

Critical Current Limiting Factors in Post Annealed $(\text{Bi,Pb})_2\text{Sr}_2\text{Ca}_2\text{Cu}_3\text{O}_x$ Tapes

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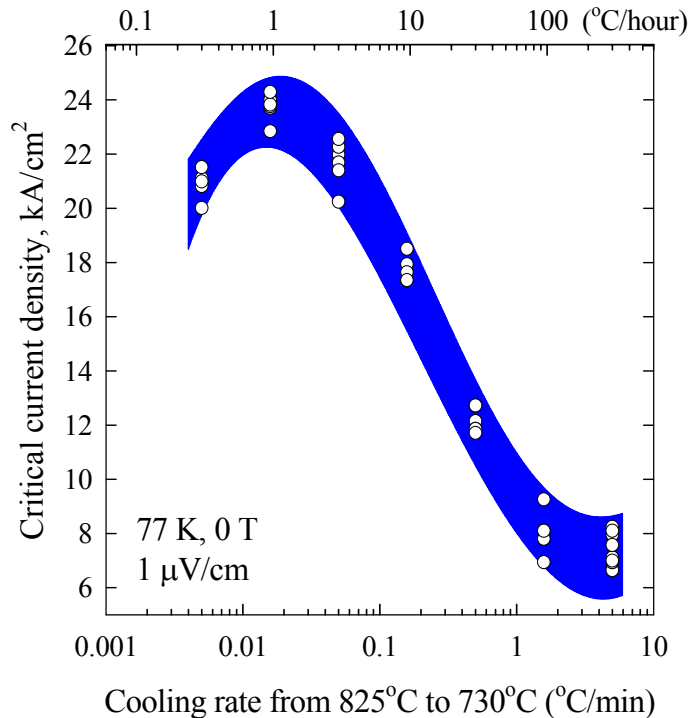
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Outline

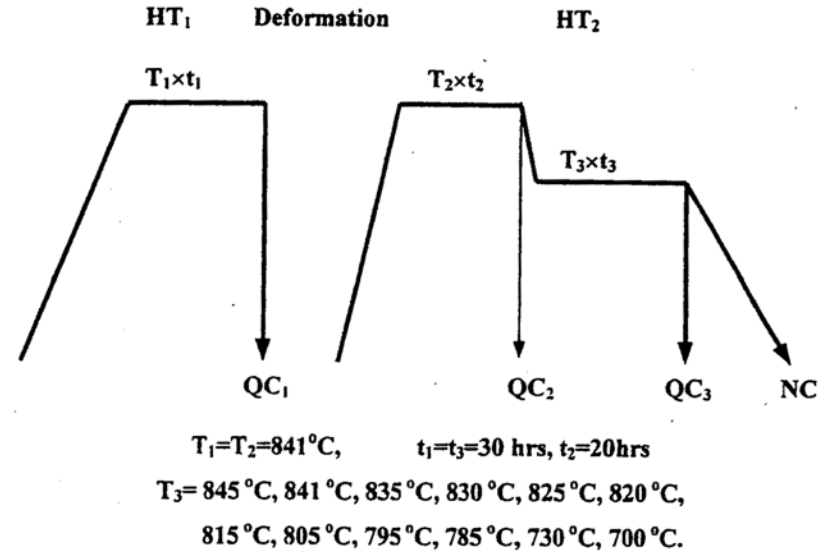
- Post anneal procedures
- Effects of Post anneal
 - Critical current density J_c
 - Microstructure
 - Characteristic field H_p
 - Bi-2212 intergrowths
- Summary



Slow cooling or two step HT improves J_c



Parrell et al APL 69, 2915 (1996)



Wang et al Physica C 291, 1 (1997)

Guo et al Physica C 300, 38 (1998)

Liu et al Physica C 325,70 (1999)

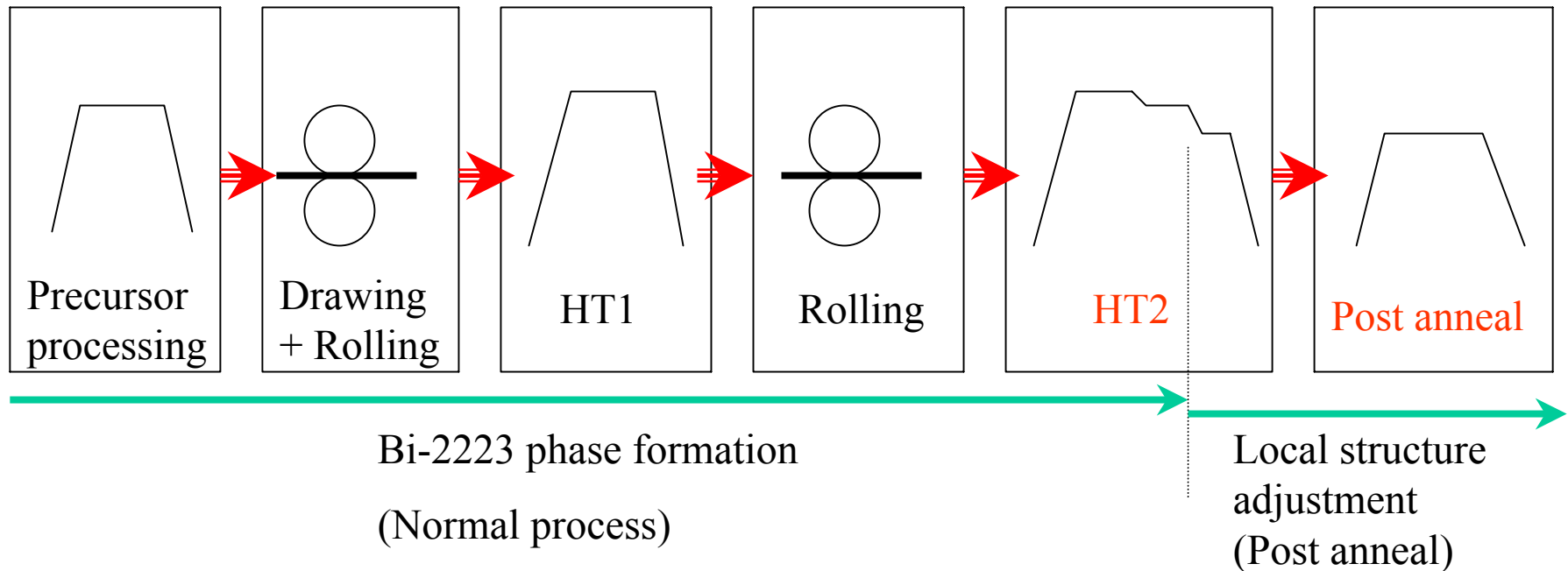
Li et al, US Patent 5798318 (1998)

