Microstructure and Jc improvements in overpressure processed Ag-sheathed Bi-2223 tapes

Yongwen Yuan, Jianyi Jiang, Xueyu Cai, Satyabrata Patnaik, Matt Feldmann, Anatoly Polyanskii, Eric Hellstrom and David Larbalestier

University of Wisconsin-Madison

Yibing Huang

American Superconductor Corporation

Bob Williams

Oak Ridge National Laboratory

Support from DOE-EERE and partial facilities support from NSF-MRSEC

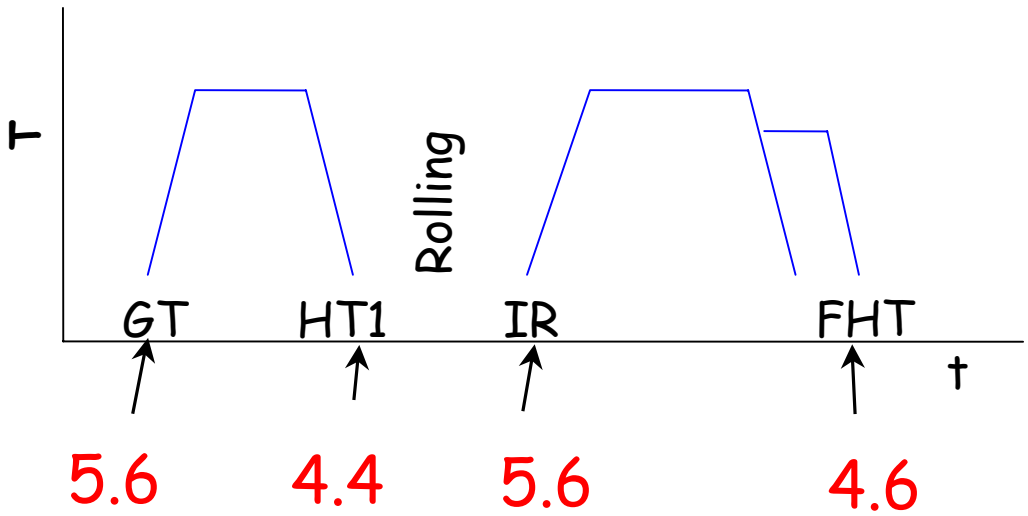
ASC 2002, Houston, TX

University of Wisconsin
Applied Superconductivity Center

Overview

- What is overpressure (OP) processing and why use it?
- OP improves microstructure
- OP increases Jc
- Summary

Density varies through multi-step 2223 process



Full density 6.3 g/cc

Jiang et al. SuST 2001

- Density decreases as 2223 forms
- Rolling increases density
- Core can dedensify in final heat treatment
- 10-30% porosity exists in best multifilament tapes
- Cracks caused by IR never completely heal

What is overpressure (OP) processing?

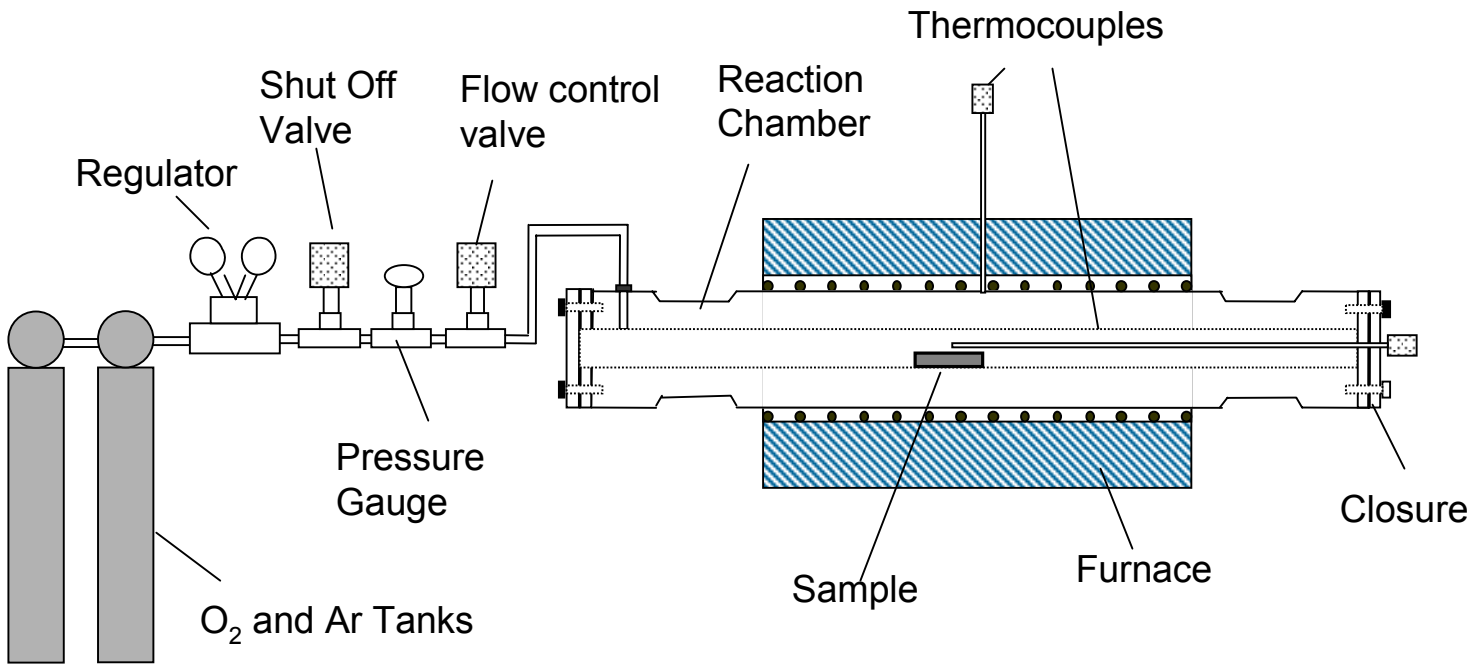
Applies isostatic pressure to compress samples

- OP processing is a variant of hot isostatic pressing (HIP)
- Mixture of inert gas and O_2
- Inert gas applies pressure <200 atm
- pO_2 sets thermodynamic condition needed to form 2223 pO_2 = 0.075 atm

Ultimate Goal: 1 deformation/sinter (1DS) process

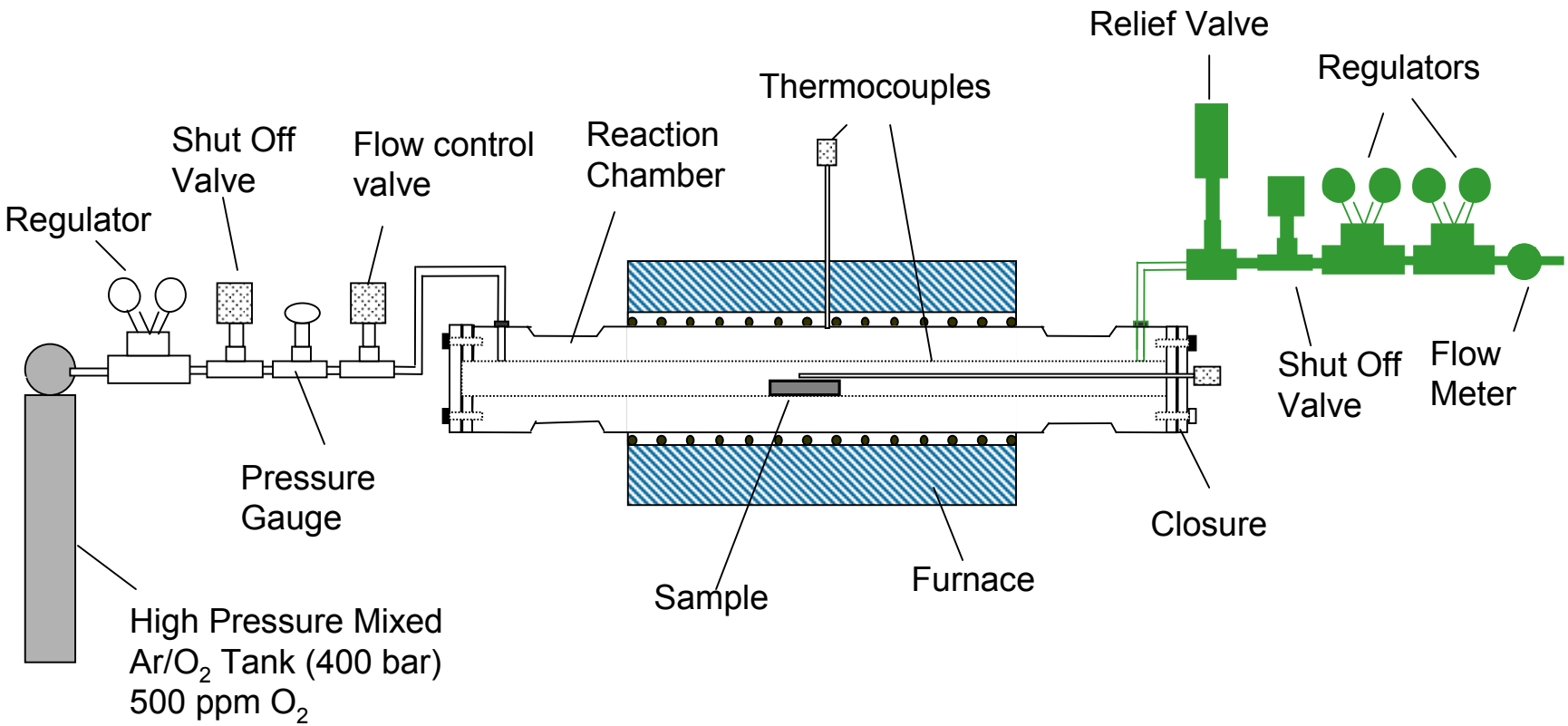
Overview of ORNL static OP system

Easy to change initial P_{total} and pO_2, but gas is not replaced, P_{total} and pO_2 change during run

