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ALBA

Investigating growth rate dependence of $REBa_2Cu_3O_{7-x}$ films grown by TLAG

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J. Gutierrez[1], X. Obradors[1], T. Puig[1]

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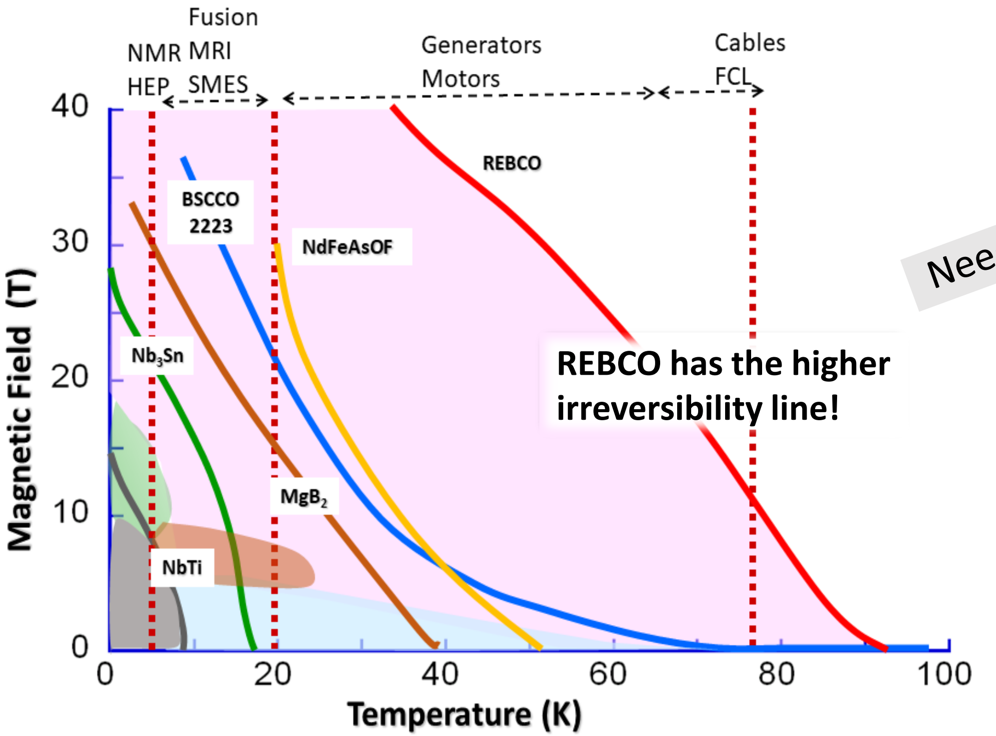
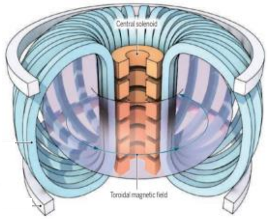
Introduction



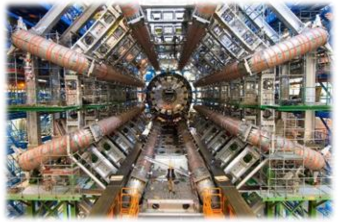
REBCO has the higher irreversibility line!