Previous Ideas: Reduced residual liquid or 2201 => Increased J_c

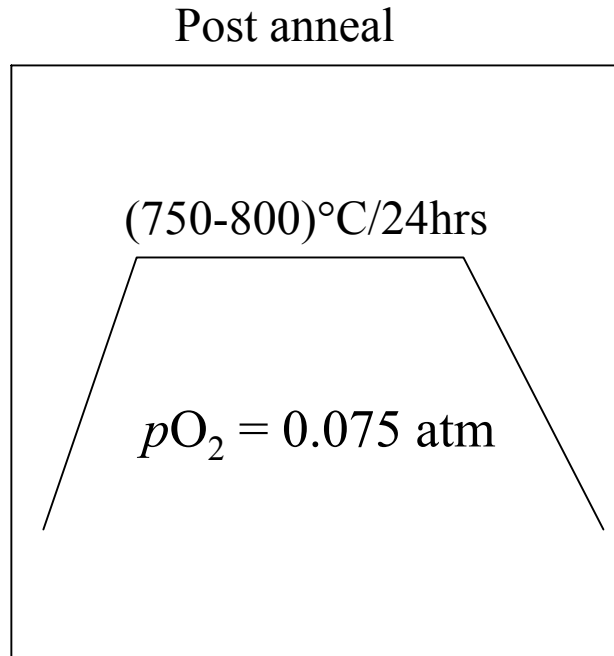


Bi-2223 processing procedure

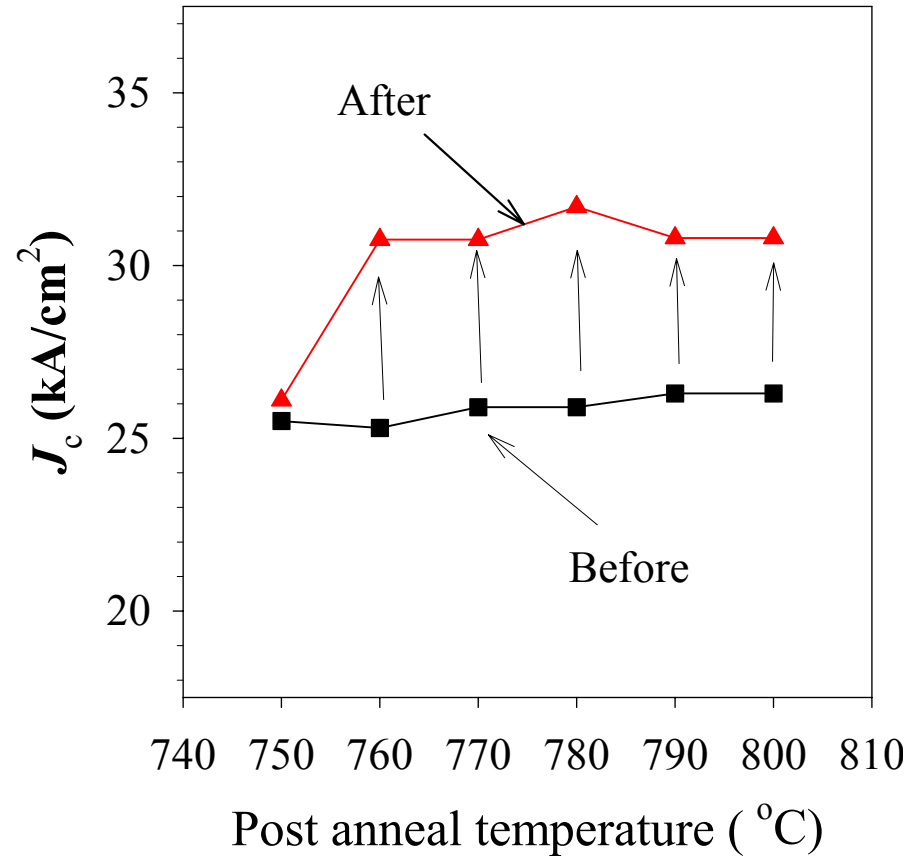
Monofilament Tapes



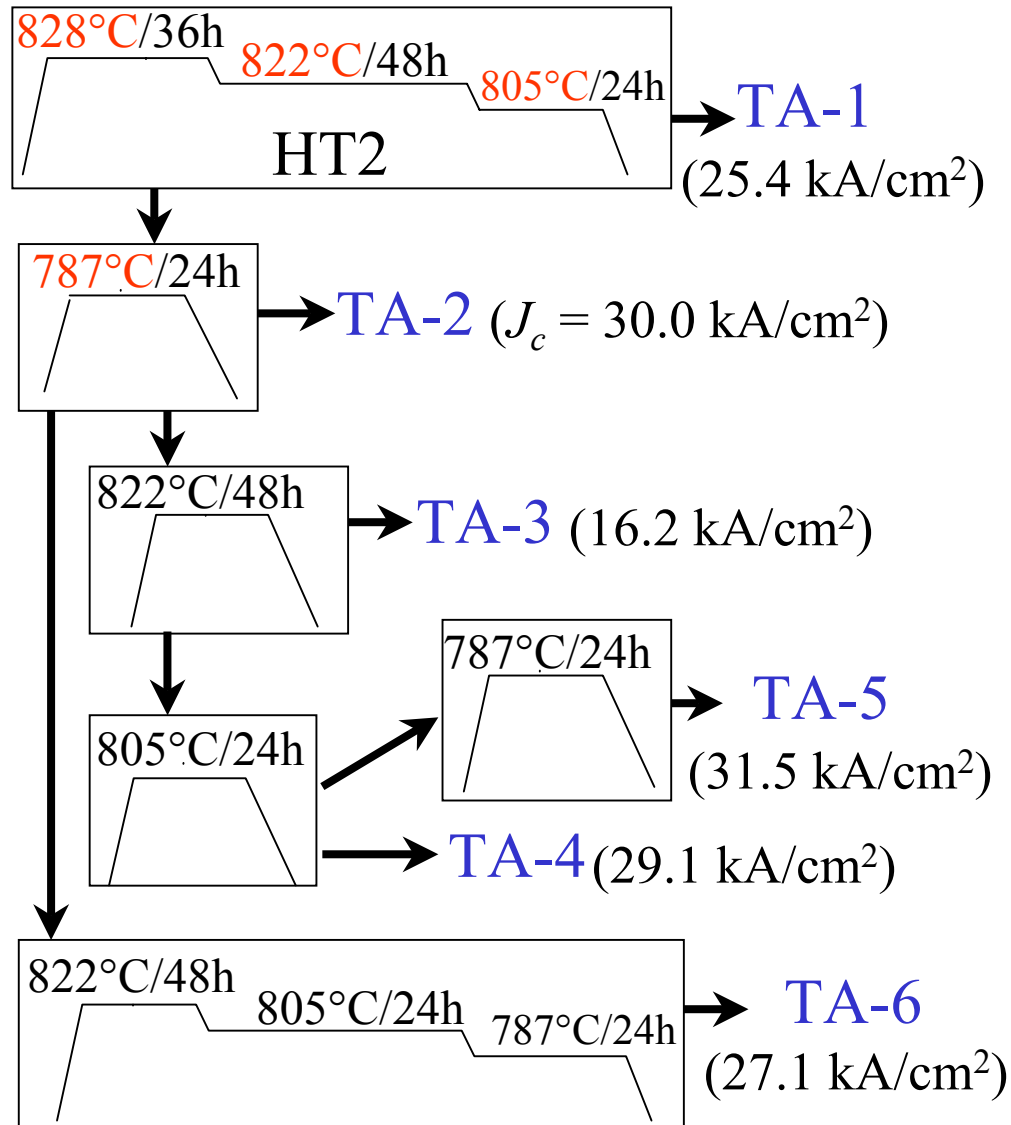
Post anneal improves J_c



Monocore Bi-2223



Post anneal HT procedures and J_c



828°C: (more liquid)

Heal cracks and form 2223

822°C: (less liquid)

Form 2223 or dissolve Pb-3221

805°C:

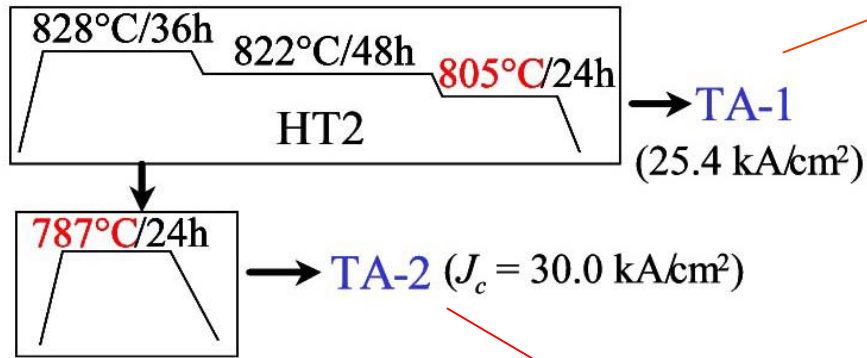
Remove liquid

787°C:

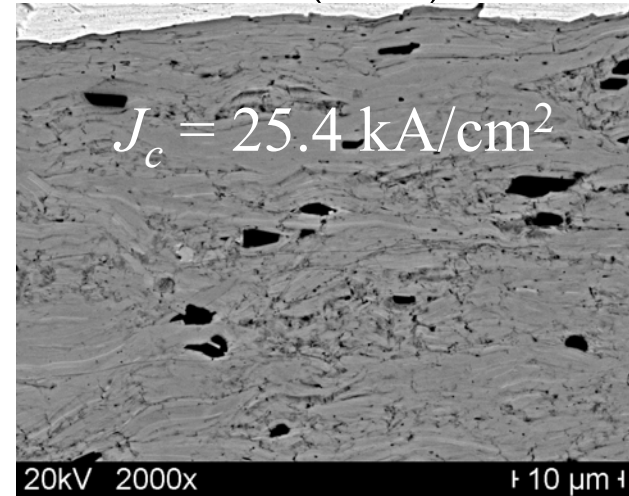
Precipitate Pb



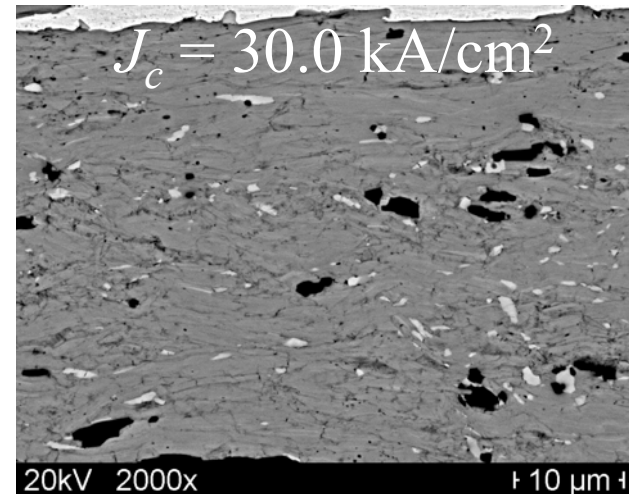
Microstructure varies with post anneal



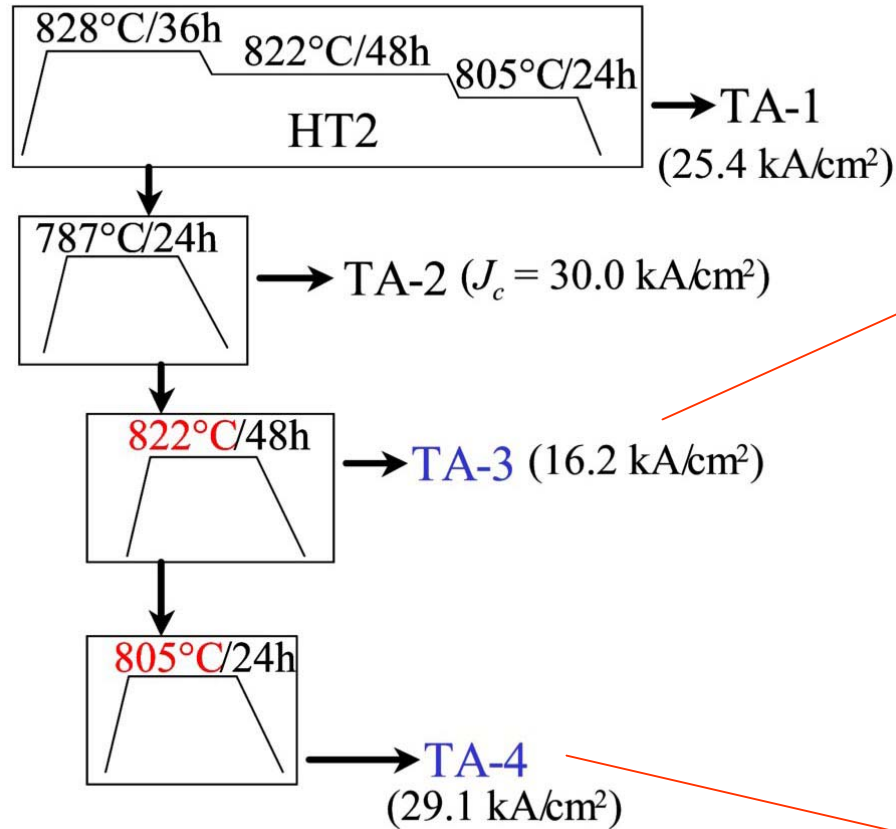
TA-1 (HT2)



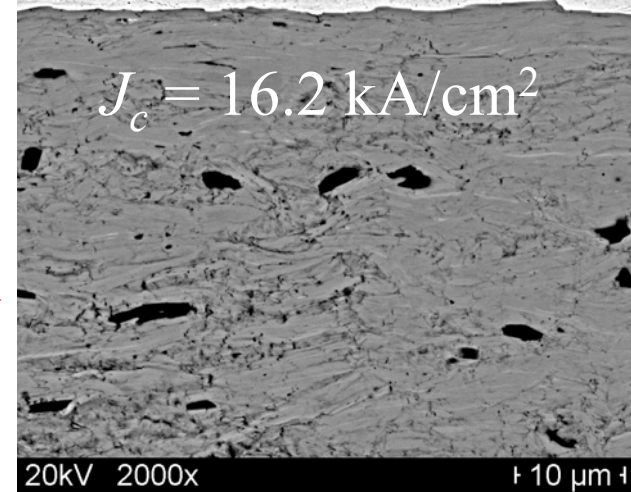
TA-2 (TA-1 + 787°C/24h)



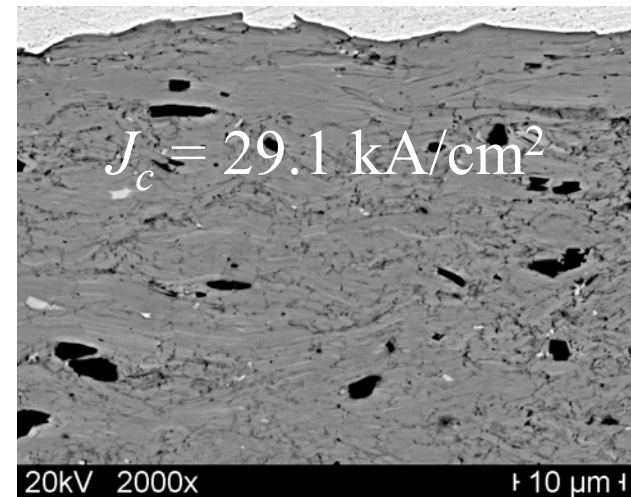
Microstructure varies with post anneal



TA-3 (TA-2 + 822°C/48h)