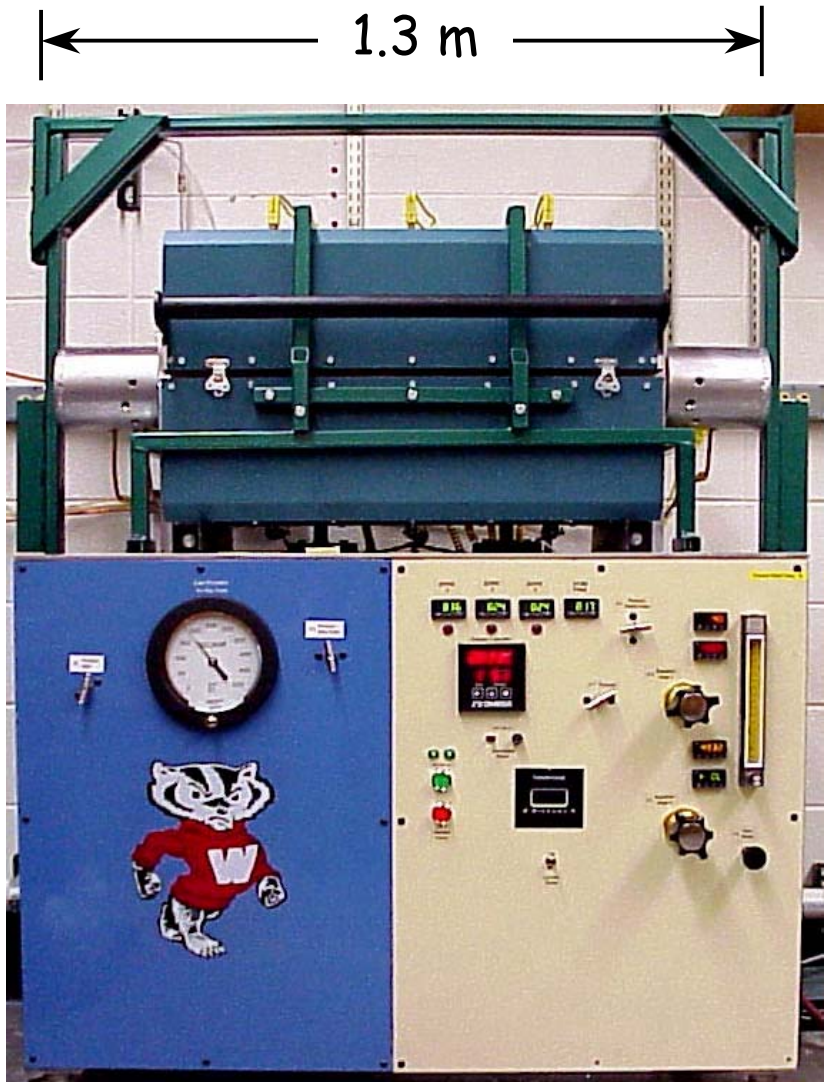


Overview of UW flow OP system

Gas continuously replaced during run;
P_{total} and pO_2 remain constant



UW flow OP system, 900°C, 200 atm



University of Wisconsin
Applied Superconductivity Center

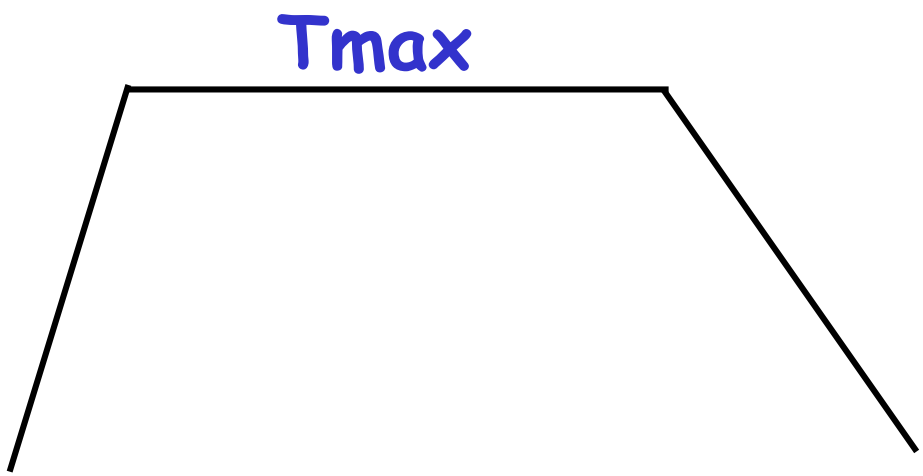
Where to begin with OP?

T_{max}, P_{total}, and pO_2 are the most important OP parameters

- Use simple HT schedule to optimize T_{max}
- Modify J.Jiang's 1 atm processing schedule for OP
- Address pO_2 uncertainty in OP gas mixture pO_2 = 0.075 to 0.10 atm at 148 atm

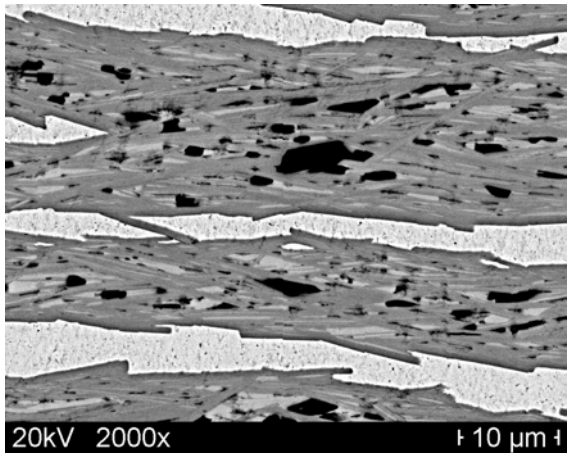
Simple heat treatment to optimize Tmax

P_{total}=148atm, pO_2=0.077atm (design)

