

Understanding of vortex pinning in the ultrafast Transient Liquid Assisted Growth (TLAG) process of coated conductors

Teresa Puig¹

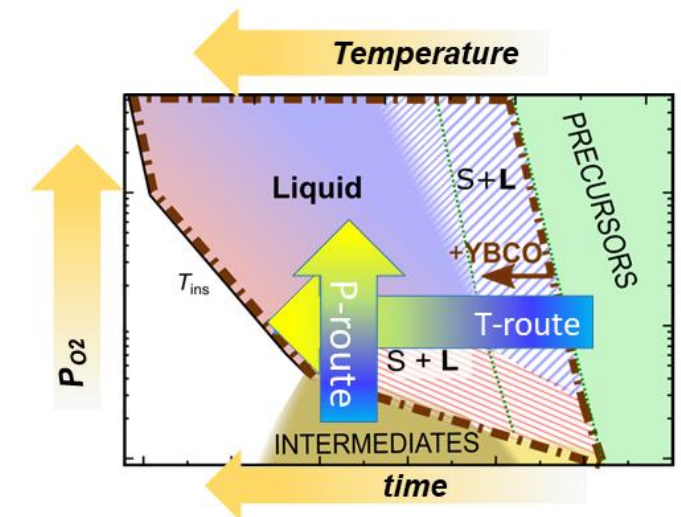
X. Obradors¹, A. Kethamkuzhi¹, O. Mola¹, K. Gupta¹, C. Torres¹, R. Vlad¹, E. Pach^{1,4}, E. Guiara¹, M. Voulhoux¹, L. Saltarelli¹, D. Garcia^{1,2}, S. Rasi¹, V. Fuentes^{1,4}, C. Pop¹, D. Sanchez³, S. Ricart¹, R. Yanez², J. Farjas³, J. Gutierrez¹, E. Solano⁴, L. Simonelli⁴

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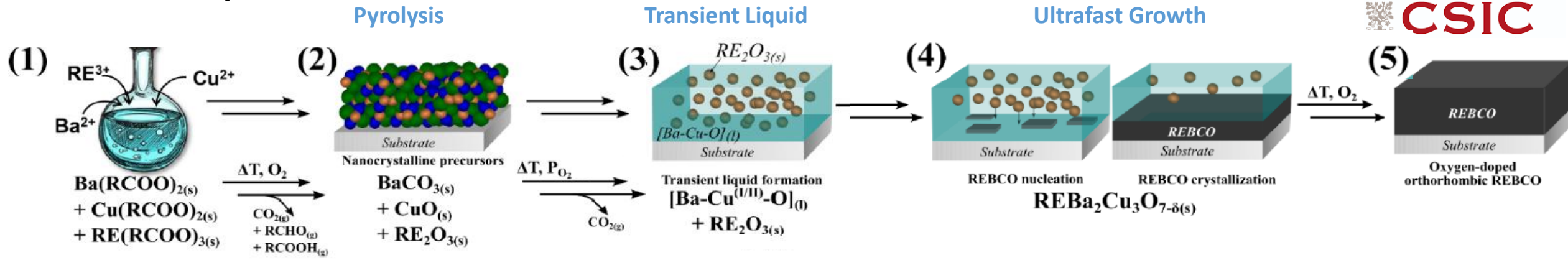
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TLAG-CSD process

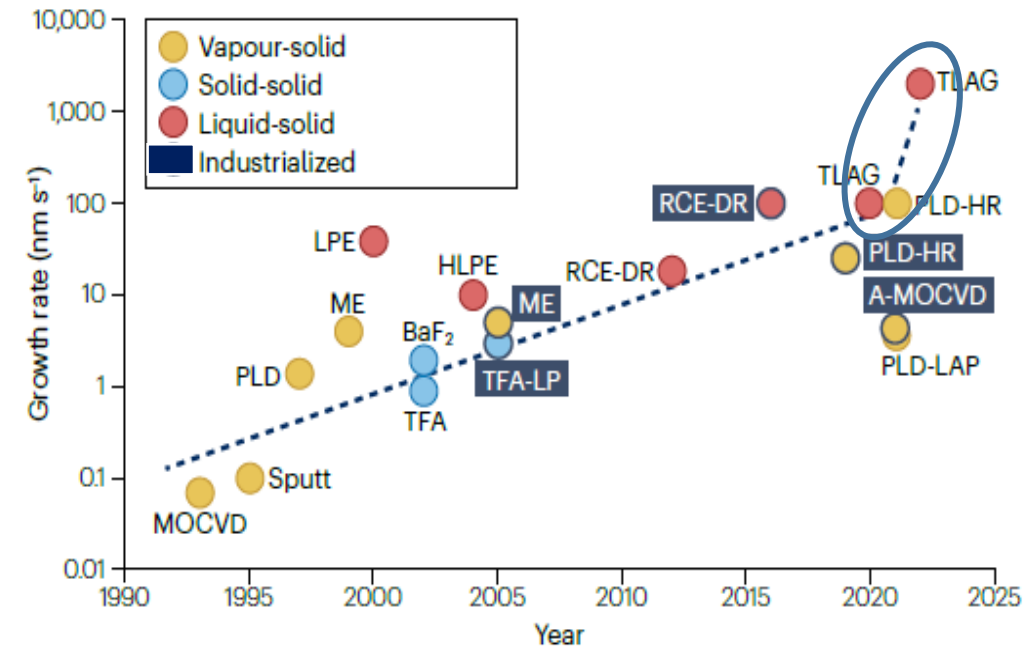
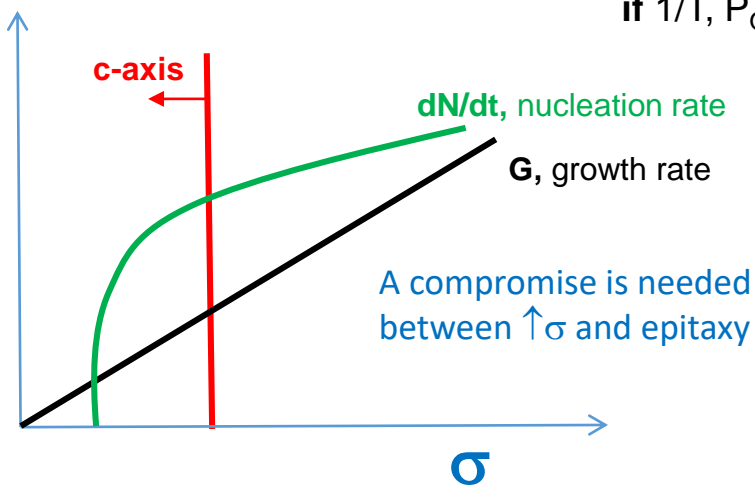


Kinetically governed by RE liquid supersaturation $\sigma = (C_\delta - C_e) / C_e$

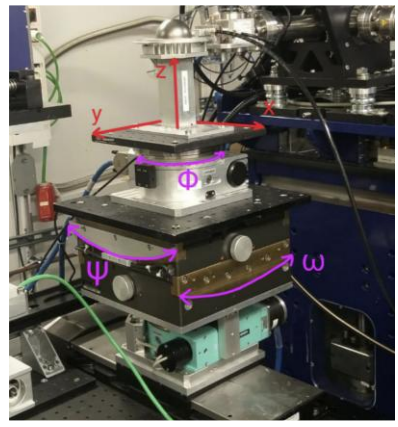
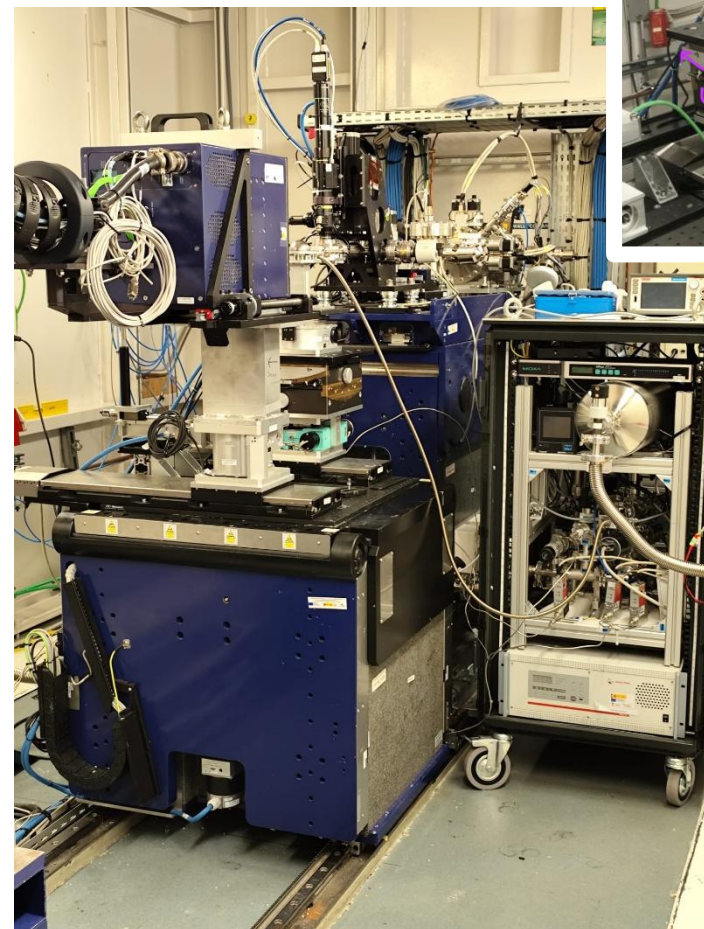
C_e : thermody. param. (T, P_{O_2} , Ba/Cu liq. composition, RE ion)

C_δ : kinetic param. (heating ramp, pressure ramp, ...)