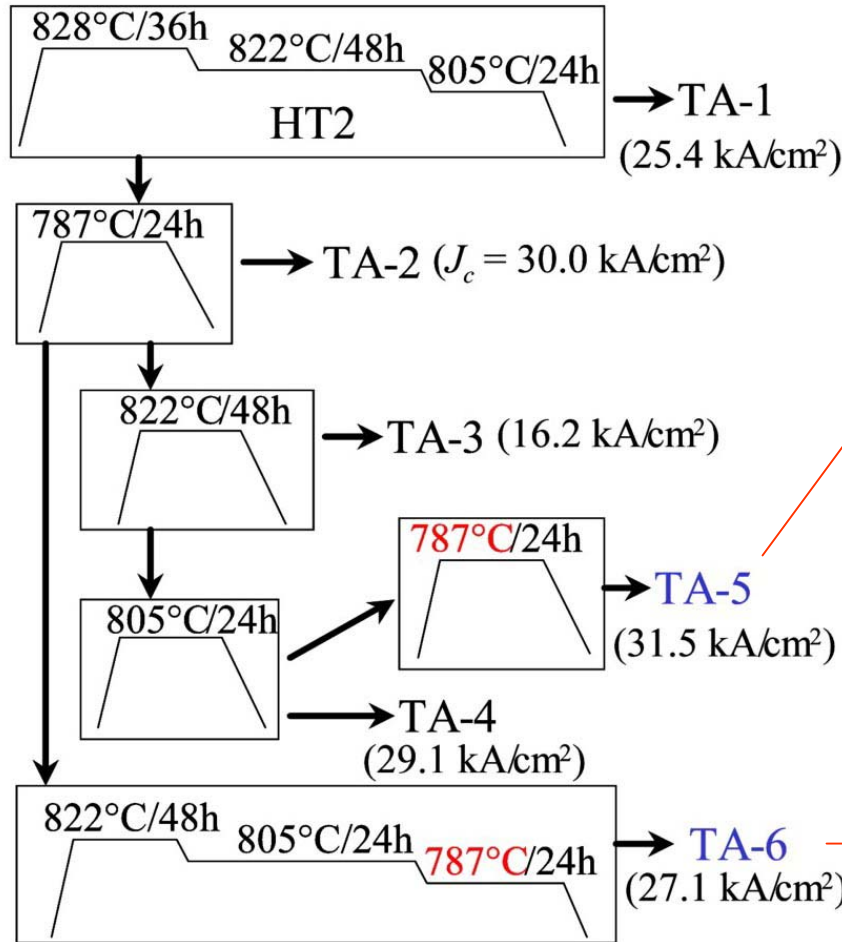
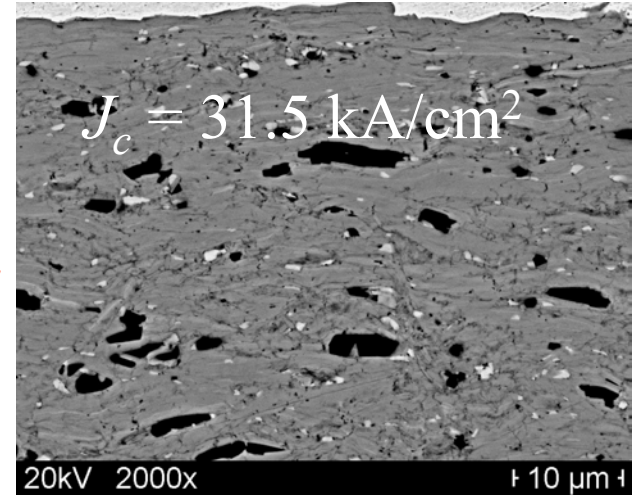


TA-4 (TA-3+805°C/24h)