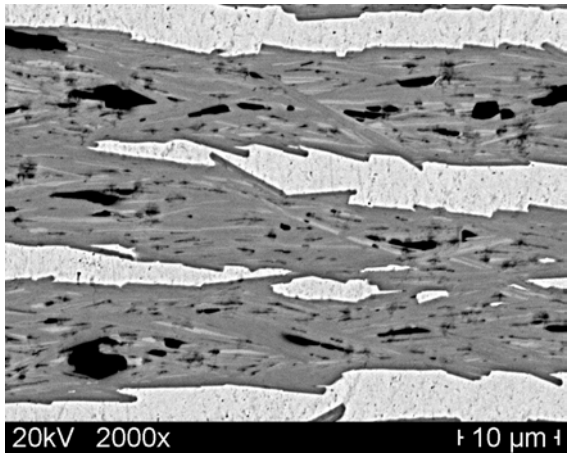


Microstructure as a function of Tmax, 148atm

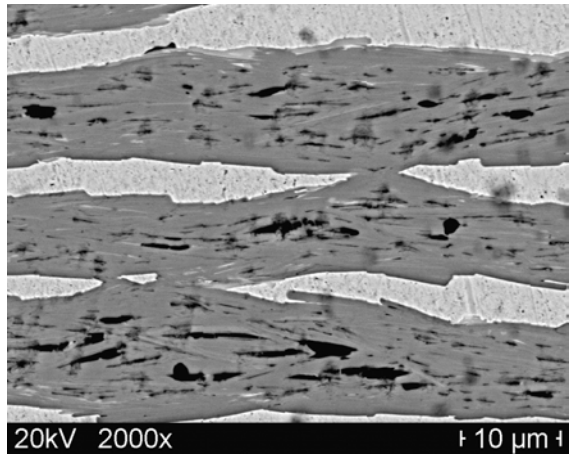
804C



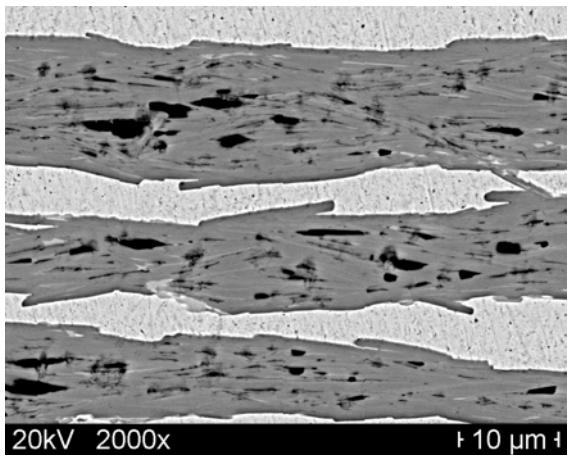
808C



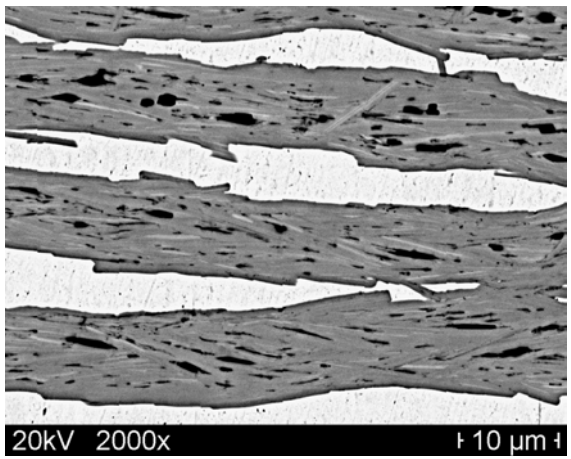
812C



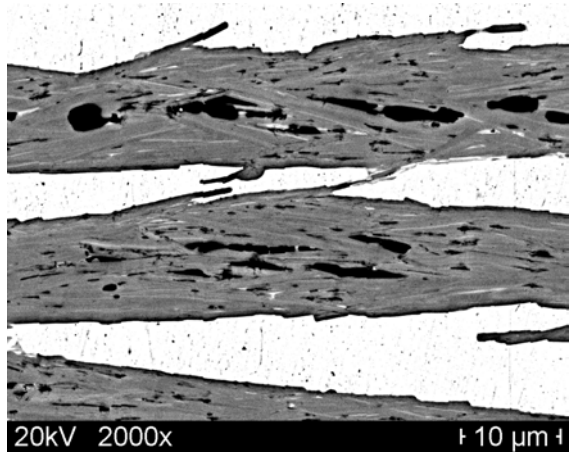
816C



820C

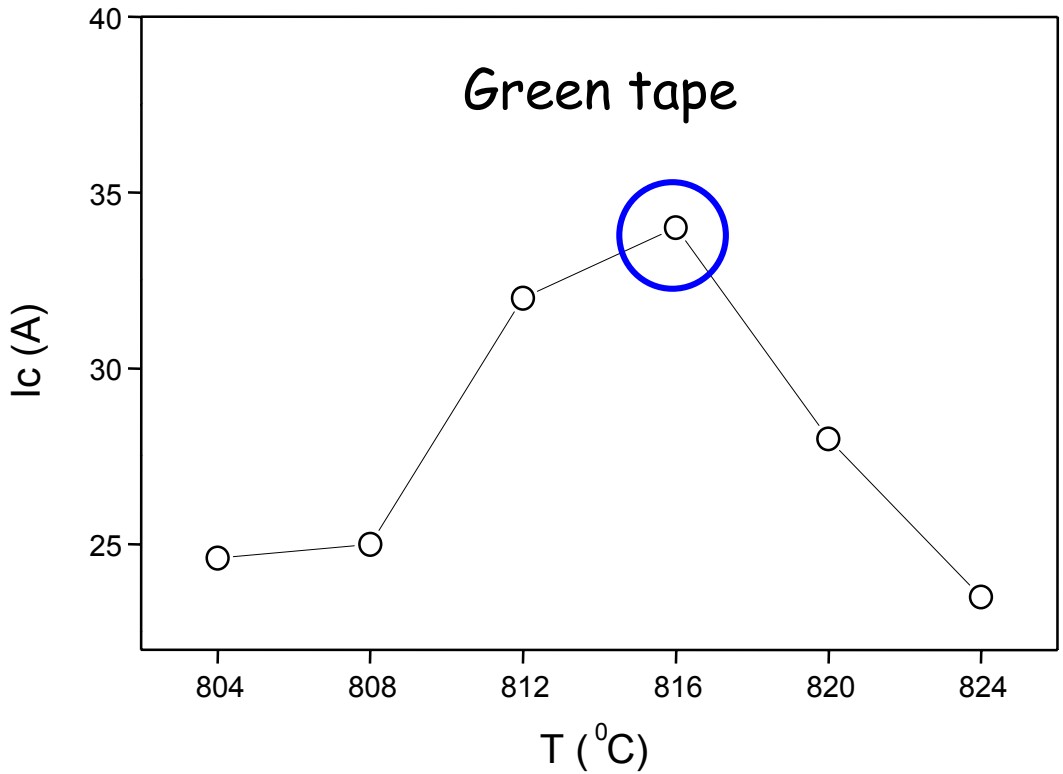


824C



University of Wisconsin
Applied Superconductivity Center

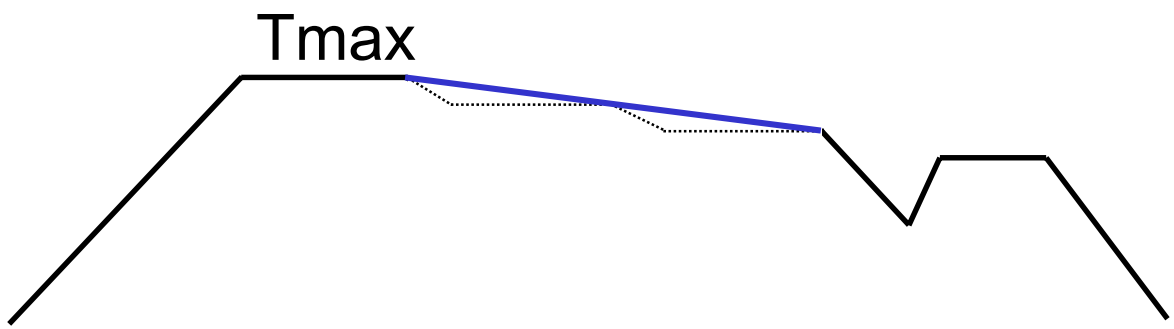
Ic varies with temperature – OP 148 atm



OP thermal process

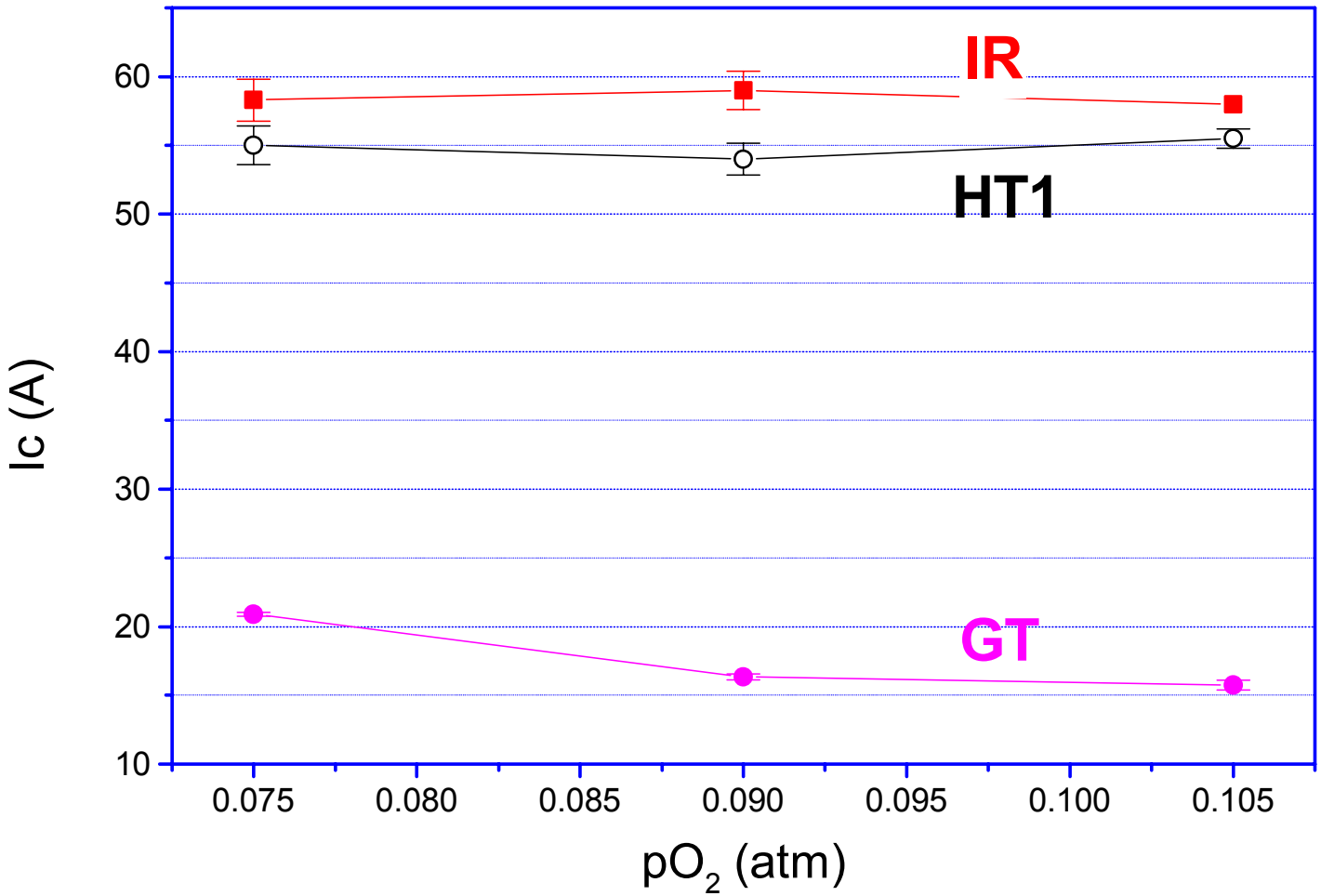
Simplified the 1 atm HT for OP processing

P_{total}=148 atm, pO_2=0.077 atm (design)