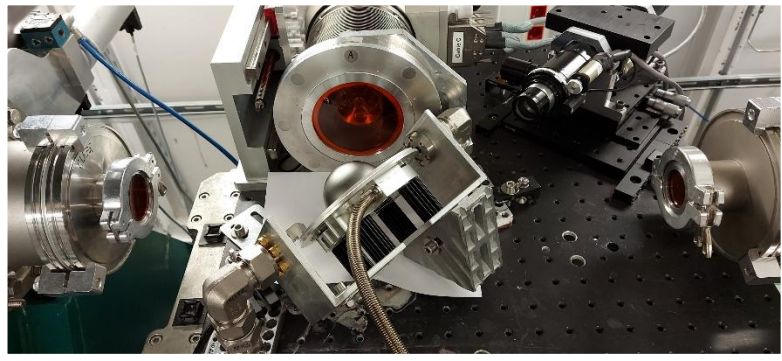
if $1/T, P_{O_2}, Ba/Cu$ or $r_{RE} \uparrow \rightarrow \sigma \uparrow$



**NCD_SWEET beamline:
XRD with 2D fast detector**

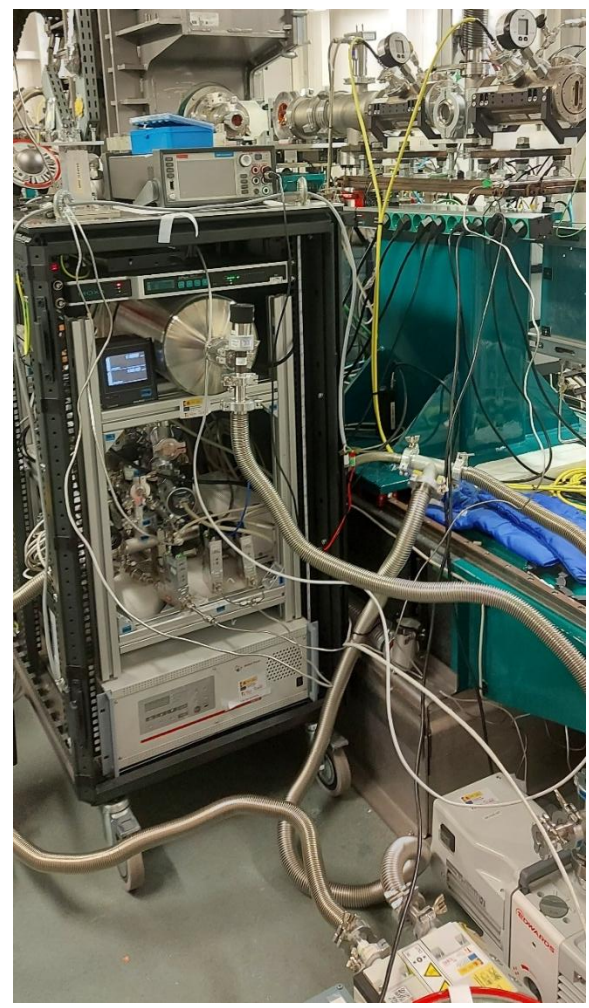


**CLAESS beamline
XAS with fluorescence detector**



- In-situ resistivity
- Mass spectrometry
- Time synchronized installation

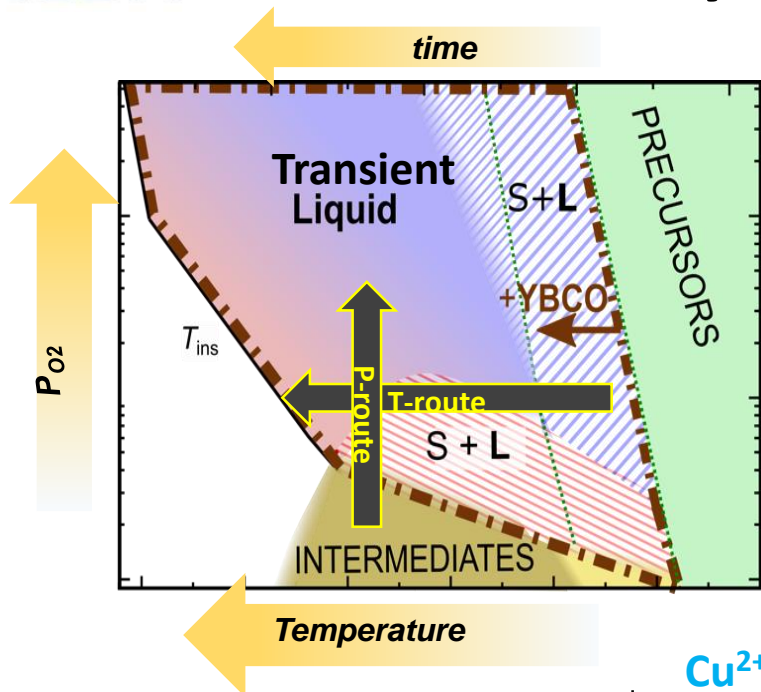
Energy Transition ALBA-CSIC Joint laboratory



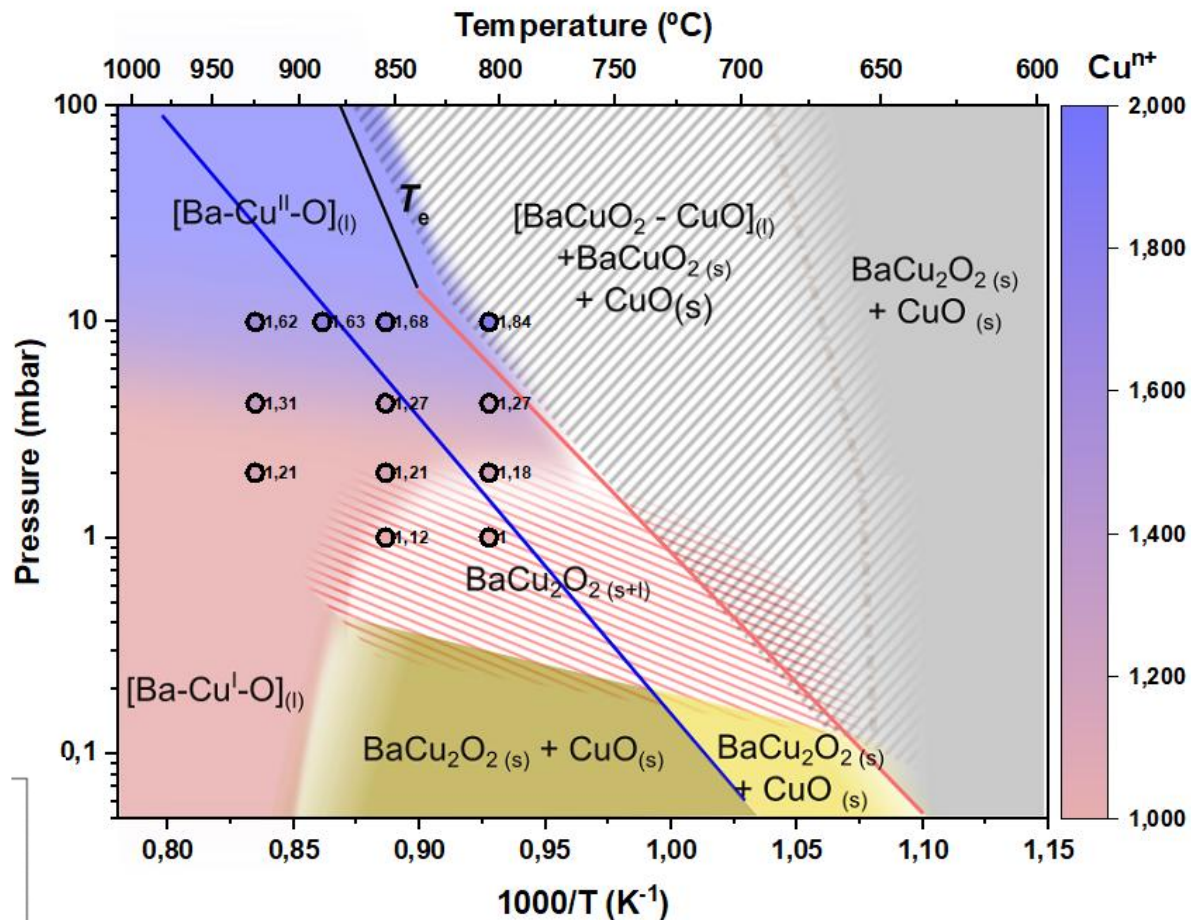
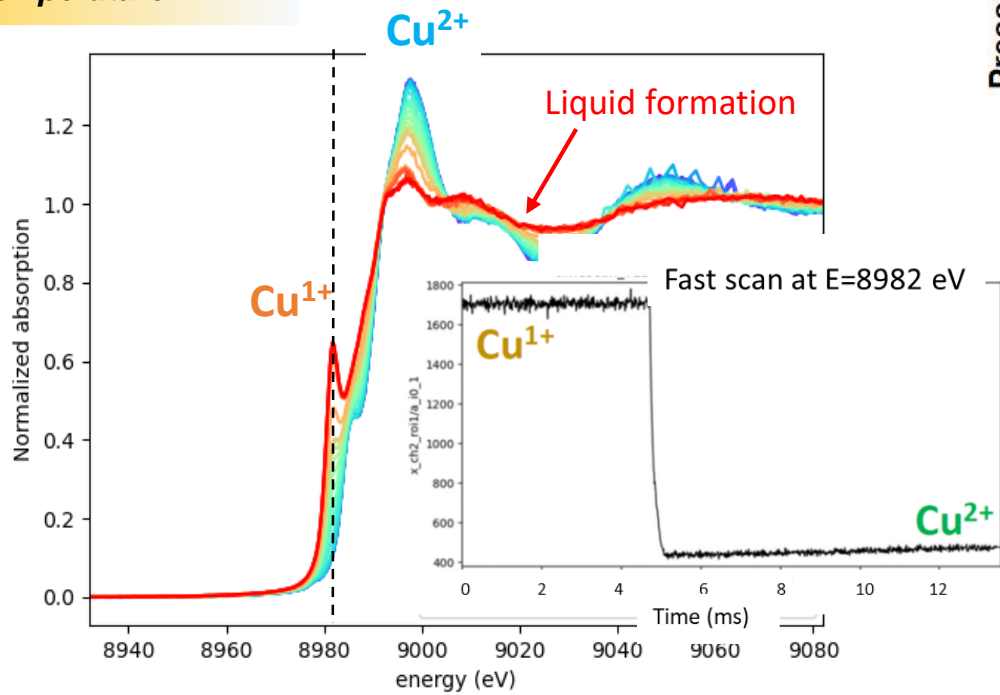
See E. Pach, 3-MO-FP.3

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Study of the properties of the transient liquid