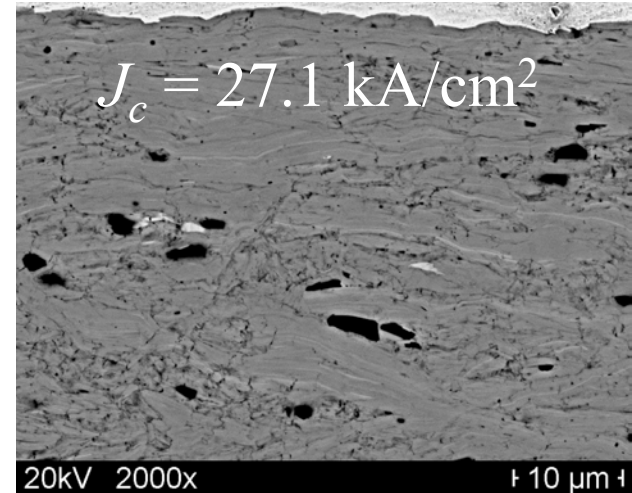


Microstructure Varies with Post Anneal

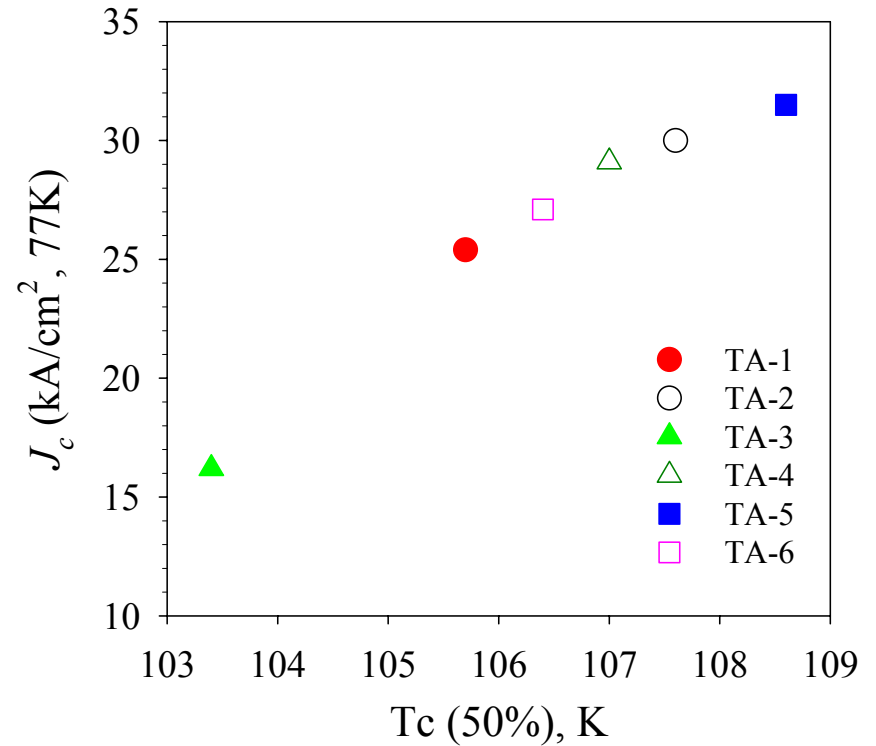
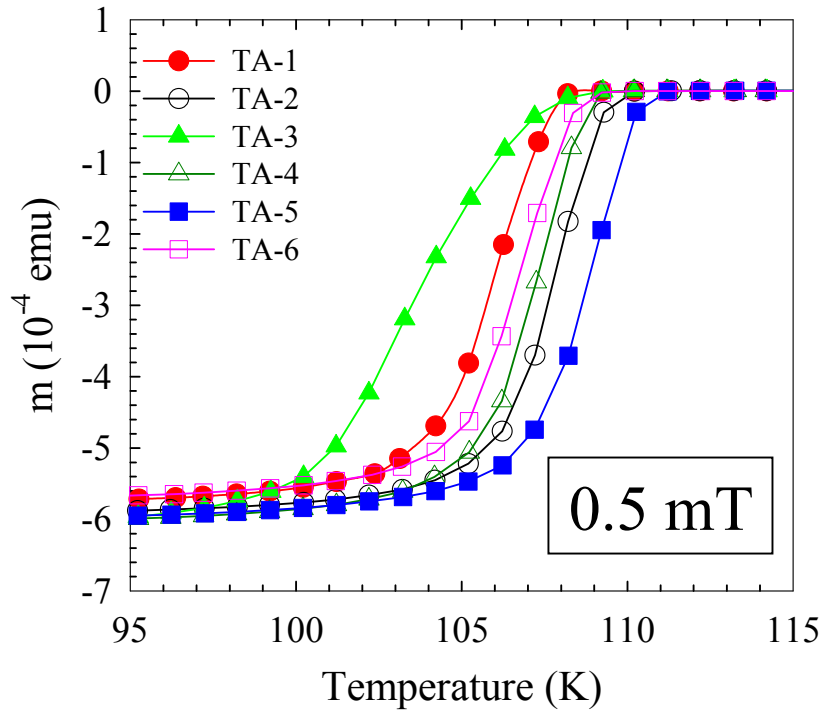
TA-5 (TA-4+787°C/24h)



TA-6
TA-2+(822C/48h+805C/24h+787C/24h)



T_c varies with post anneal, and correlates to J_c



Definition of characteristic field H_p

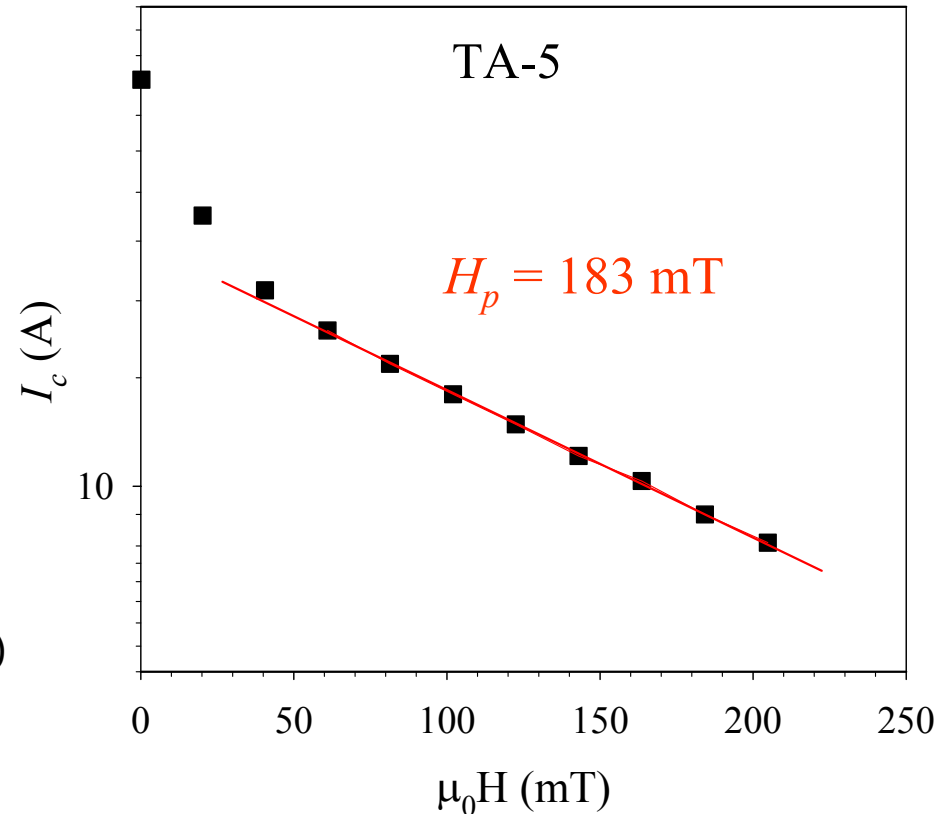
Flux pinning regime to

60-200 mT

$$J_c(H) \propto \exp(-H/H_p)$$

characteristic field H_p

Schwartzkopf et al. APL **75**,3168 (1999)



J_c , H_p are both controlled by T_c

Tape	Last HT	$J_c(0)$, kA/cm ²	$J_c(0.1T)$, kA/cm ²	H_p , mT	T_c (50%), K
TA-5	787°C	31.5	9.9	183	108.6
TA-2	787°C	30.0	8.8	180	107.6
TA-4	805°C	29.1	8.5	179	107.0
TA-6	787°C	27.1	7.6	171	106.4
TA-1	805°C	25.4	6.8	163	105.7
TA-3	822°C	16.2	3.7	126	103.4