See Jiang – 2MM04
Tuesday 4:00pm

At P_{total} = 1 atm, pO_2 has small influence on HT1 and IR, some on GT,



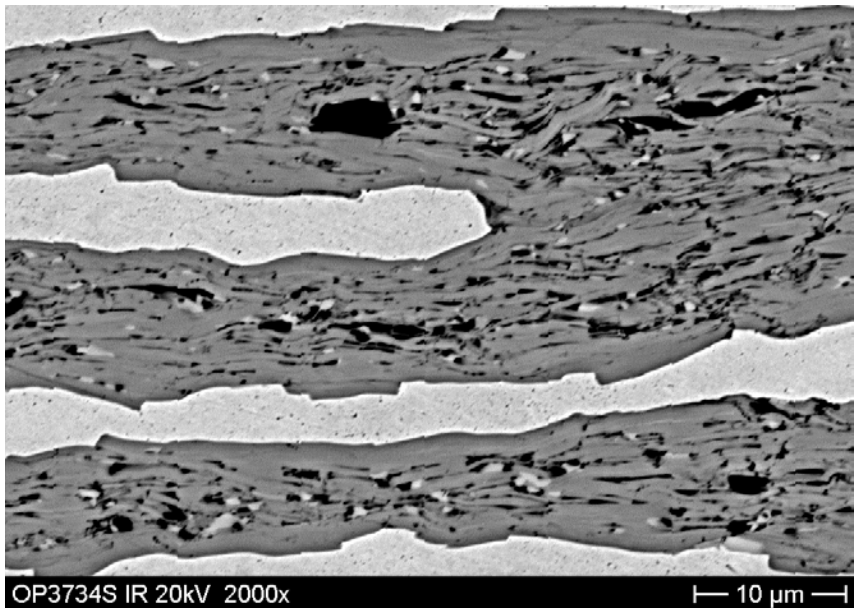
OP improves microstructure

- Densifies filaments
- Removes porosity
- Heals deformation cracks

OP removes porosity and heals cracks

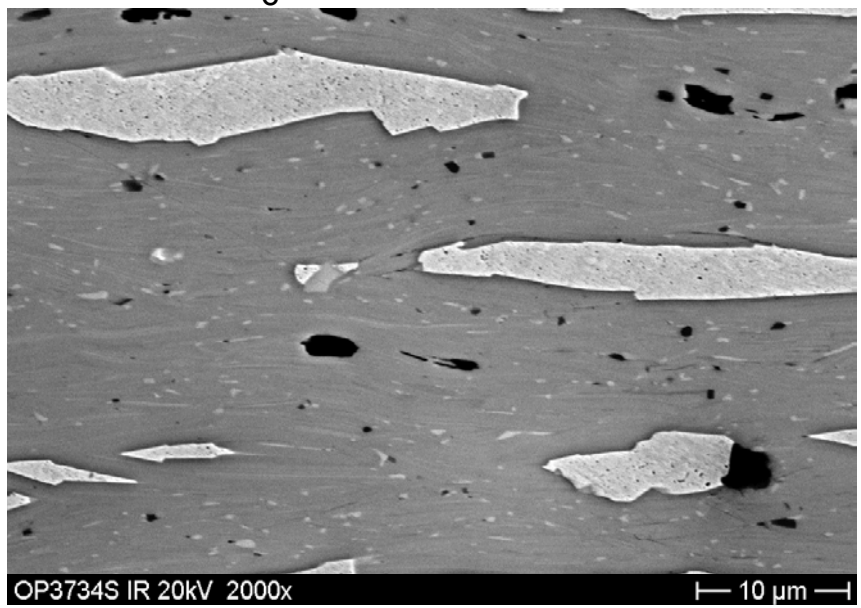
1atm, multifilamentary IR tape

J_c = 33.5 kA/cm^2

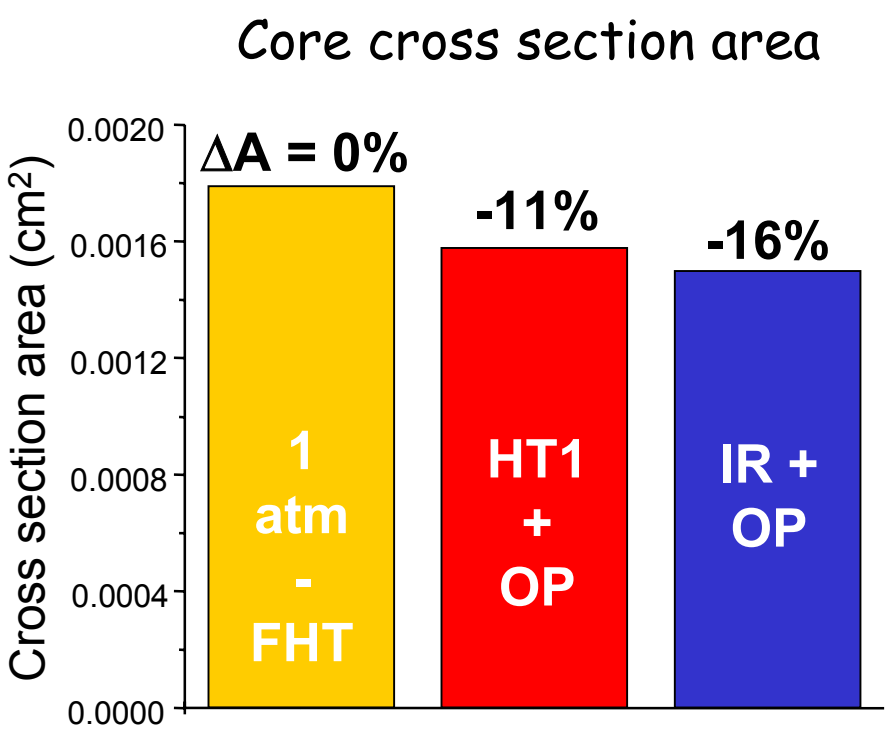


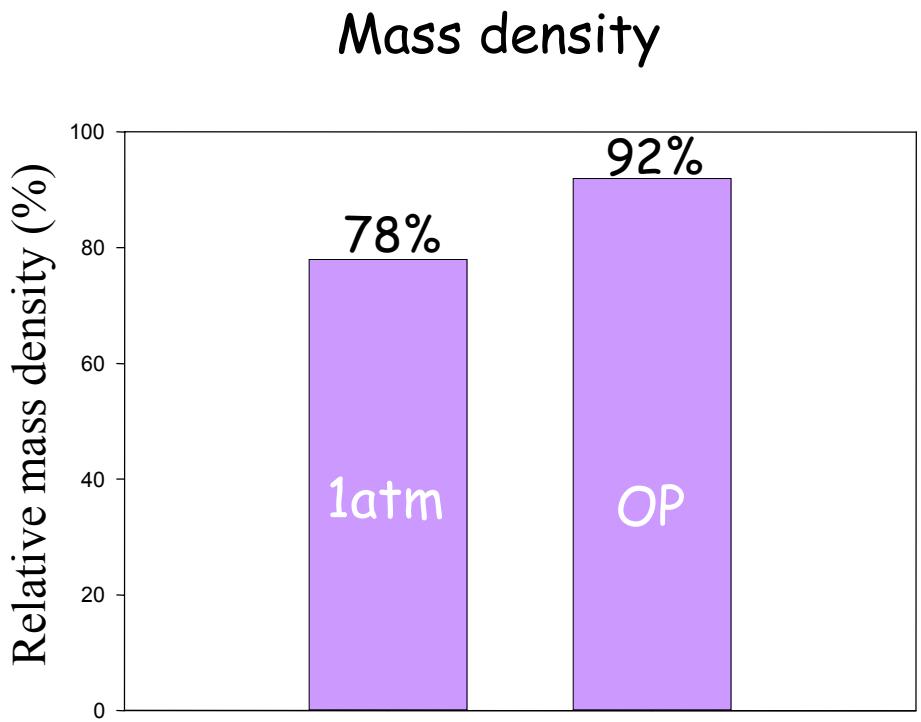
148atm, multifilamentary IR tape

J_c = 58.7 kA/cm^2



OP densifies BSCCO filaments



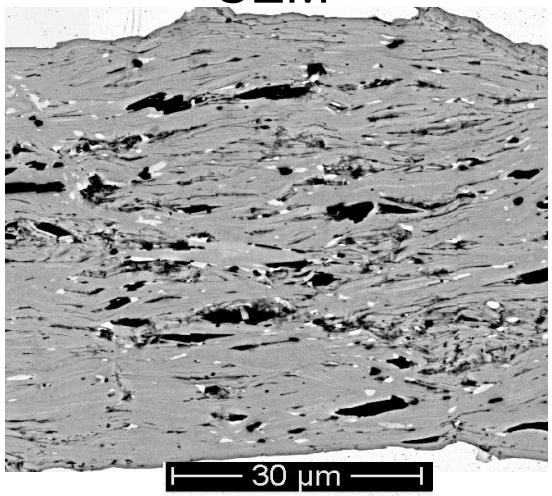


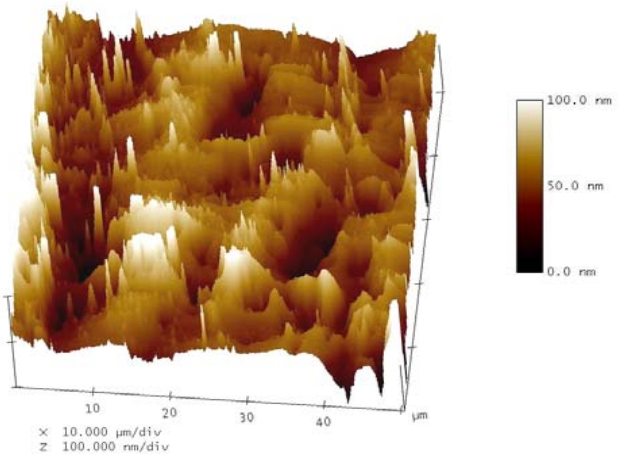
AFM micrographs show lower porosity in OP tape