Fusion



Superconducting wires

CERN - HEP



A. Molodyk et al, Science, (2023)
B. G. Marchionini et al, IEEE TAS, (2017)
A. Romanov et al, Sci Rep, (2020).

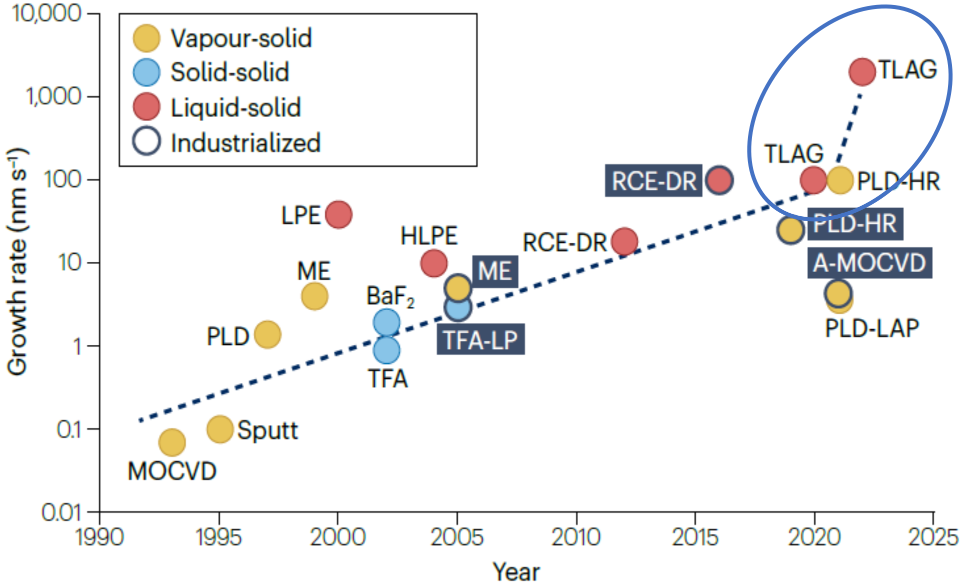
Need to reduce costs

$$\frac{\text{cost}}{\text{performance}} = \frac{\text{total cost per year}}{G \cdot W \cdot J_c \cdot t} = \frac{\$}{\text{kA} \cdot \text{m}}$$

G = growth rate
W = width
t = thickness

Transient Liquid Assisted Growth (TLAG)

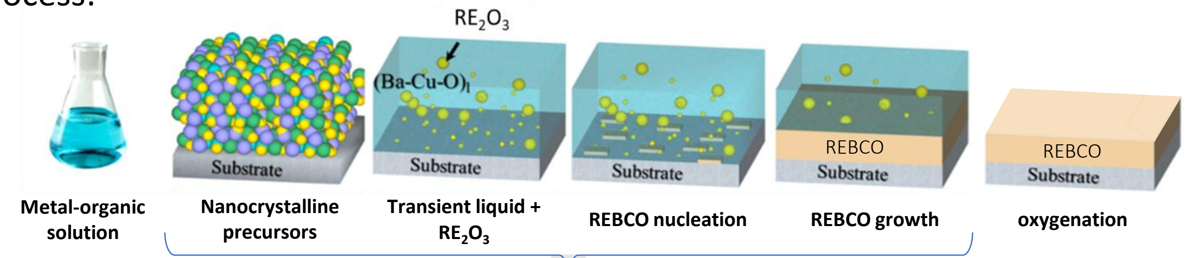
- Use of Chemical Solution Deposition
- Jc(77K, sf) = 3-5 MA/cm^2
- Thick films t≈1.2µm
- **High growth rates (100-1000 nm/s)**