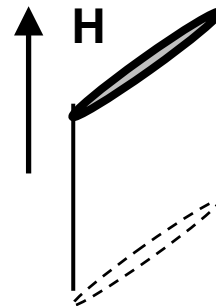
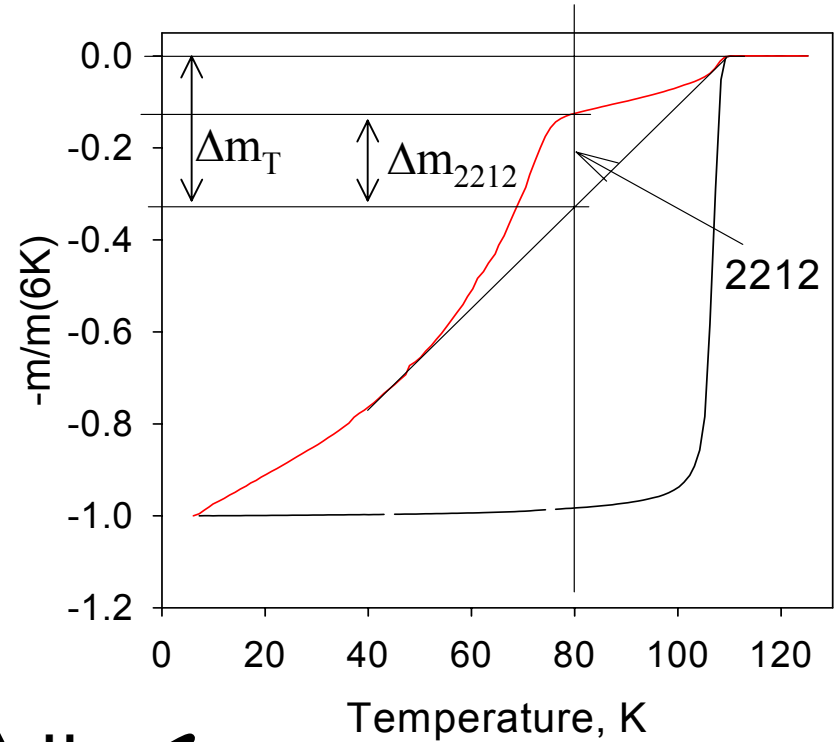
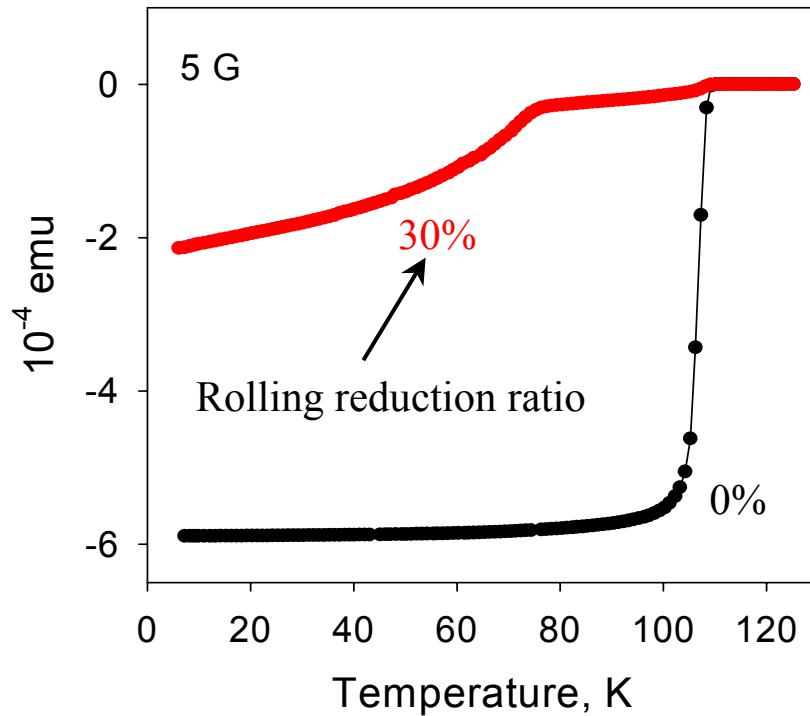
More
Pb-3221

Are Bi-2212 intergrowths the cause of T_c variation
or does Pb precipitating from Bi-2223 increase T_c ?