SEM

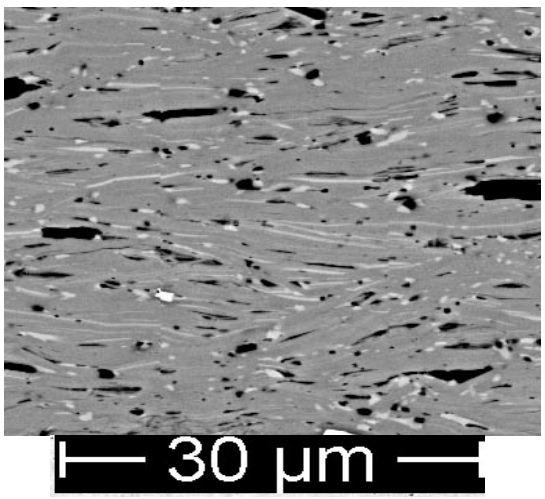
AFM

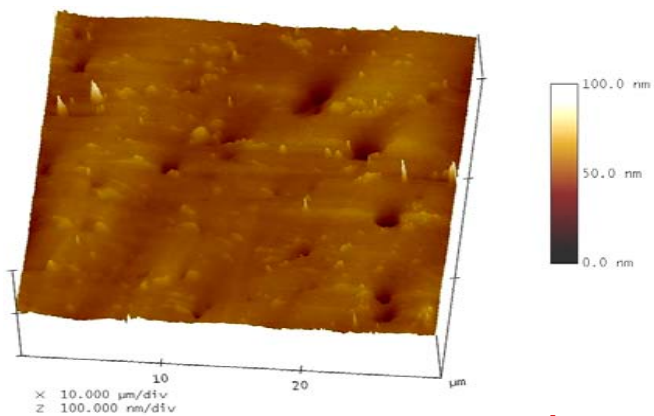
1 atm





148 atm



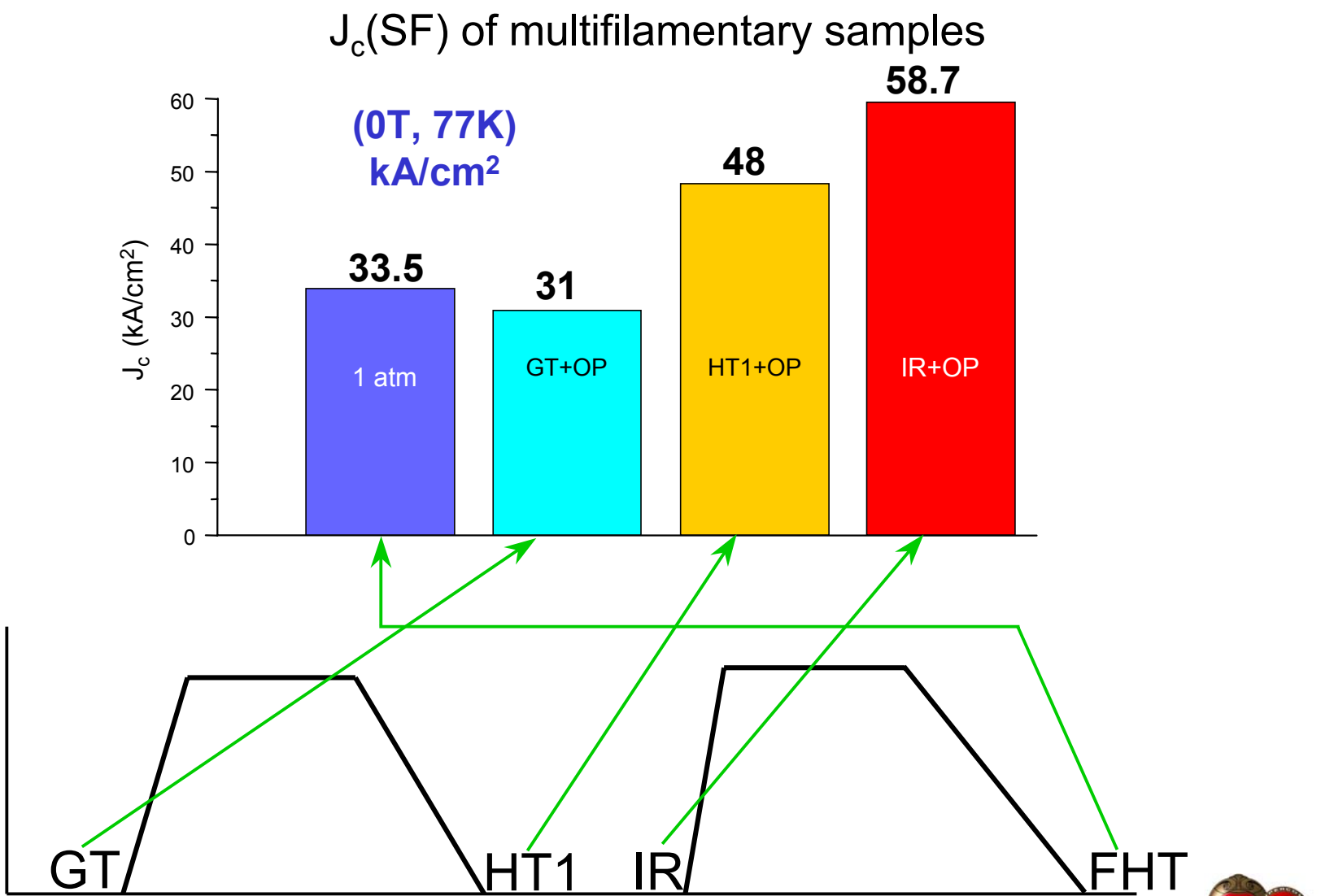


University of Wisconsin
Applied Superconductivity Center

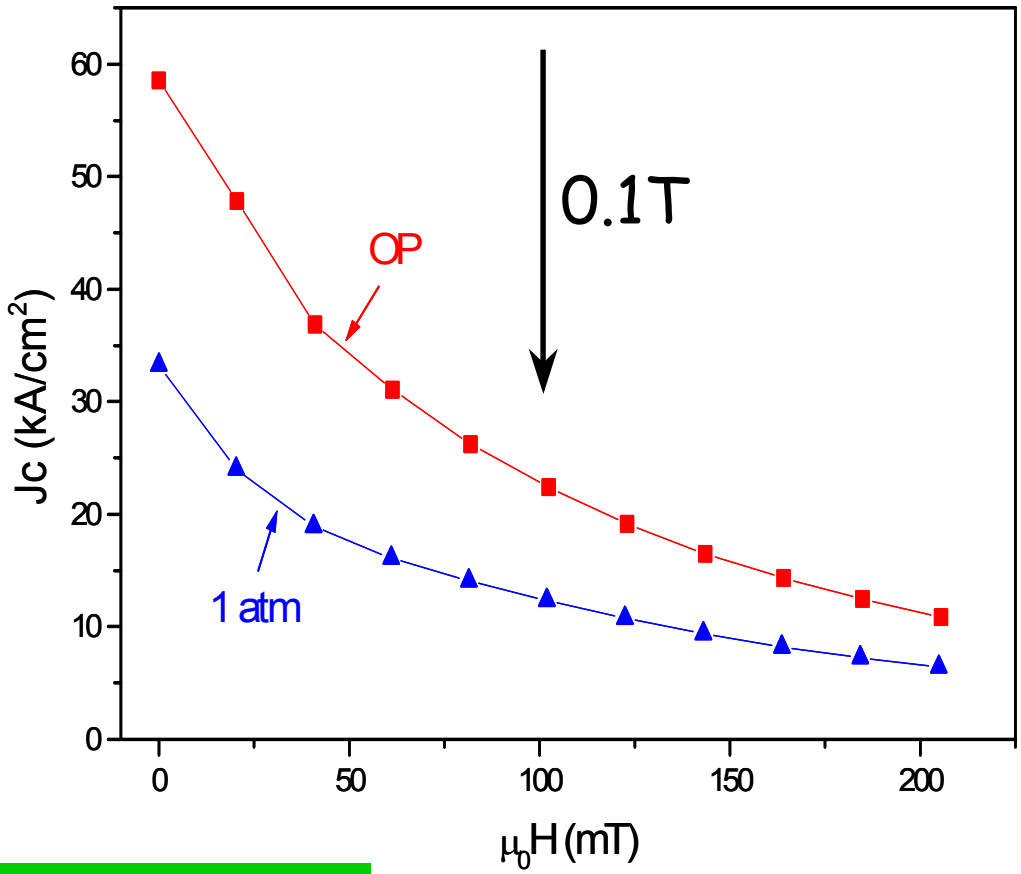
OP increases Jc

- **OP drives Jc up by**
  - Densifing core
  - Reducing 2212
  - Improving connectivity