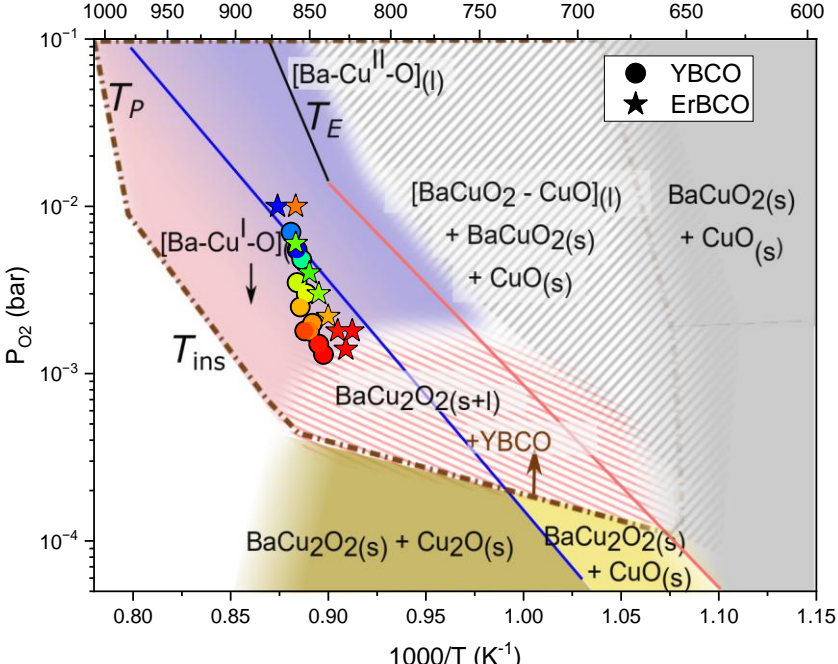
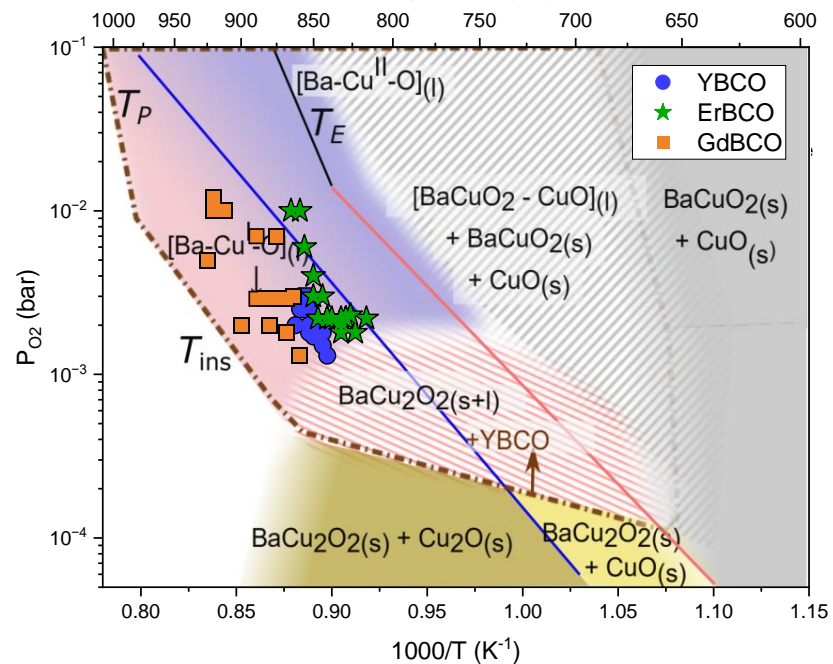
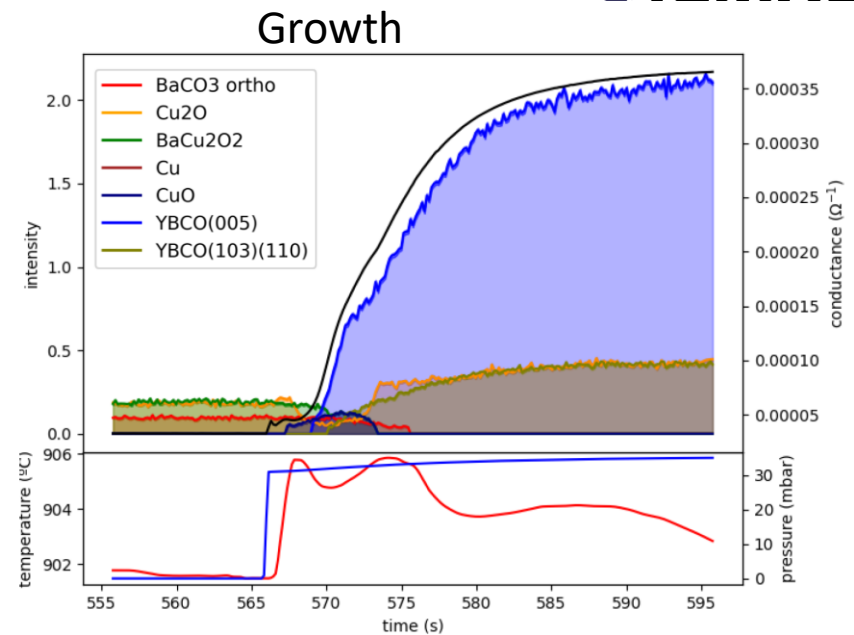
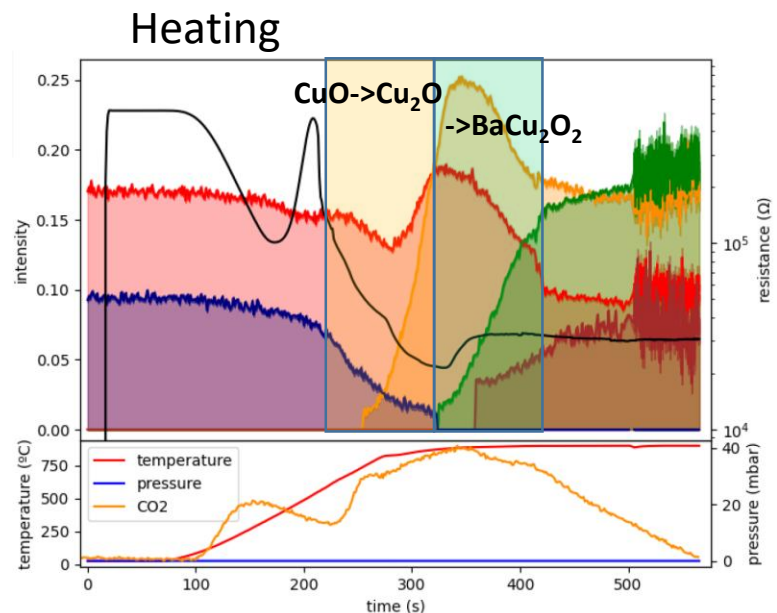
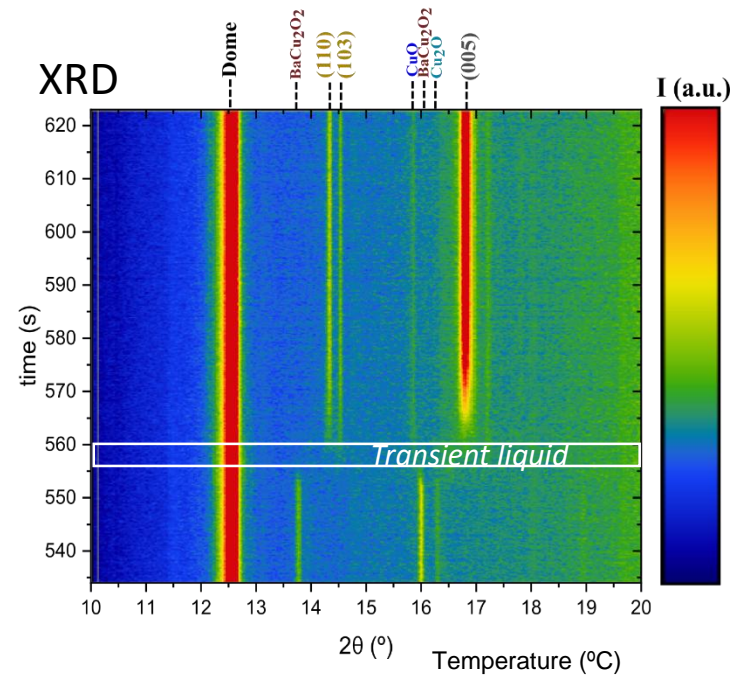


XANES and fast single energy scan at CLAES beamline

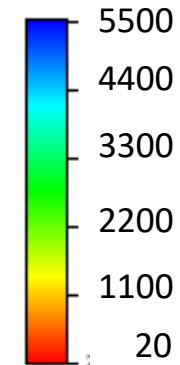


Liquid with a continuous change of Cu valence by varying T , P_{O_2} , through which REBCO grows

Understanding ultrafast TLAG growth process with in-situ multiple analysis



Average growth rate (nm/s)

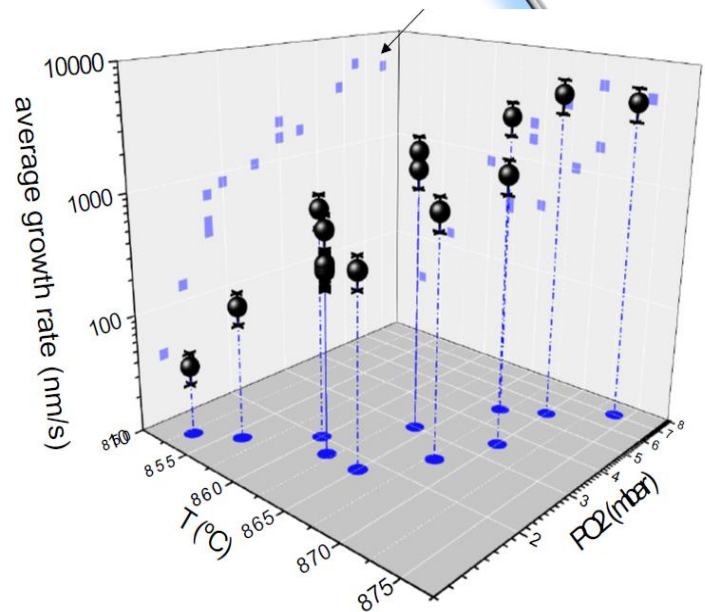


Growth rate increases with increasing supersaturation

See C. Torres, 1-MO-CC.2,
O. Mola, 1-MO-CF1.2

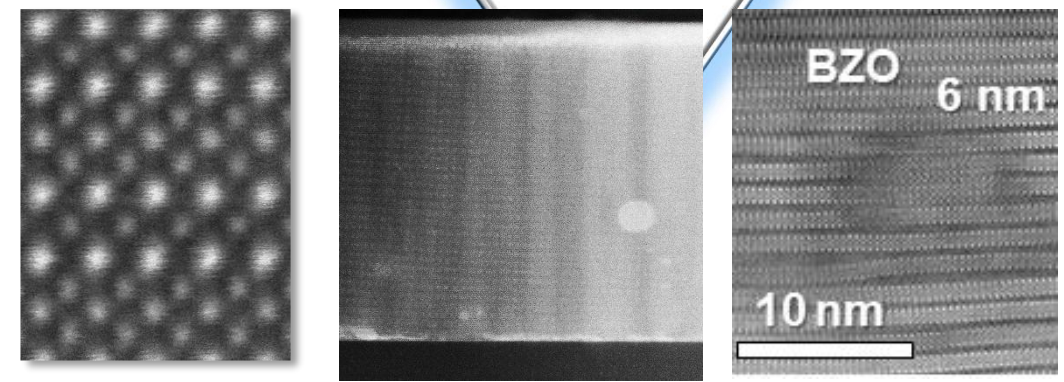
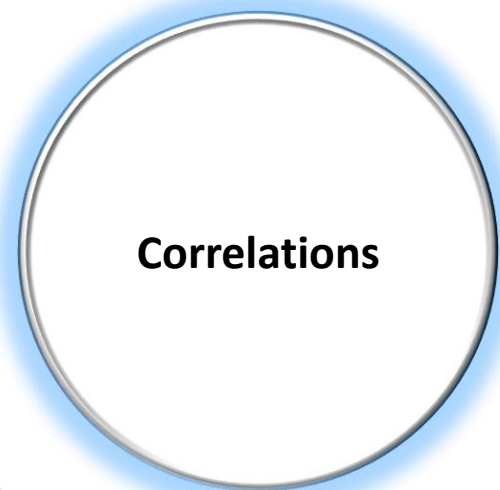
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Correlation pinning-microstructure-growth rate

