for 220 kV HTS
Fault Current Limiter

35kV/2kA, 33.5 m HTS cable 3 phases, 2004.

220kV FCL, Tianjin, 2012.

1MW HTS motor for ship propulsion



5kW HTS-PM generator prototype for wind turbine

Participating ITER Project,
Bi2223/AgAu tape for current leads.

12kA HTS current leads for JINR