OP increases Jc

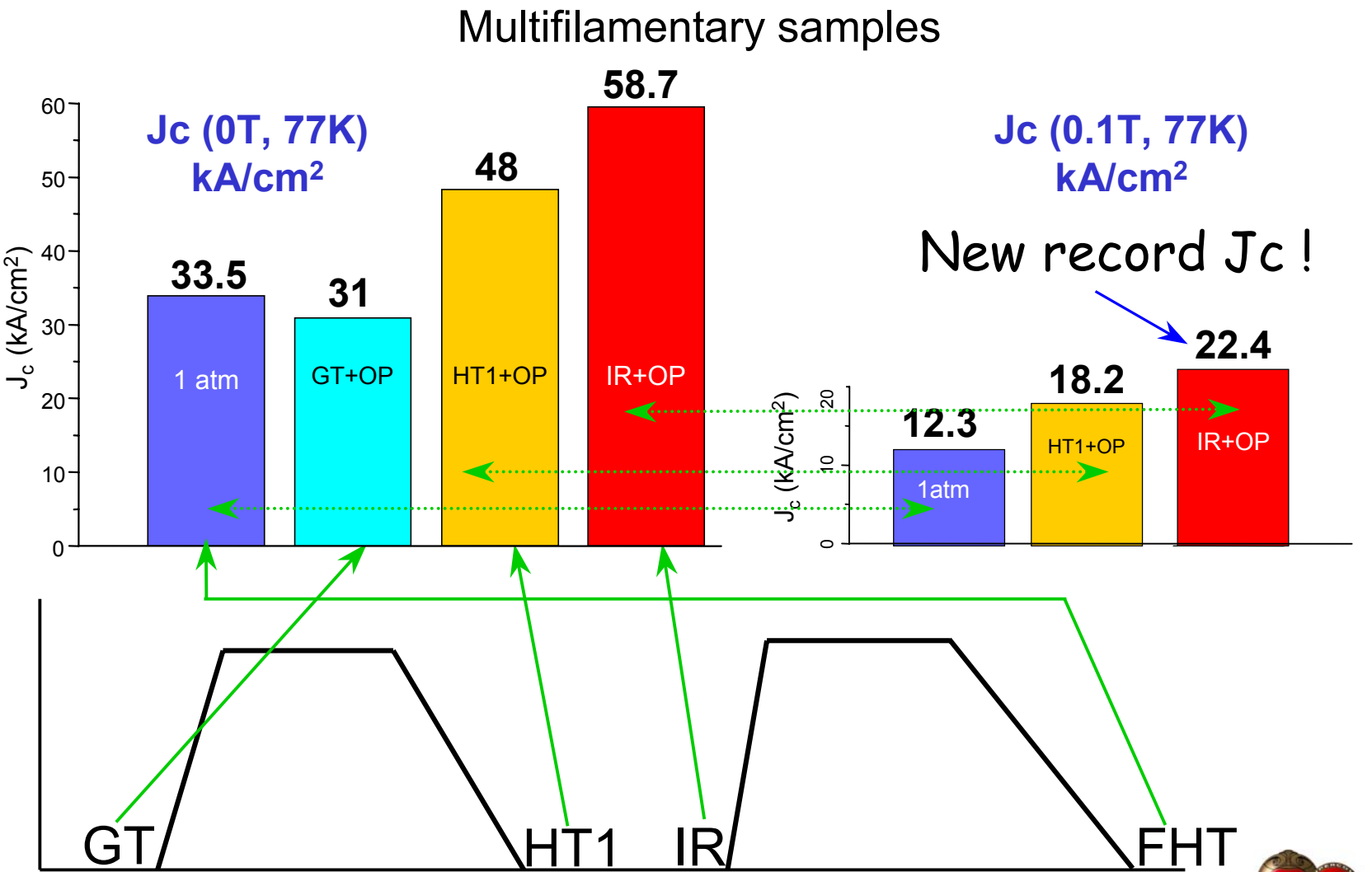


Field dependence of 1 atm and OP multifilament tape



See Chandler – 2ME07
Tuesday 1:00pm

OP increases critical current density



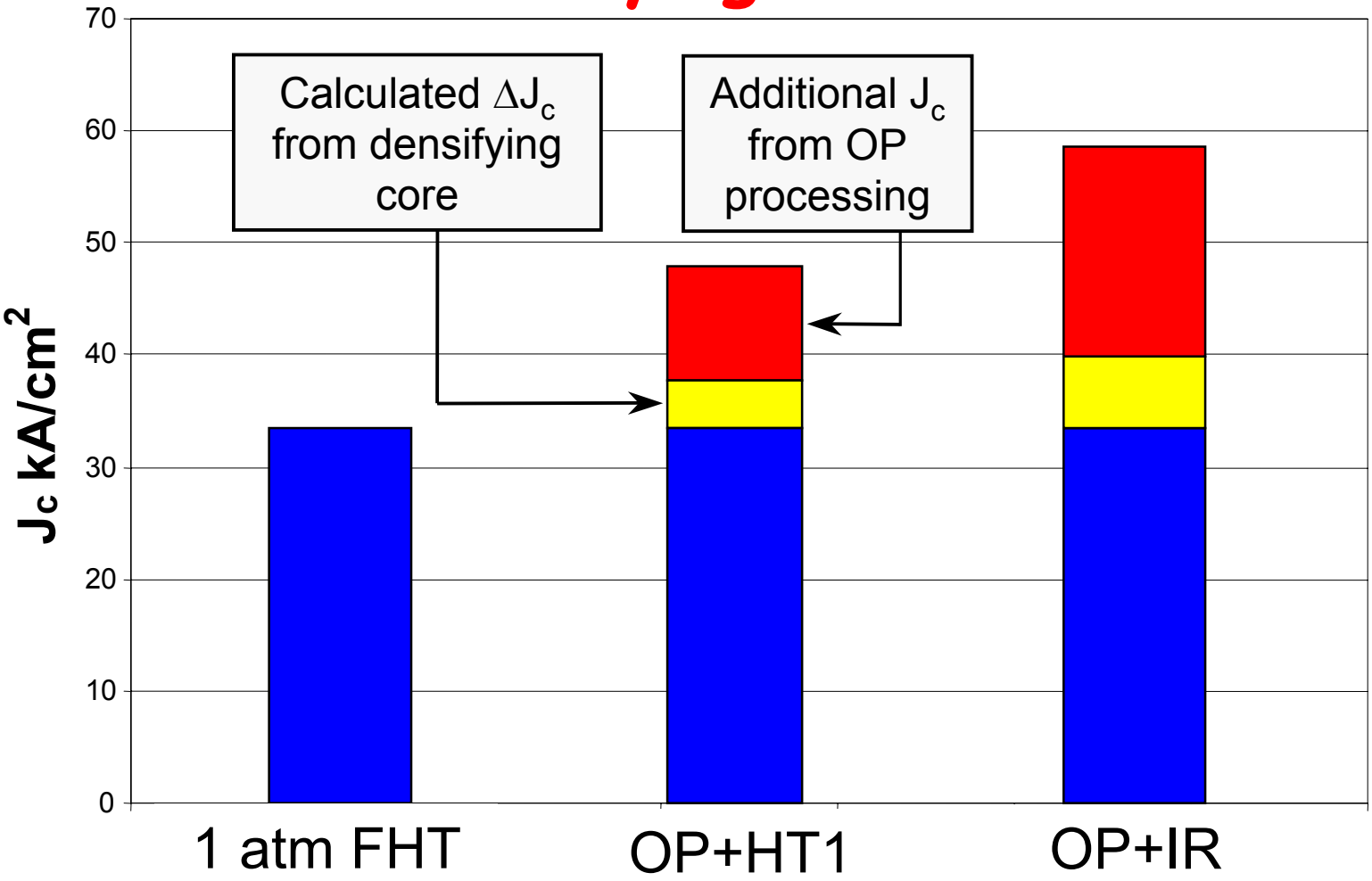
Thermomechanical Processing of Bi2223

University of Wisconsin
Applied Superconductivity Center

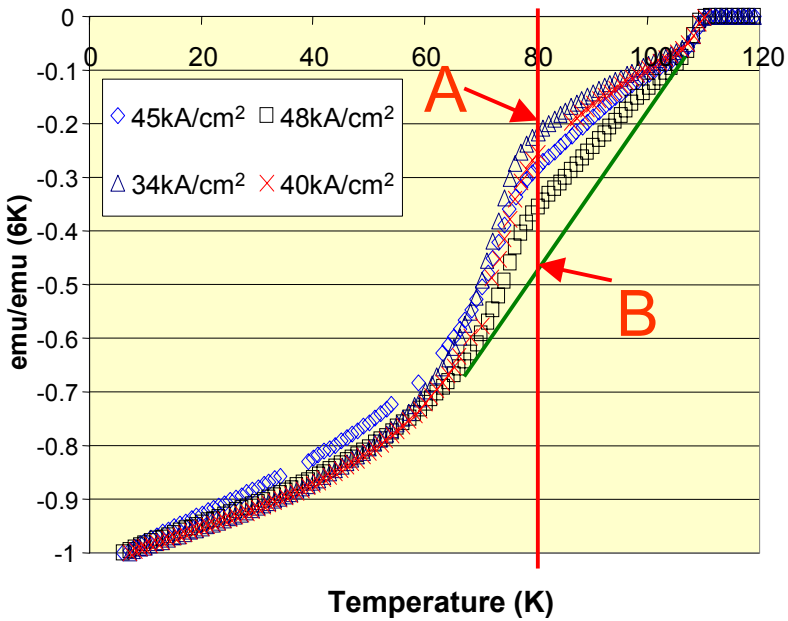
OP succeeds in other tapes too

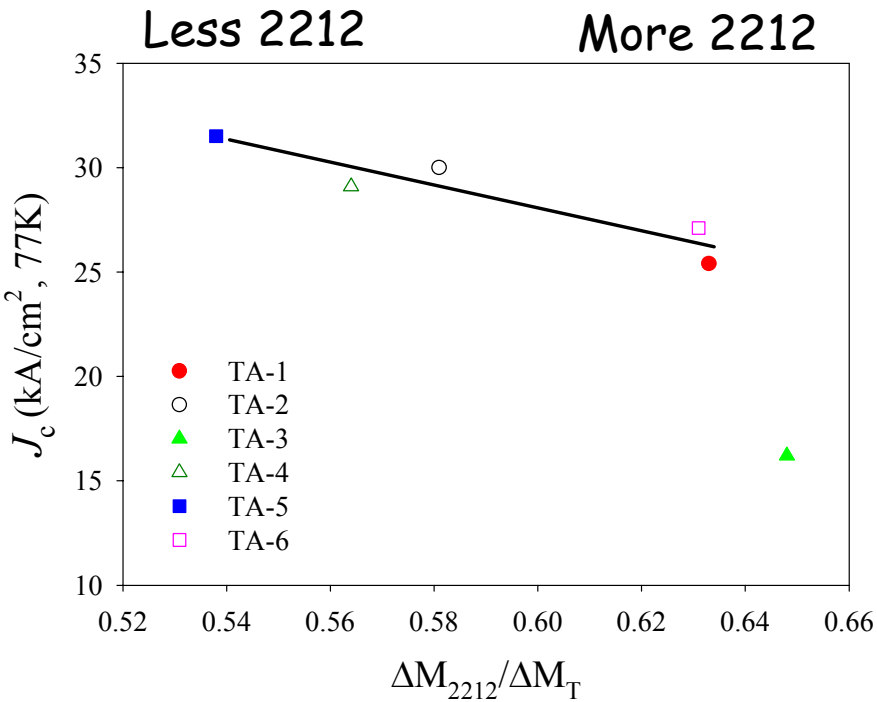
Samples	1atm (kA/cm^2)	OP (kA/cm^2)
Multi - 1 - IR	33.5	58.7
Multi - 2 – HT1	29	46.8
Multi – 2 – IR	41	48.5
Mono – IR	38.7	48