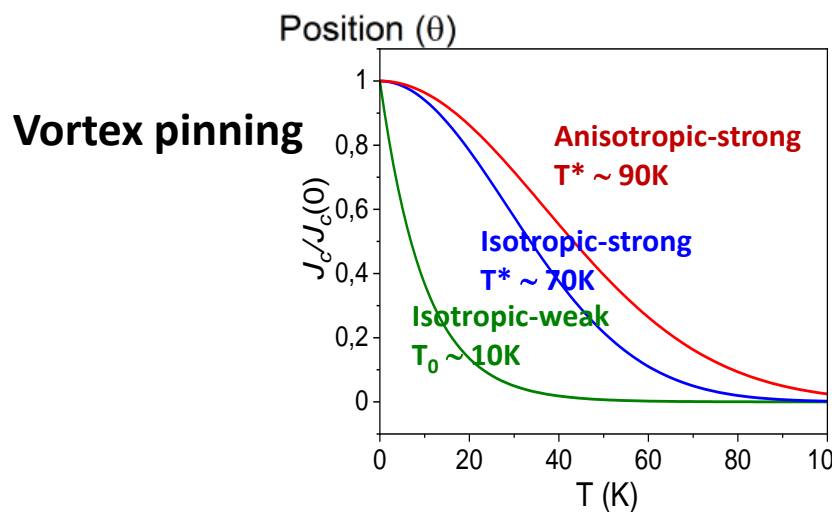
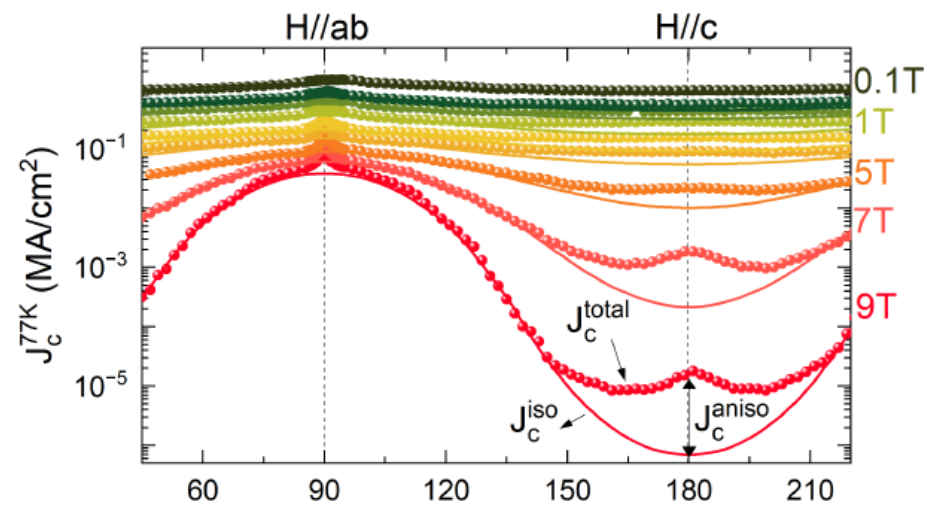


Growth rate
(process parameters)

see M. Voulhoux, 2-MP-CC-167



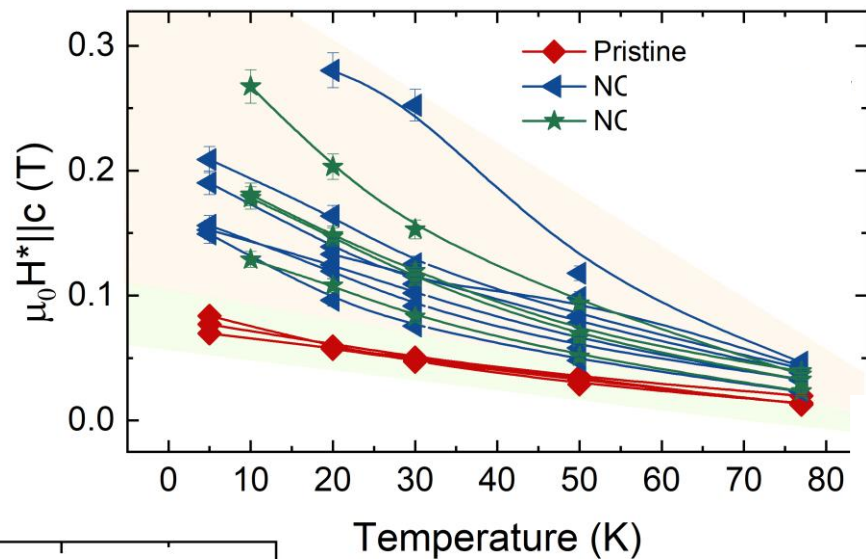
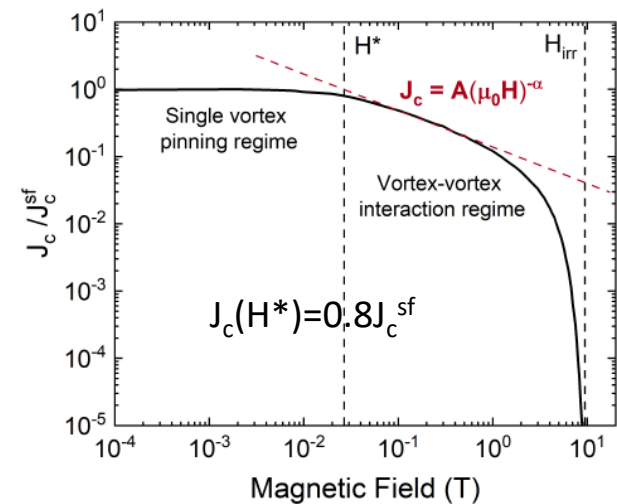
Microstructural defects



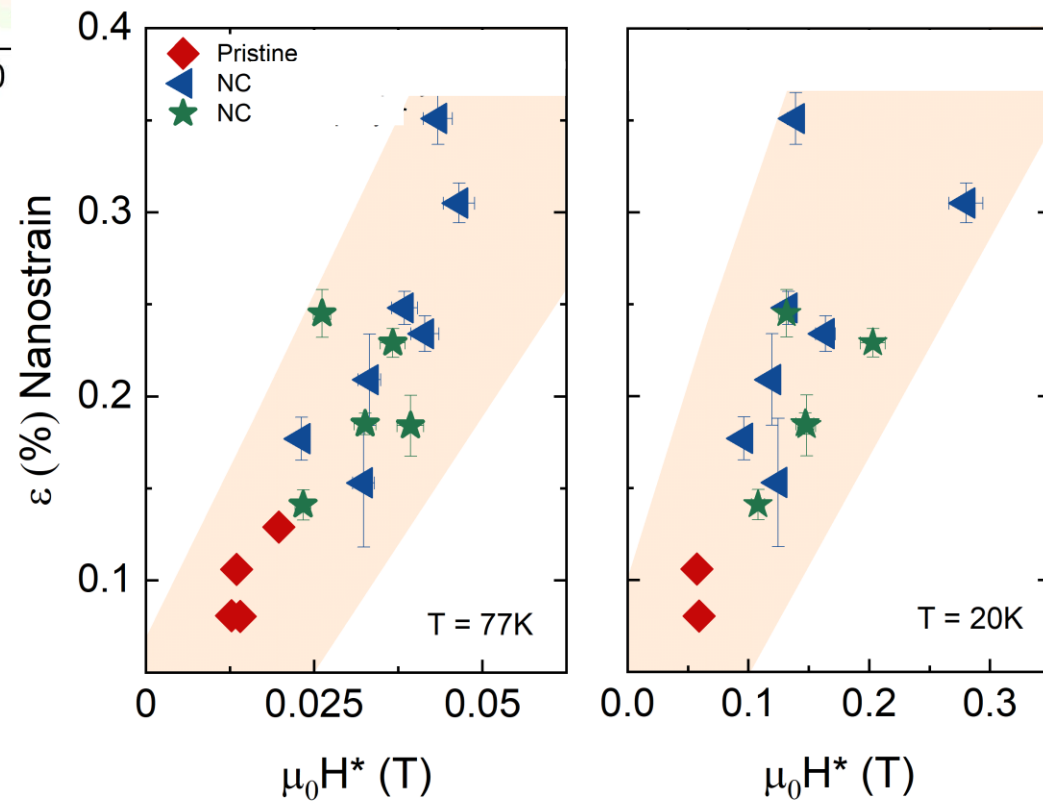
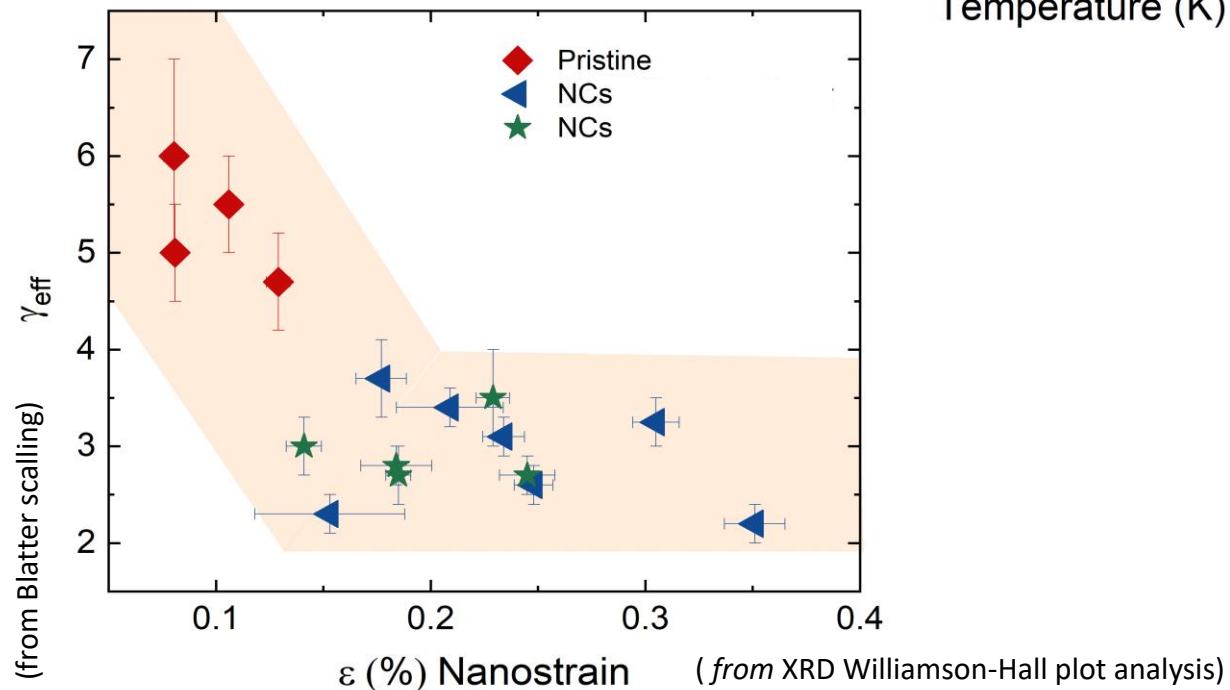
T. Puig et al, Nat Rev Phys (2024)