Bi-2212 is revealed by rolling the tape

TA-6

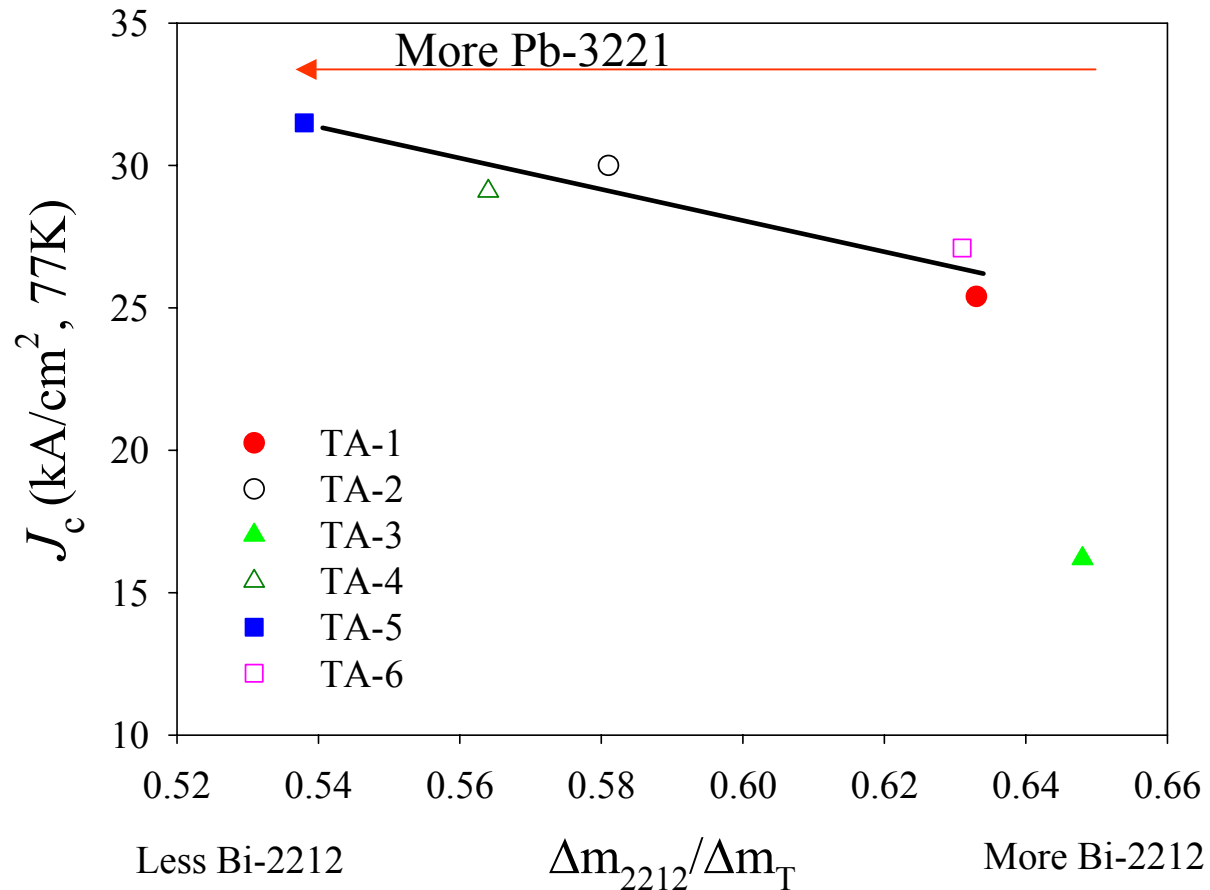


Huang et al ICMC 2001



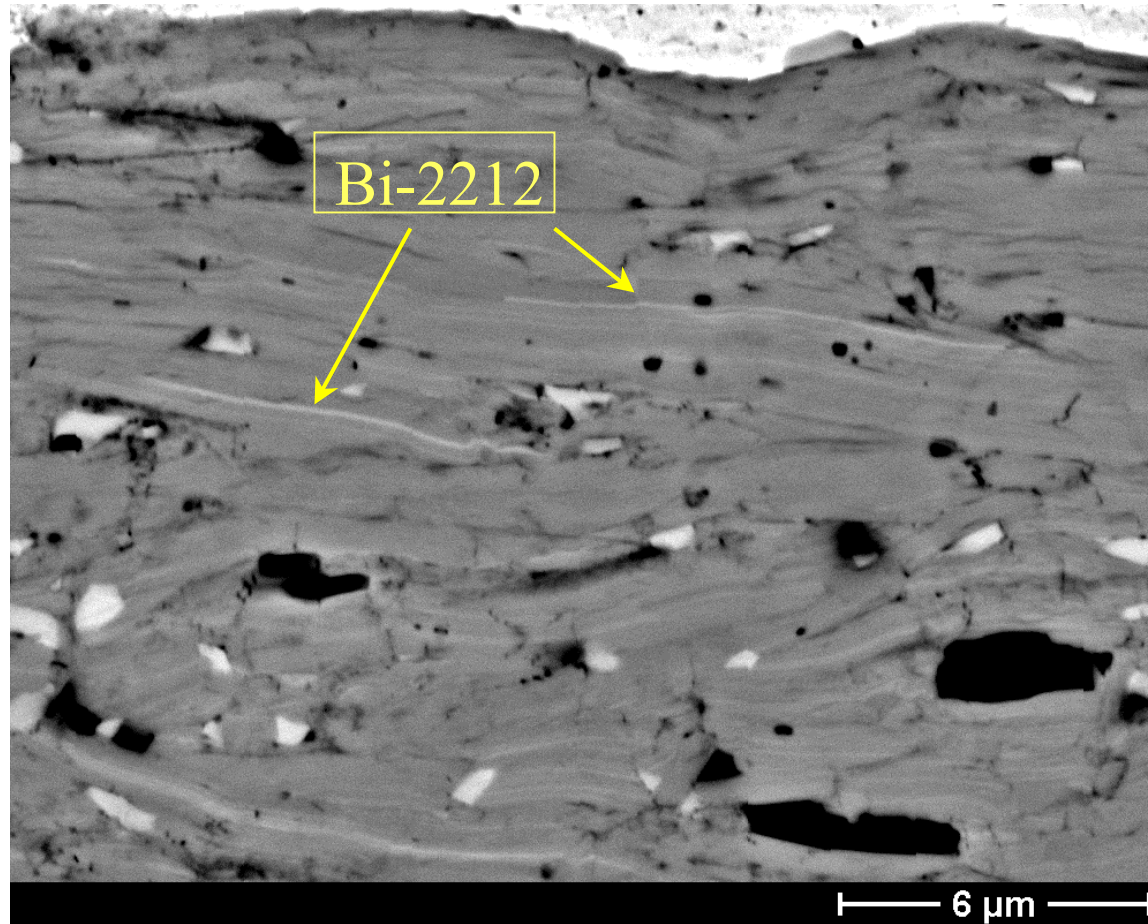
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Bi-2212 content varies with post anneal, and correlates to J_c



SEM shows Bi-2212

TA-5 , $J_c = 31.5 \text{ kA/cm}^2$



Summary

- *Raising T_c and minimizing 2212* are decisive factors for J_c
 - Strong correlation between T_c and J_c
 - J_c is raised as Bi-2212 intergrowth is lessened
- **Post anneal at 787°C benefits T_c , H_p and J_c**
 - Midpoint T_c is raised from 103 to 109K by post annealing
- **Post anneal at 787°C precipitates Pb from Bi-2223 phase**
 - Microstructure looks worse but J_c and T_c are raised
- **HT finishing at 822°C is really detrimental for J_c , T_c and H_p**



Acknowledgements

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