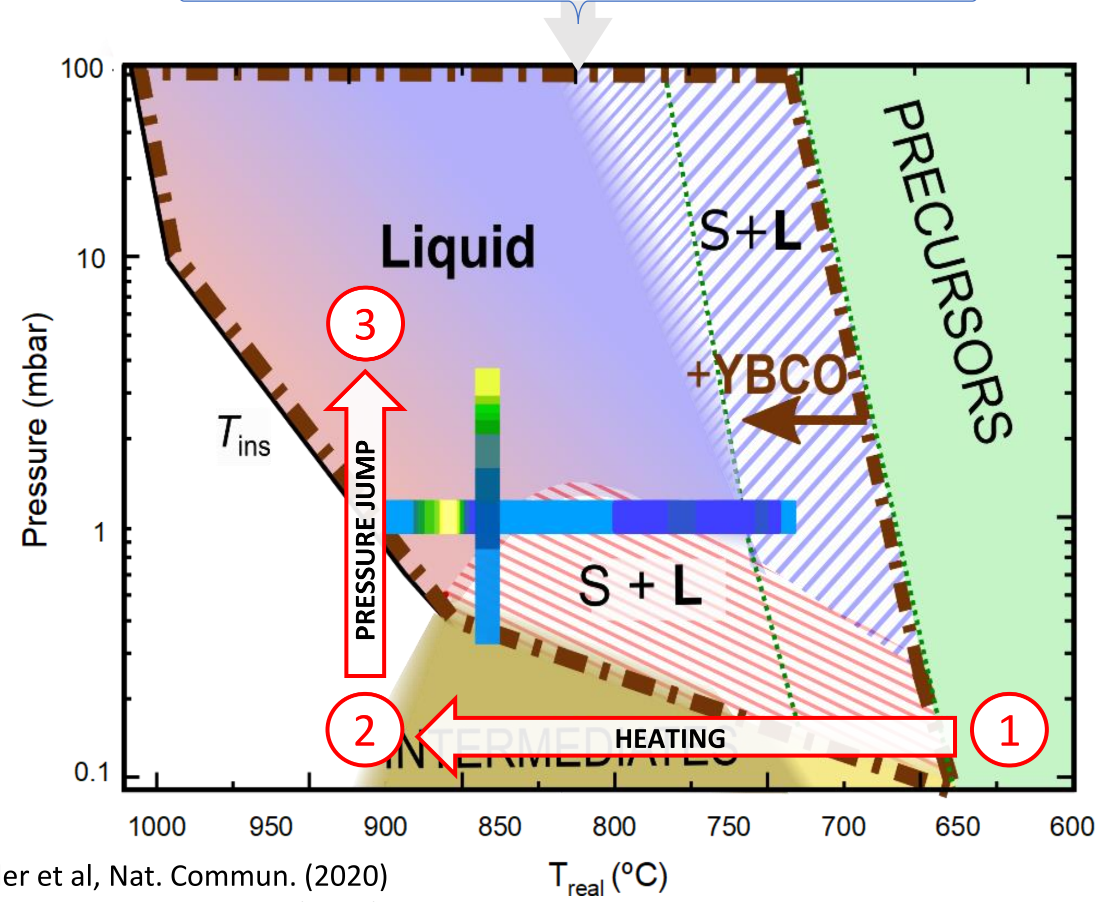


L. Soler et al, Nat. Commun. (2020)
S. Rasi et al, Adv. Sci. (2022)
T. Puig et al, Nat. Rev. Phys. (2023)

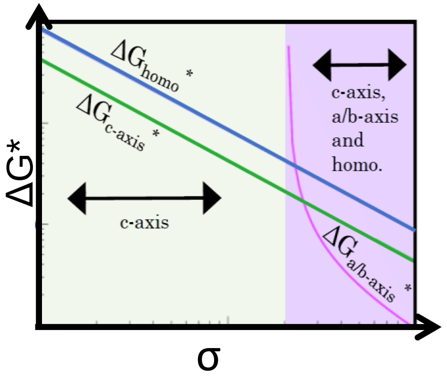
Transient Liquid Assisted Growth – Chemical Solution Deposition

Process:





Control of TLAG process: supersaturation σ



σ ↑ ⇒ growth rate ↑

σ ↑ ⇒ epitaxy ↓

Compromise between high growth rates and epitaxy

① Nanocrystalline precursors: $BaCO_{3(s)} + CuO_{(s)} + Y_2O_{3(s)}$

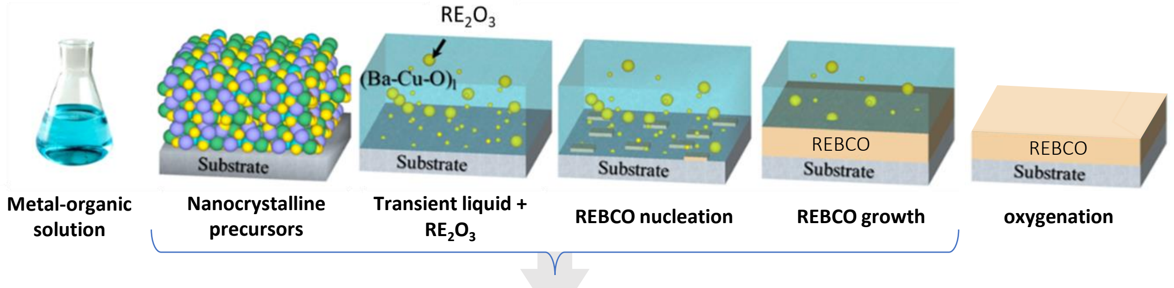
① $\xrightarrow{\text{HEATING}}$ ② Intermediate reactions

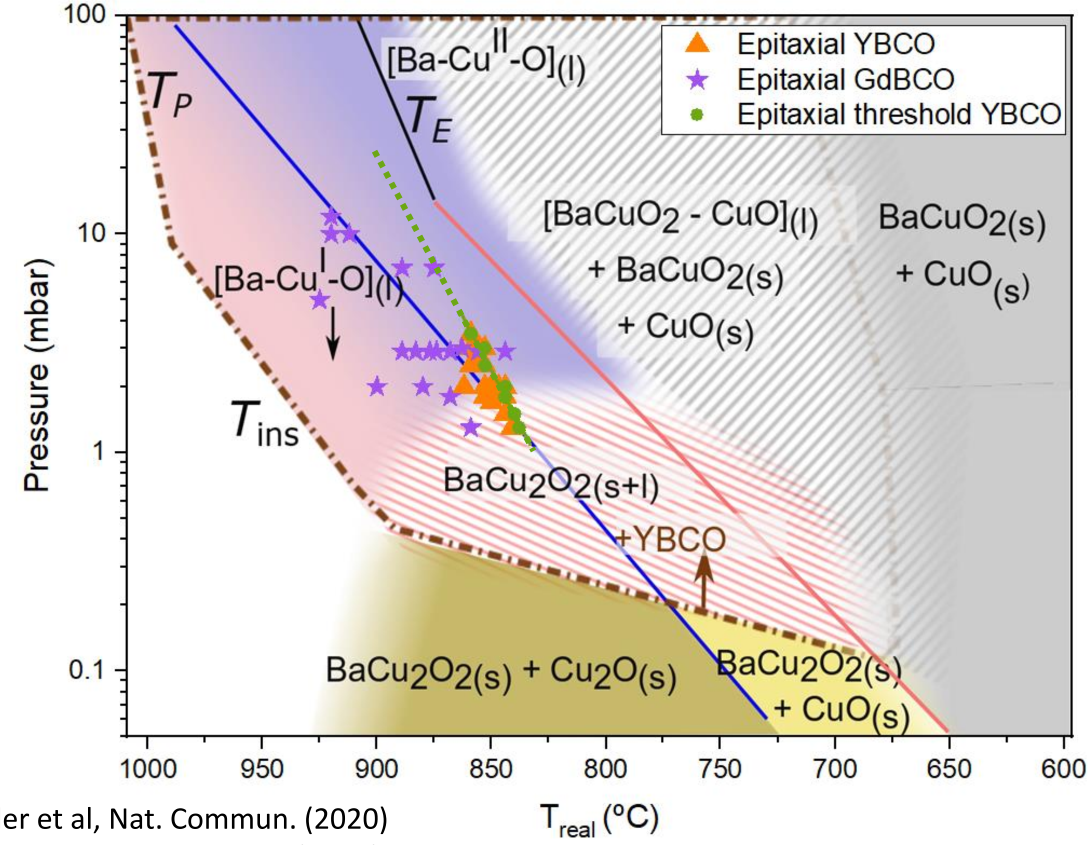
② $\xrightarrow{\text{PRESSURE JUMP}}$ ③ Transient liquid formation: $(Ba - Cu^{I/II} - O)_{(l)} + Y_2O_{3(s)}$