T. Puig -EUCAS-2025

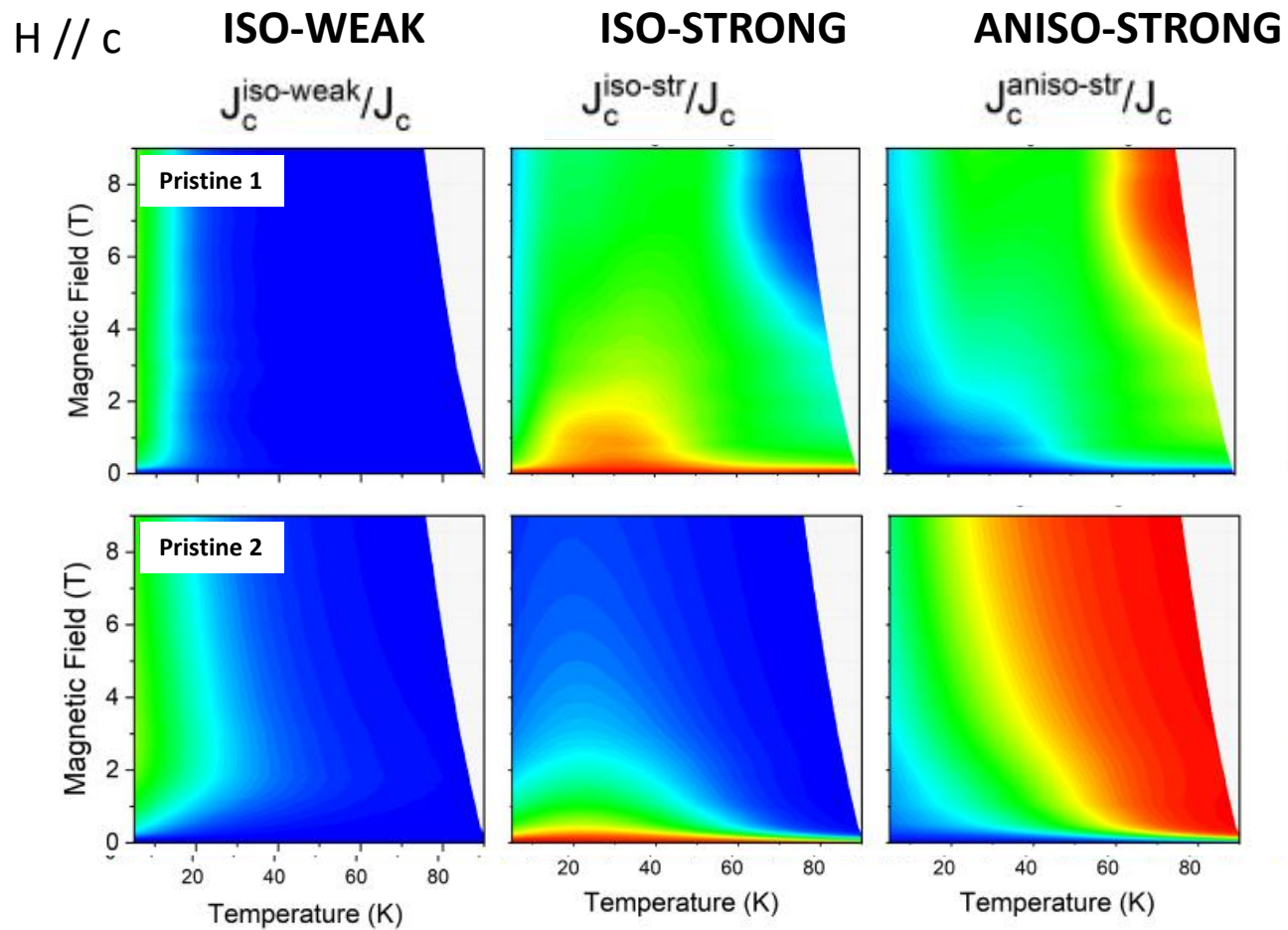
Properties of TLAG films



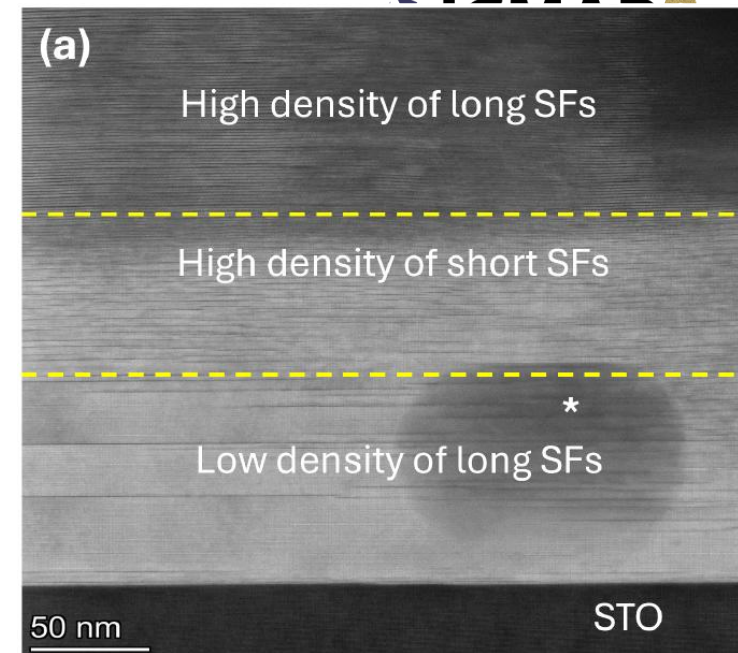
Nanocomposites increase H^* and nanostrain while decrease effective anisotropy



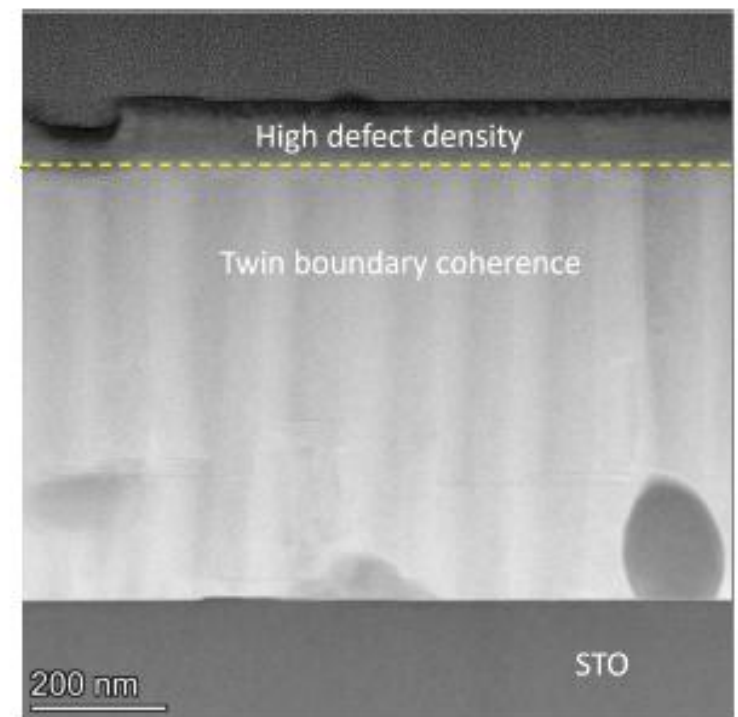
YBCO Pristine vs processing



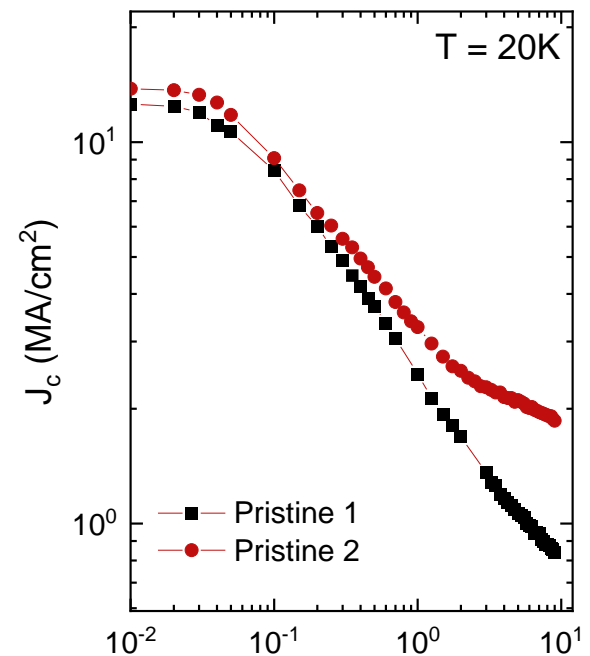
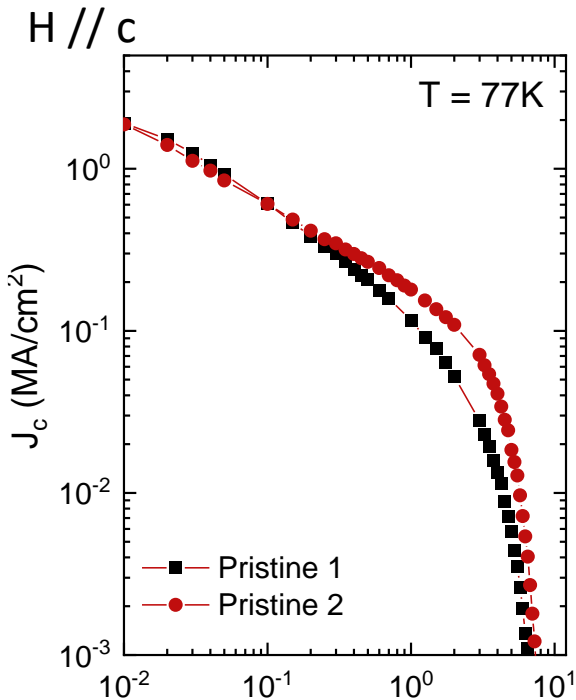
Pristine 1