Jc increase in OP due to more than densifying the core



Jc increases as 2212 decreases

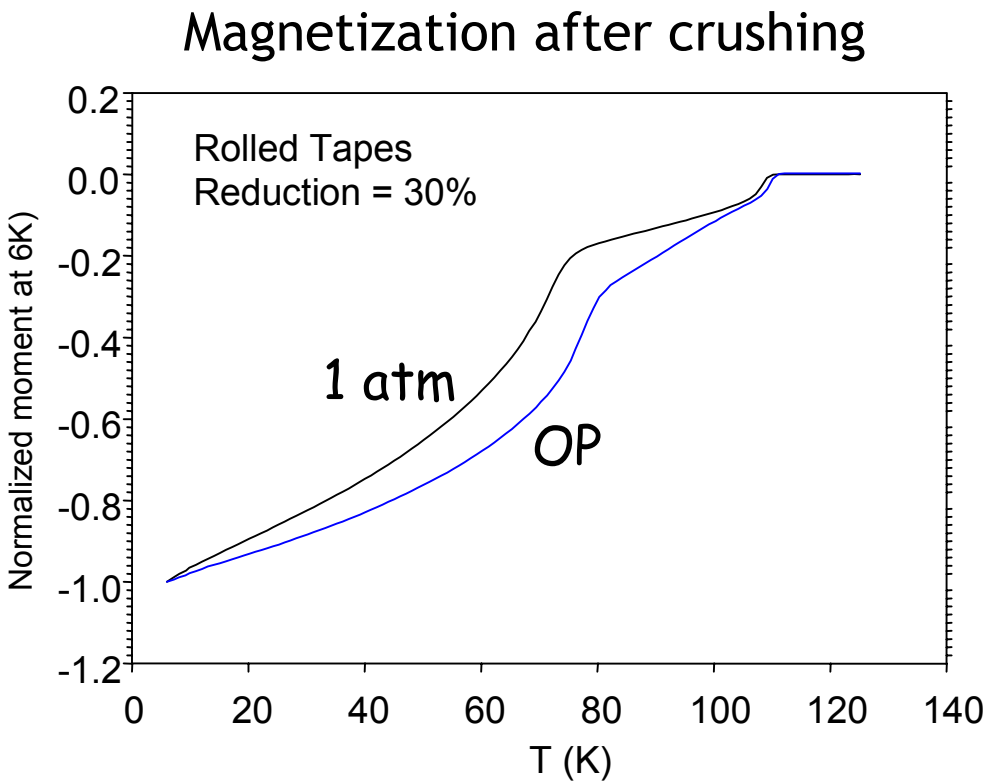




See Jiang – 2MM04
Tuesday 4:00pm &

See Huang – 2MM10
Tuesday 5:30pm

OP reduces 2212



MO-CR shows OP improves connectivity

See Patnaik – 2MA04
Tuesday 11:00am &

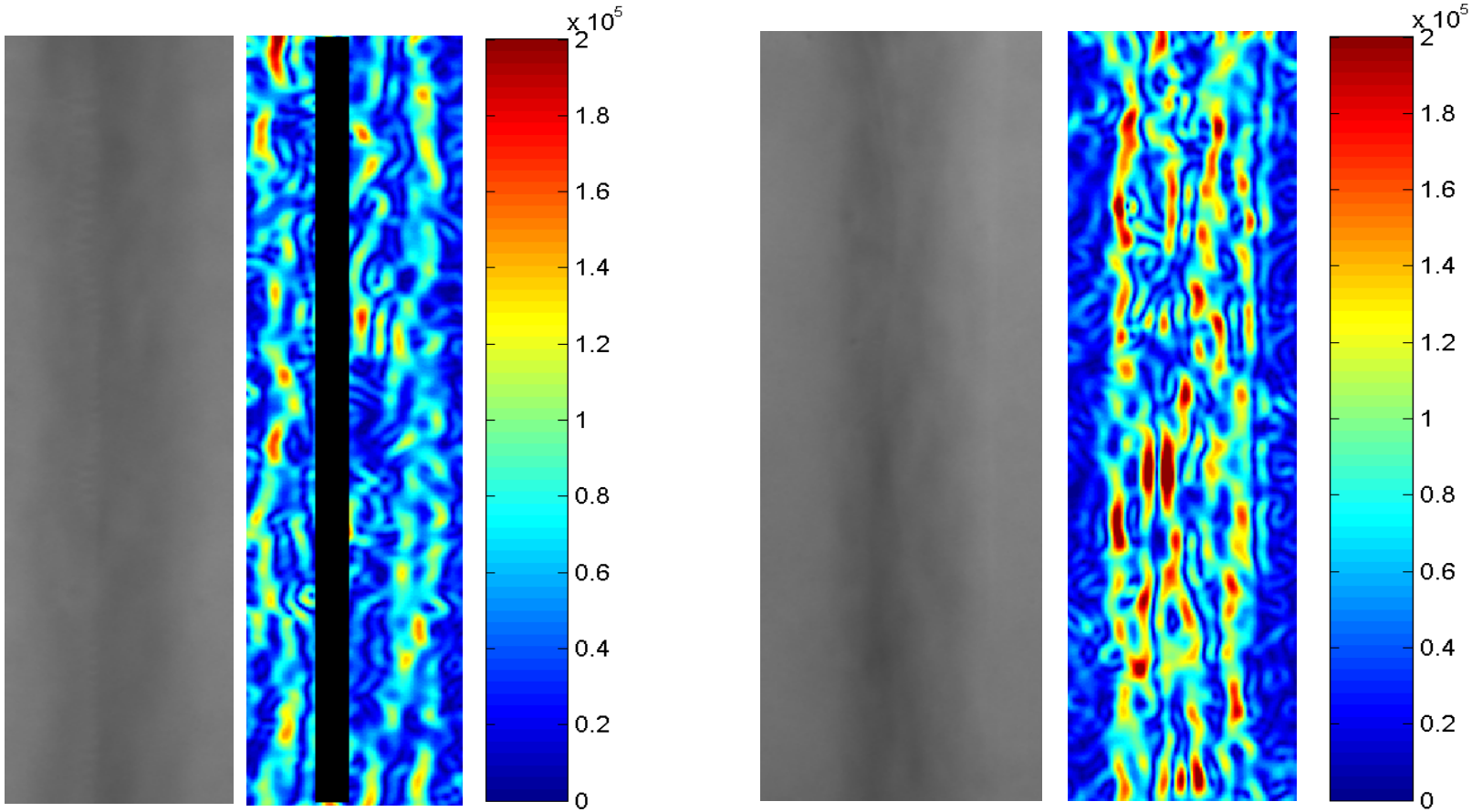
Cai – 2ME09
Tuesday 1:00pm

1 atm

Magneto-optic

Current-Reconstruction

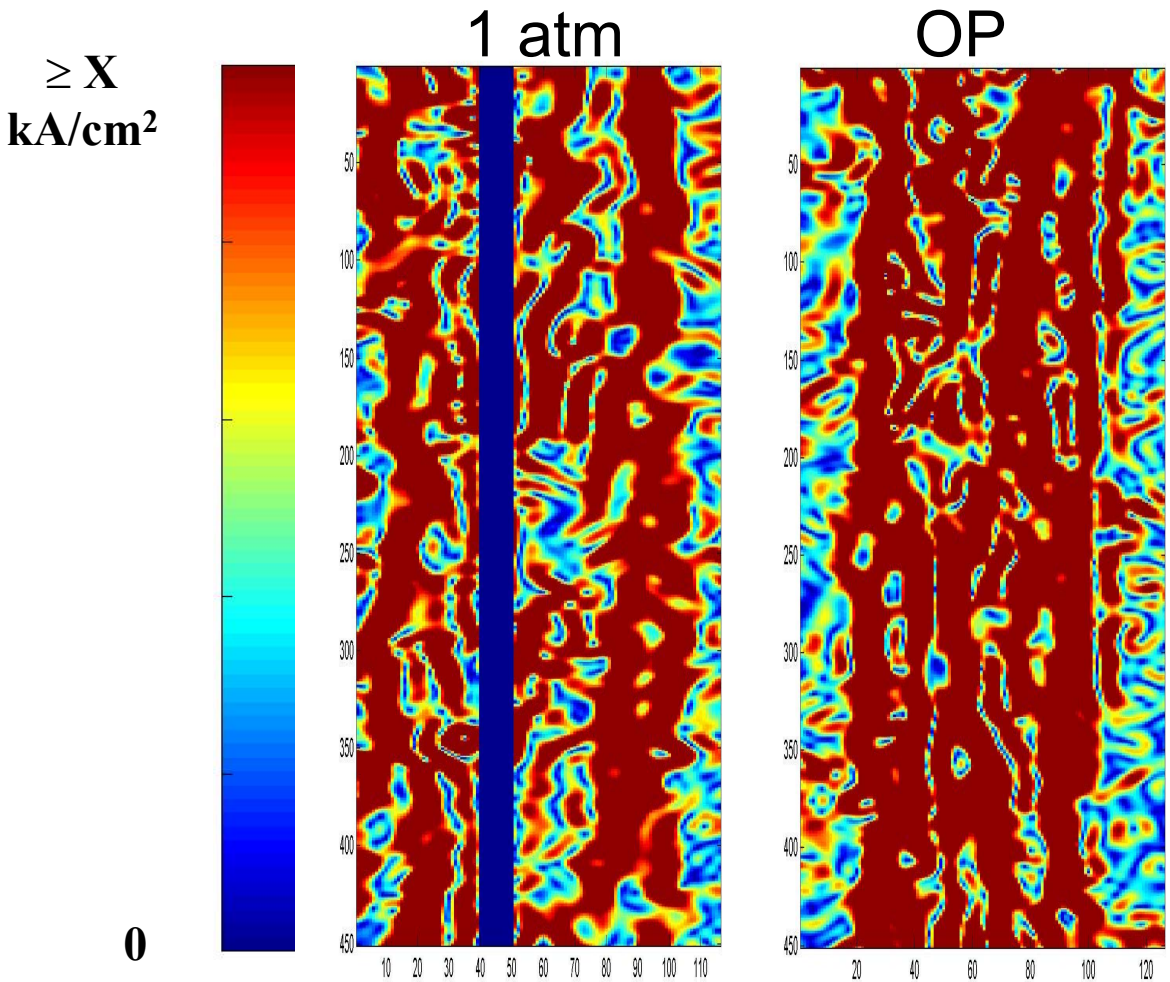
OP



Mono, 46mT, 77K

Direct comparison of connectivity

X = 50 kA/cm²



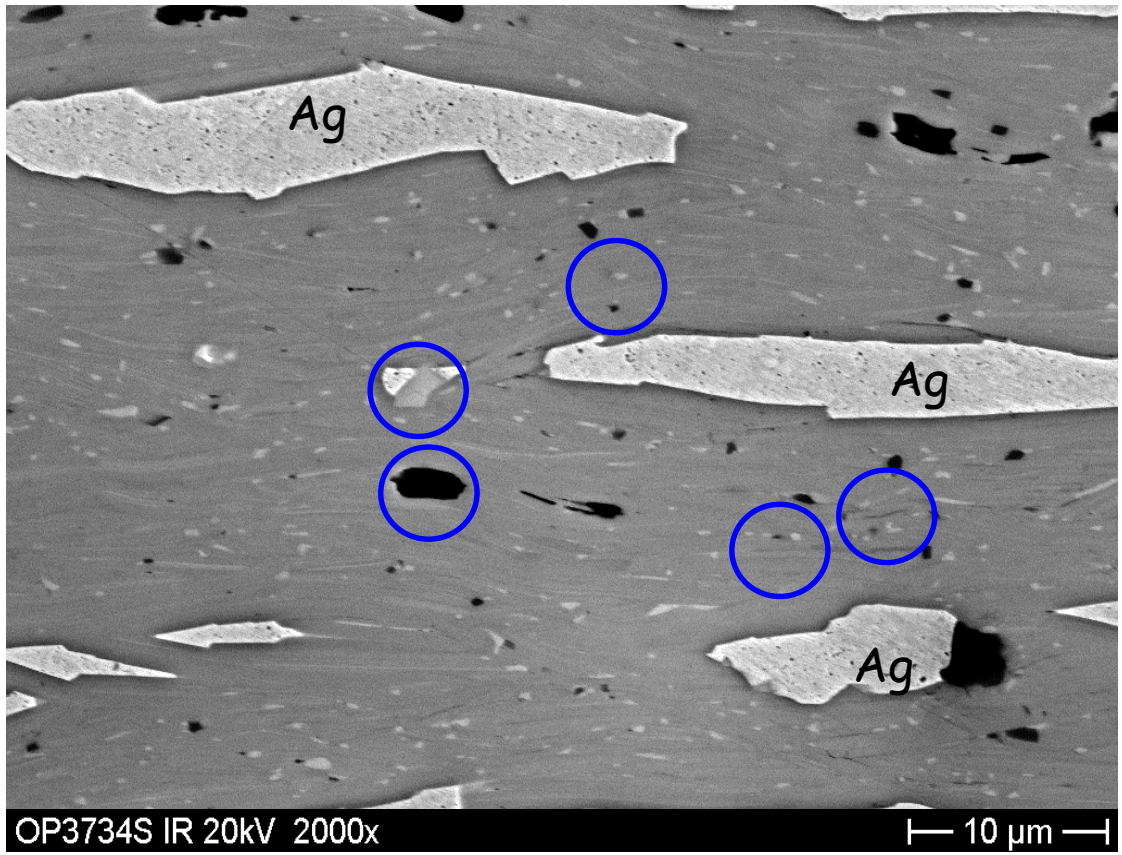
Transport Jc: 1 atm 39 kA/cm², OP 48 kA/cm²

What next?

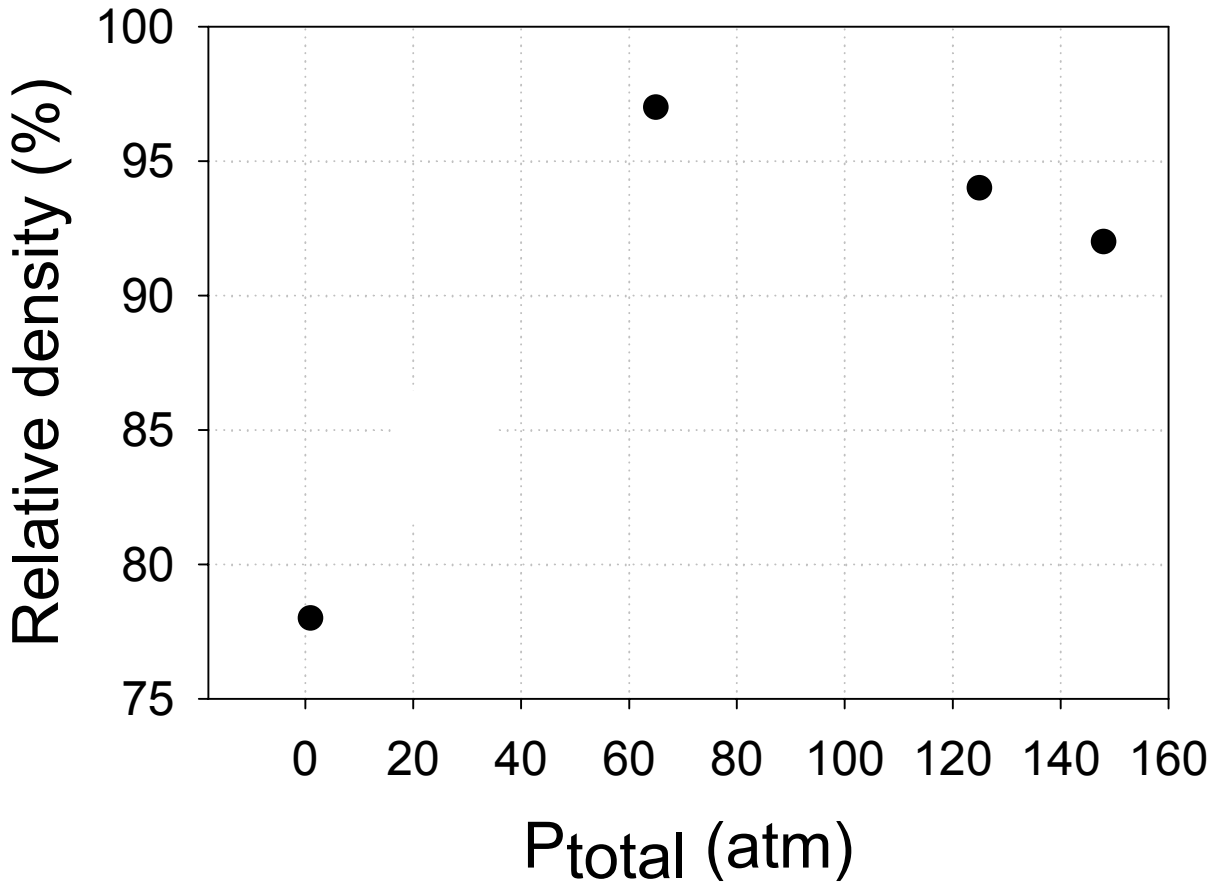
- Optimize OP processing
- Combine OP with other novel processes
- OP processing at low pressure

Nonsuperconducting 2nd phases and microporosity still in OP tape

J_c = 58.7 kA/cm^2 , 148 atm



How low can P_{total} go?



Summary

- **OP improves Bi2223 microstructure by densifying filaments – remove porosity, heal cracks**
- **OP increases Jc by several mechanisms**
  - OP increase Jc by ~20-70% wrt 1 atm processing, new record value of 22.4 kA/cm^2 at 77K,0.1T
  - OP increases Jc by densifying core, reducing 2212, improving connectivity
- **OP needs to be optimized – eliminate 2nd phases and microporosity**
- **OP densifies tape at 65 atm, lower pressure experiments are underway**