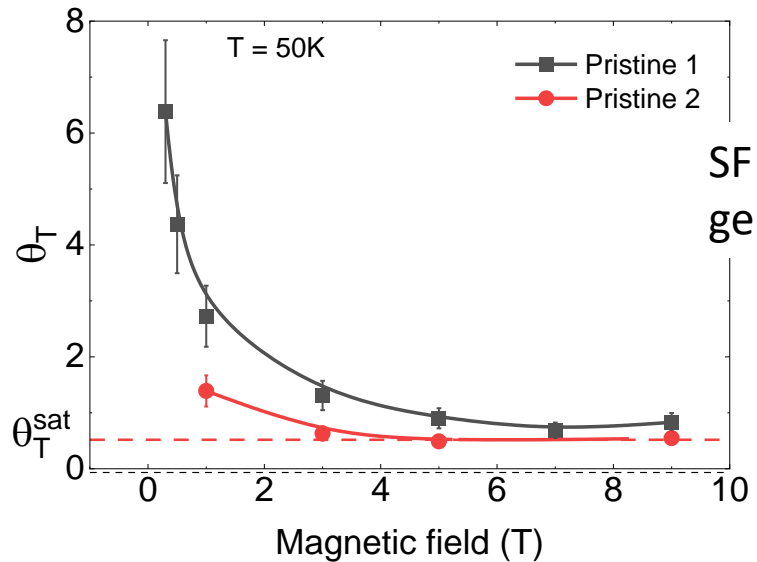
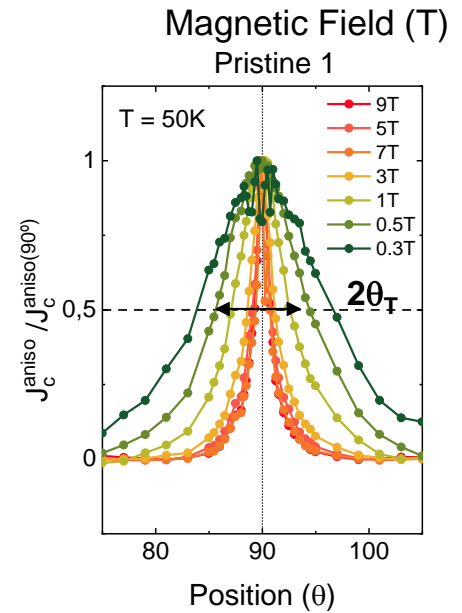
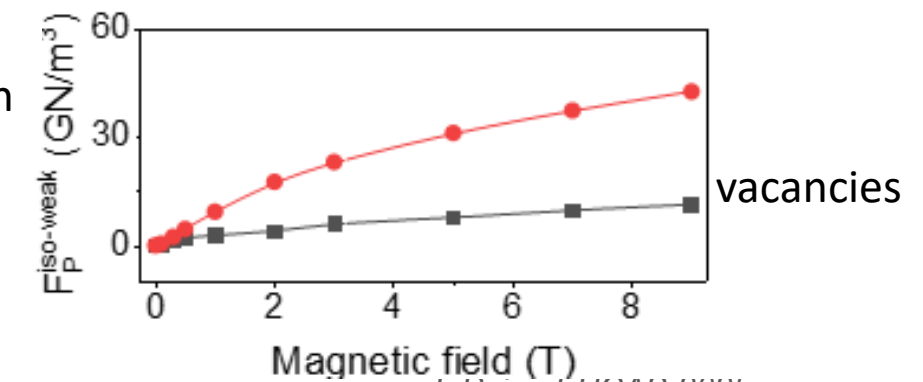
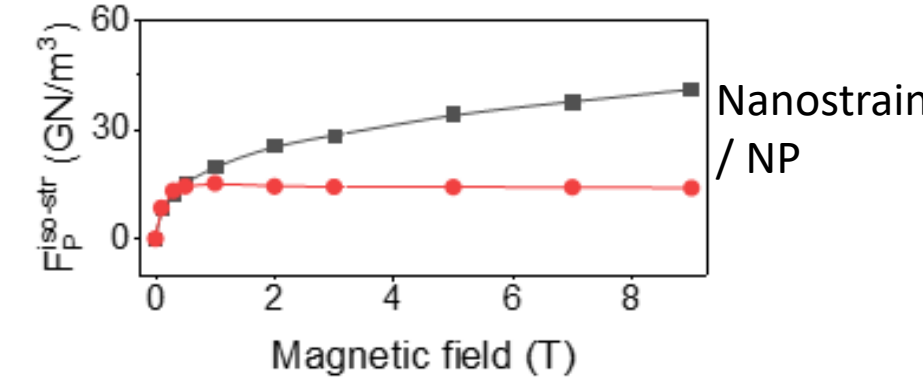
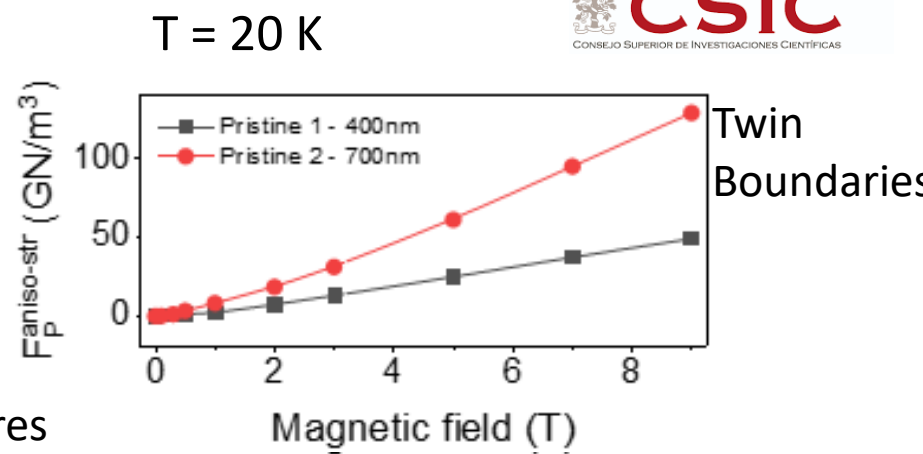
Pristine 2



YBCO Pristine vs processing



Pinning by TB can be very effective also at rather low temperatures



SF are effective generators of strain

YBCO NCs vs processing

H // c

ISO-WEAK

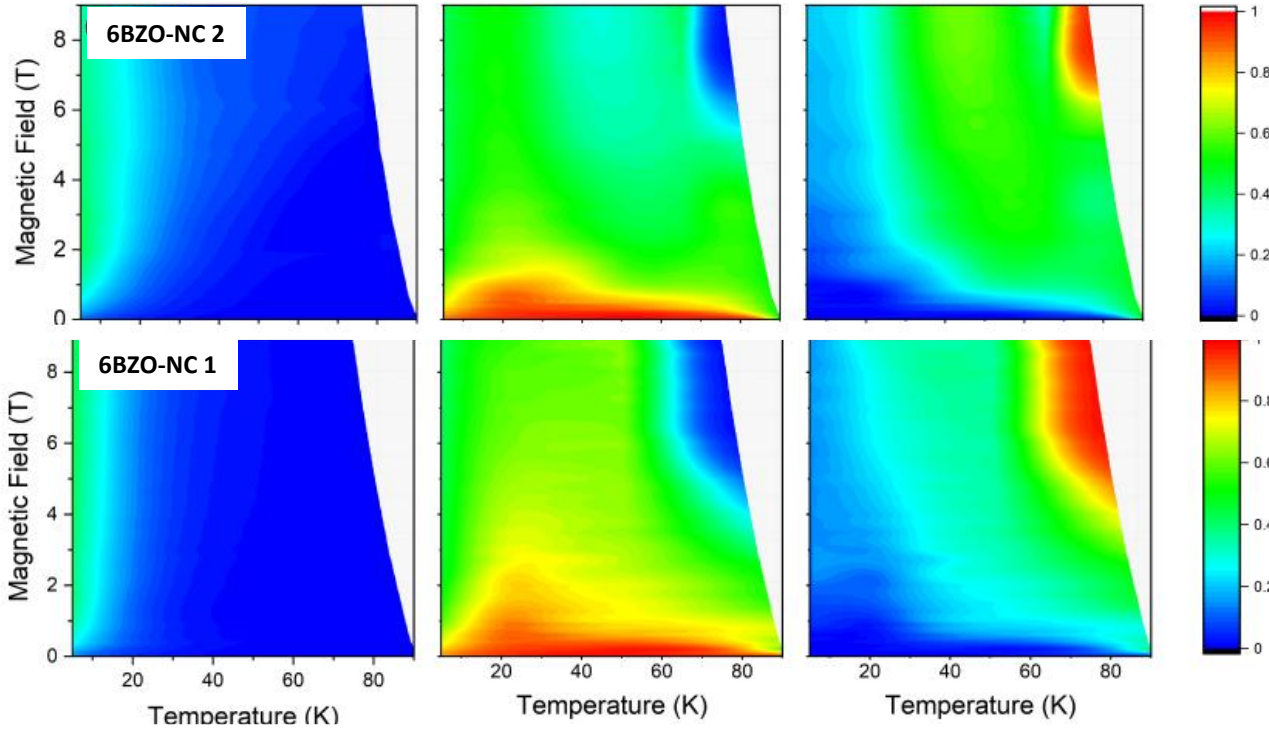
ISO-STRONG

ANISO-STRONG

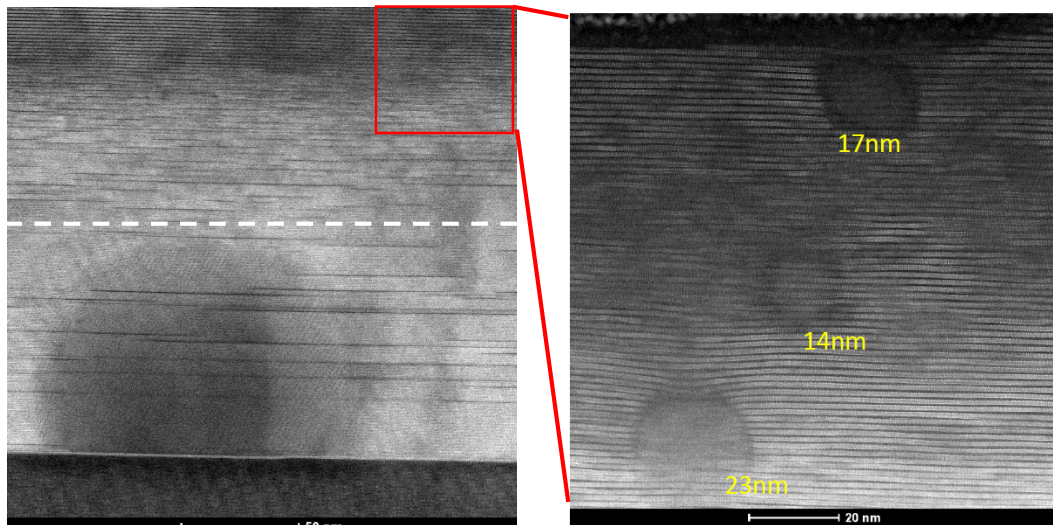
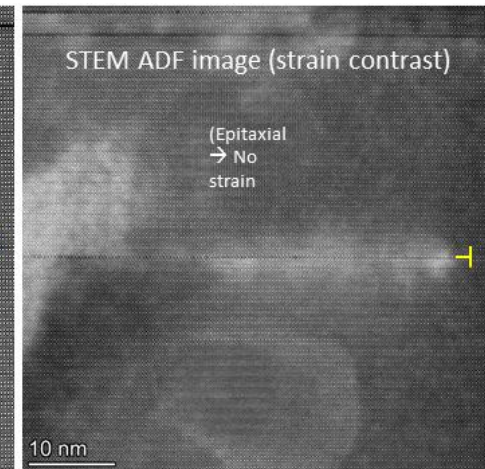
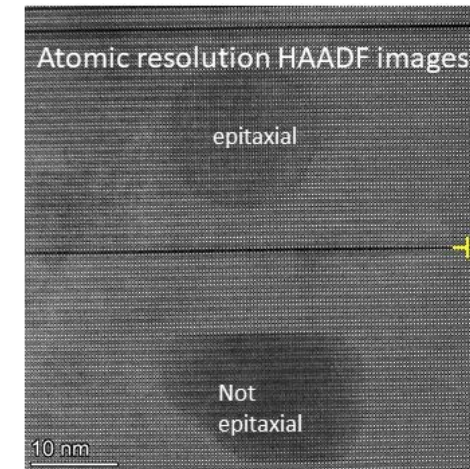
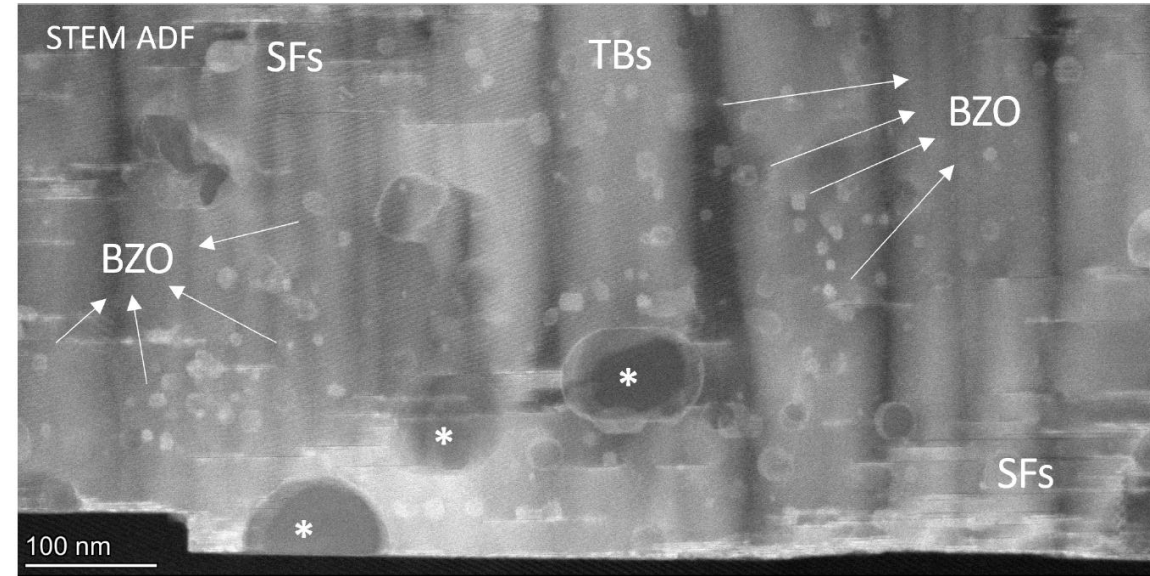
$J_c^{iso-weak}/J_c$

$J_c^{iso-str}/J_c$

$J_c^{aniso-str}/J_c$



12% Nanocomposite 2



Large density of SF
Nanostrain

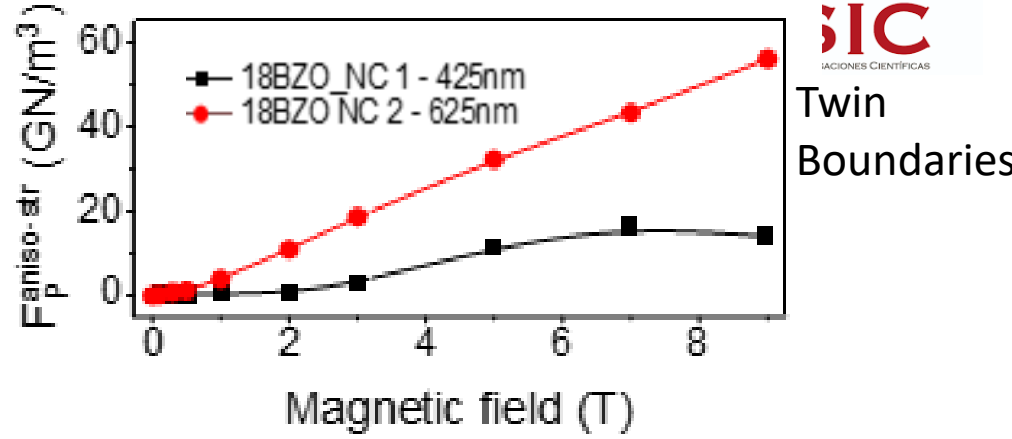
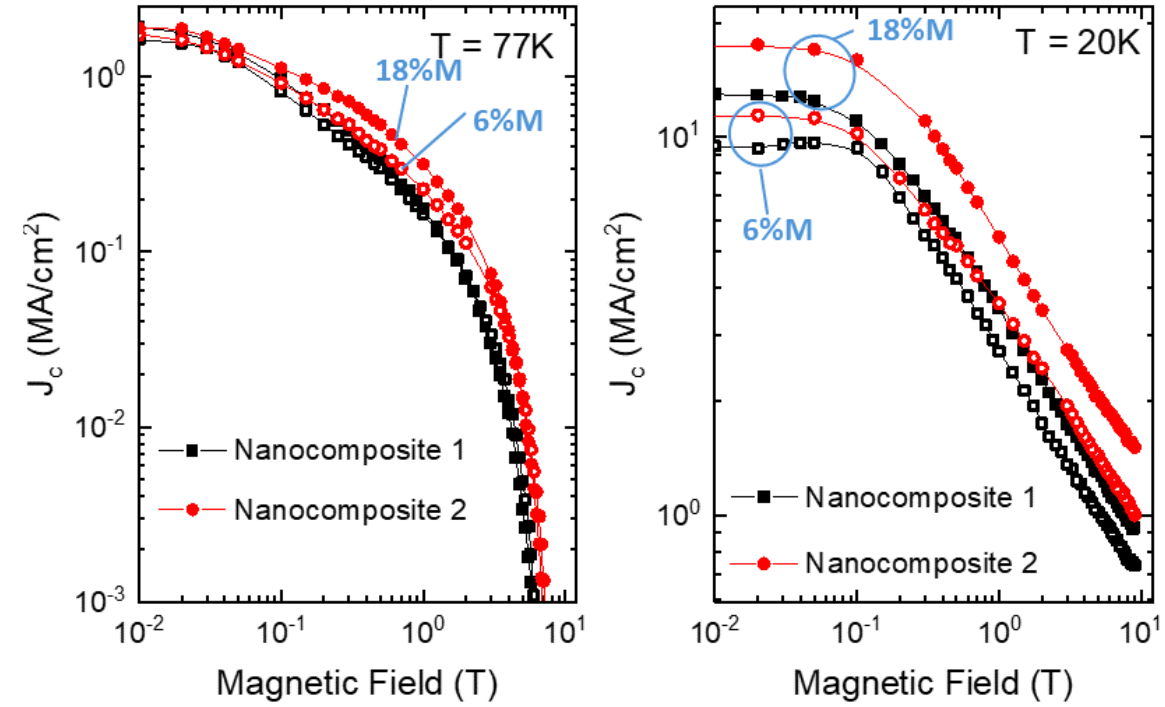
12% Nanocomposite 1

High density of TB and small nanoparticles

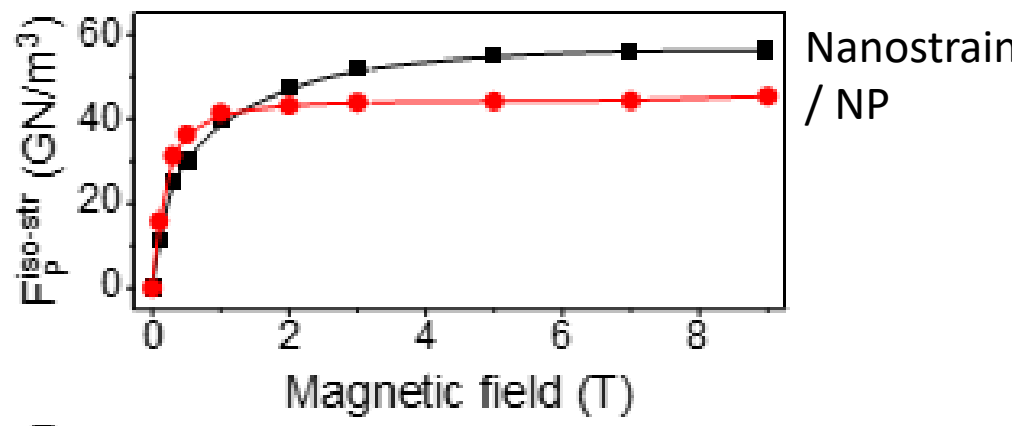
Nanocomposites vs processing

H // c

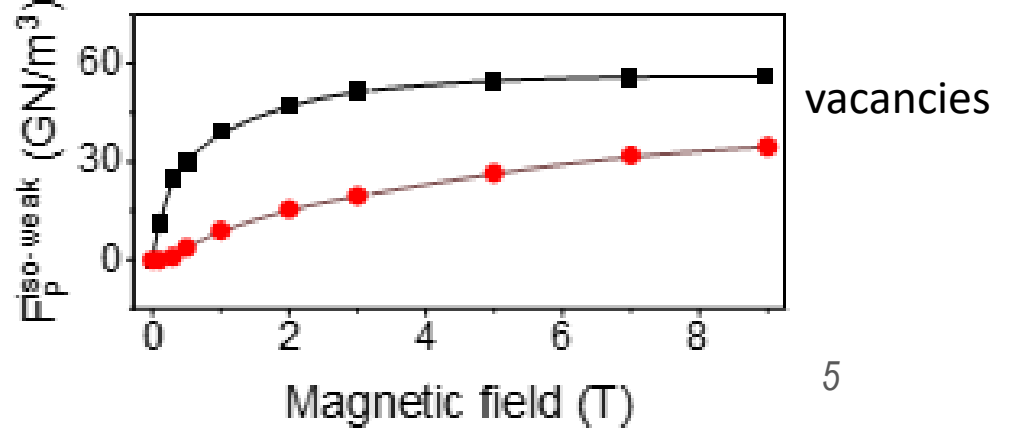
T = 20 K



Twin Boundaries



Nanostrain / NP



vacancies

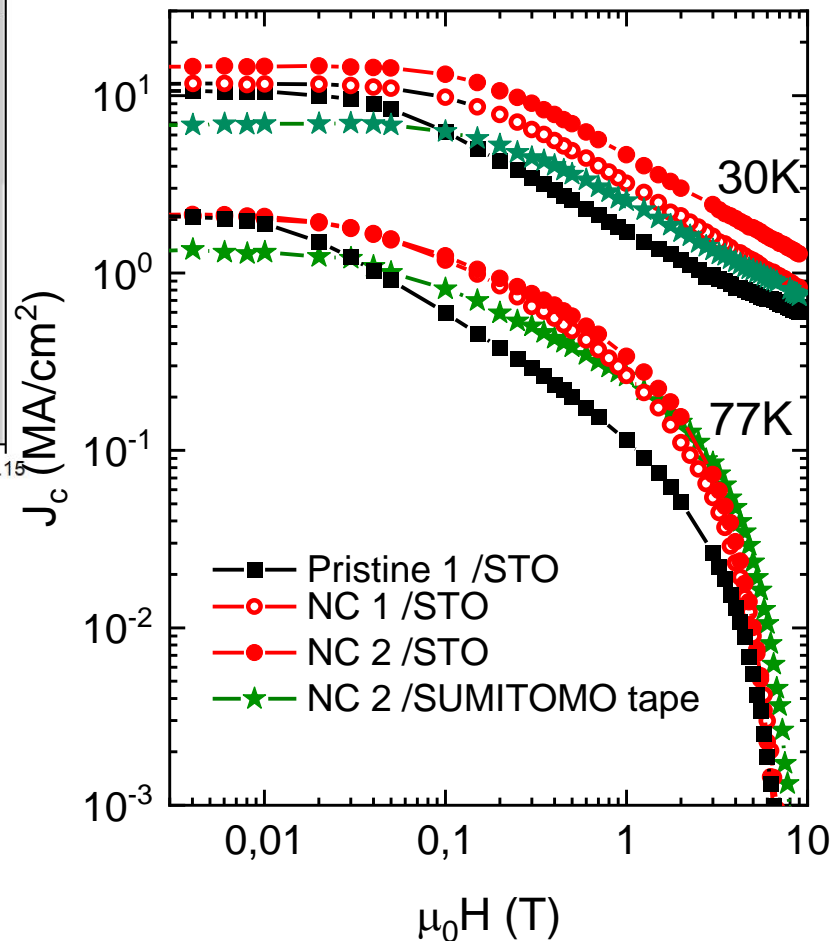
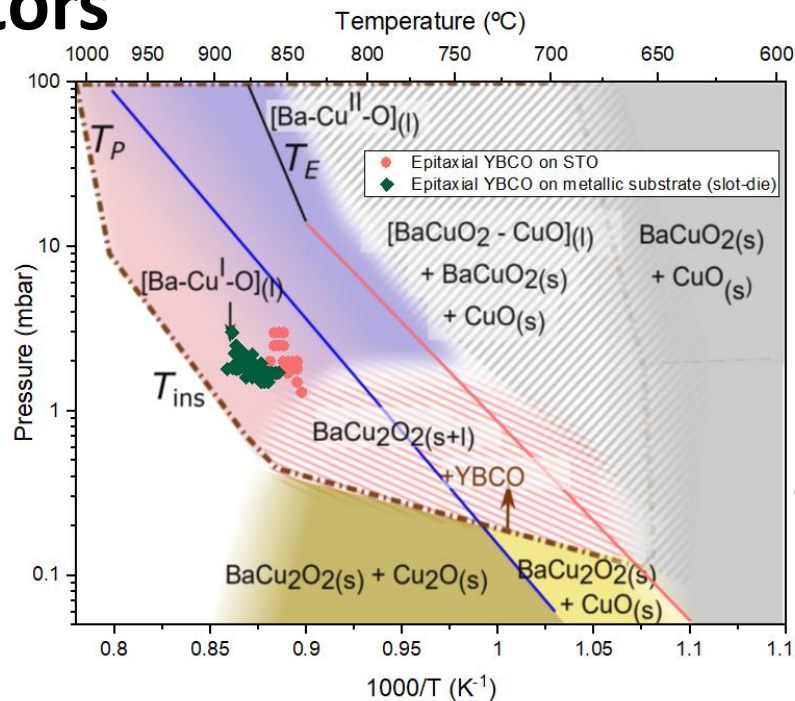
TB can very effective pinning centers in NC even at rather low temperatures too
Nanoparticles and nanostrain can bring similar contributions

Pinning landscape can be build up

TLAG Coated conductors

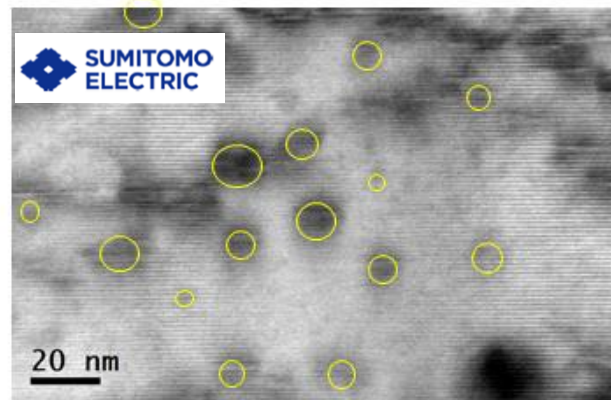
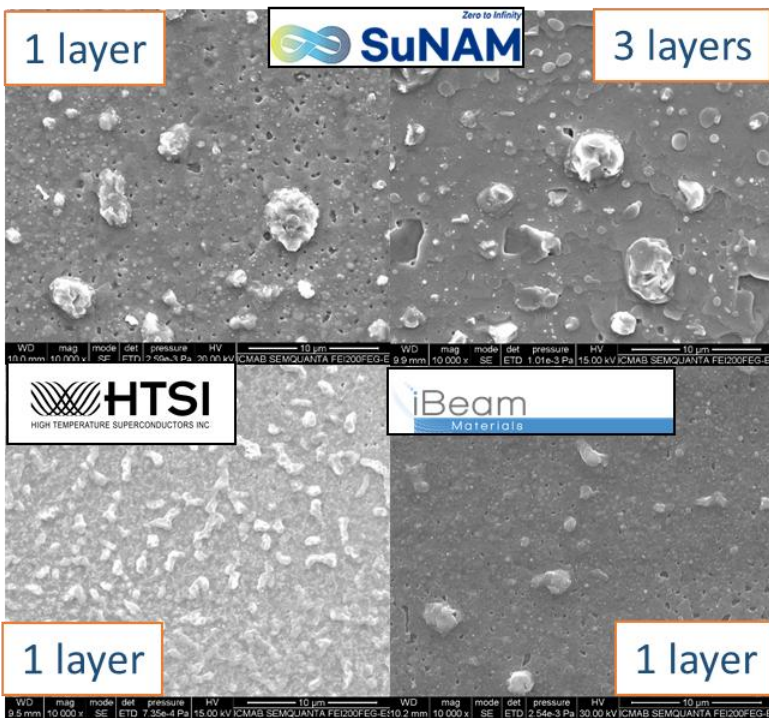


Patent EP22382741



Similar behaviour achieved

see R.Vlad, 1-MP-PM-192, V. Bertini, 1-MP-PM-193, C. Pop, 1-MO-CC.3



High superconducting properties on different tapes: $J_c(77K) = 1.7-2 \text{ MA/cm}^2$

Conclusions

- TLAG is a high-throughput process, with very high growth rates, versatile and with a large processing window, compatible with different RE and nanocomposites (see **C. Torres, 1-MO-CC.2, O. Mola, 1-MO-CF1.2**)
- In-situ Synchrotron techniques are ideal to underpin the TLAG mechanisms (see **E. Pach, 3-MO-FP.3**)
- The correlation between vortex pinning – microstructure – processing identifies a tunable pinning landscape with TLAG process (see **M. Voulhoux, 2-MP-CC-167**)
- TLAG coated conductors are feasible and we are committed to demonstrate that TLAG is a large area processing method that adapts to the needs of increased production (see **R.Vlad, 1-MP-PM-192, V. Bertini, 1-MP-PM-193, C. Pop, 1-MO-CC.3**)
- Vortex pinning in the overdoped state is the future to achieve higher efficiency due to the increase in condensation energy in a robust way (see **X. Obradors, 3-MO-FP.1**)
- High Throughput Experimentation with combinatorial gradients and AI should accelerate the selection of compositions and conditions (see **E. Ghiara, 2-MO-FP.5**)

Thank you for your attention!