③ REBCO growth: $YBa_2Cu_3O_{7-\delta}$

L. Soler et al, Nat. Commun. (2020)
S. Rasi et al, J. Phys Chem C (2020)
S. Rasi et al, Adv. Sci. (2022)

Transient Liquid Assisted Growth – Chemical Solution Deposition





L. Soler et al, Nat. Commun. (2020)
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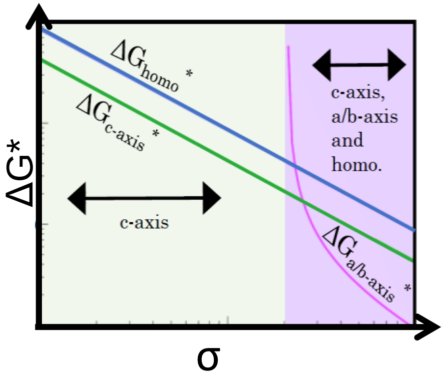
Control of TLAG process: supersaturation σ



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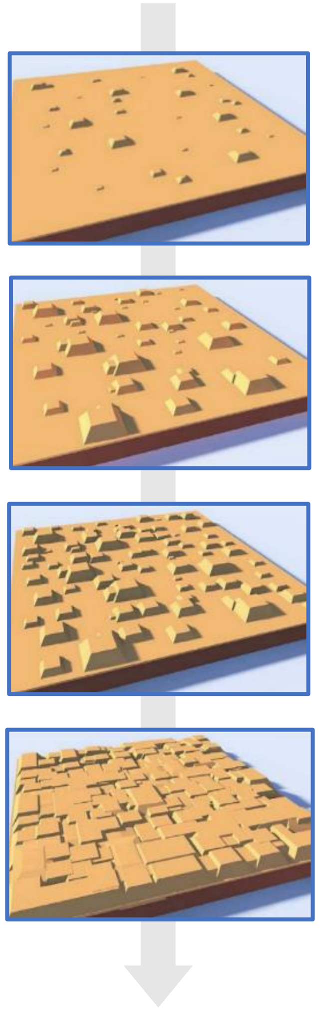
ALBA

In-situ XRD at ALBA Synchrotron enables studying intermediate phase evolution and TLAG non-equilibrium growth mechanism

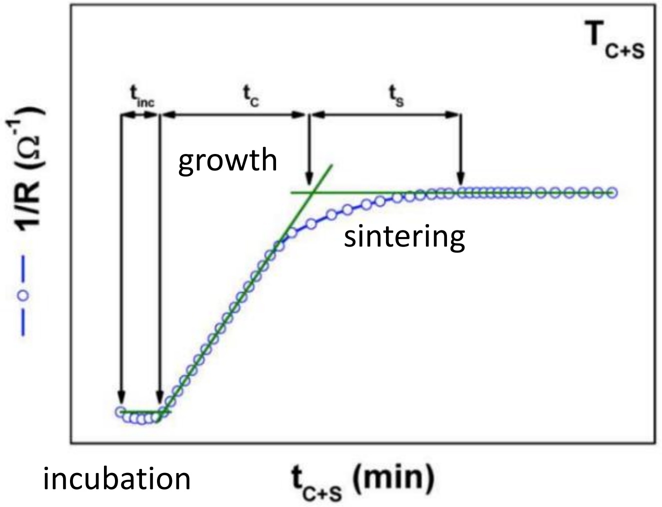
Wide window of T, P_{O2} conditions for epitaxial REBCO growth

3D island nucleation and growth model

Volmer-Weber growth model (island model)



From electrical measurements during growth:

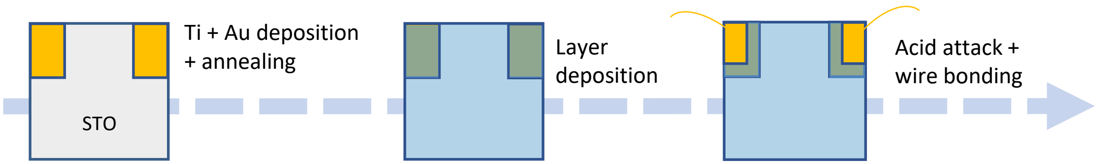


We can measure the growth rate:

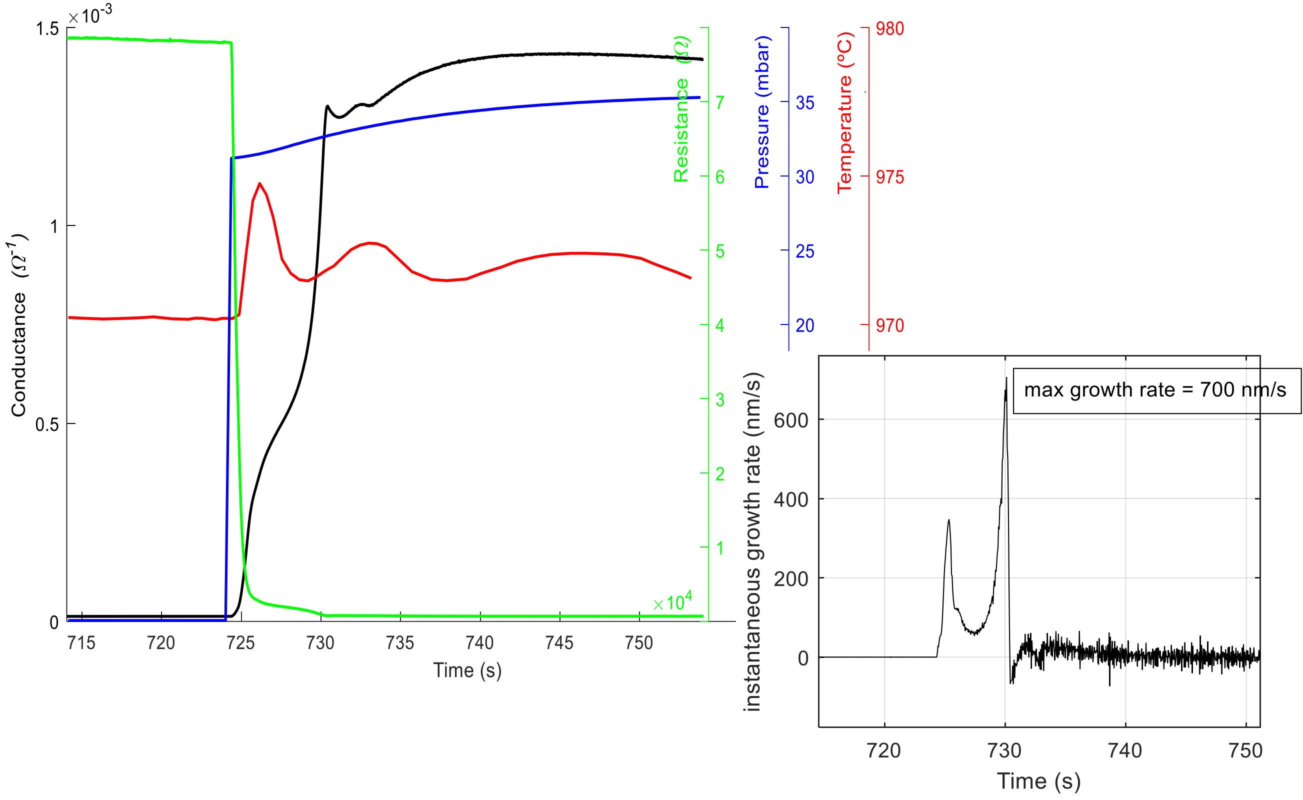
$$R^{-1} = \left(\frac{w}{\rho l}\right) G t_c; \quad G = \frac{\text{thickness}}{t_c}$$

ρ = resistivity
l = distance between contacts

- Sample preparation:

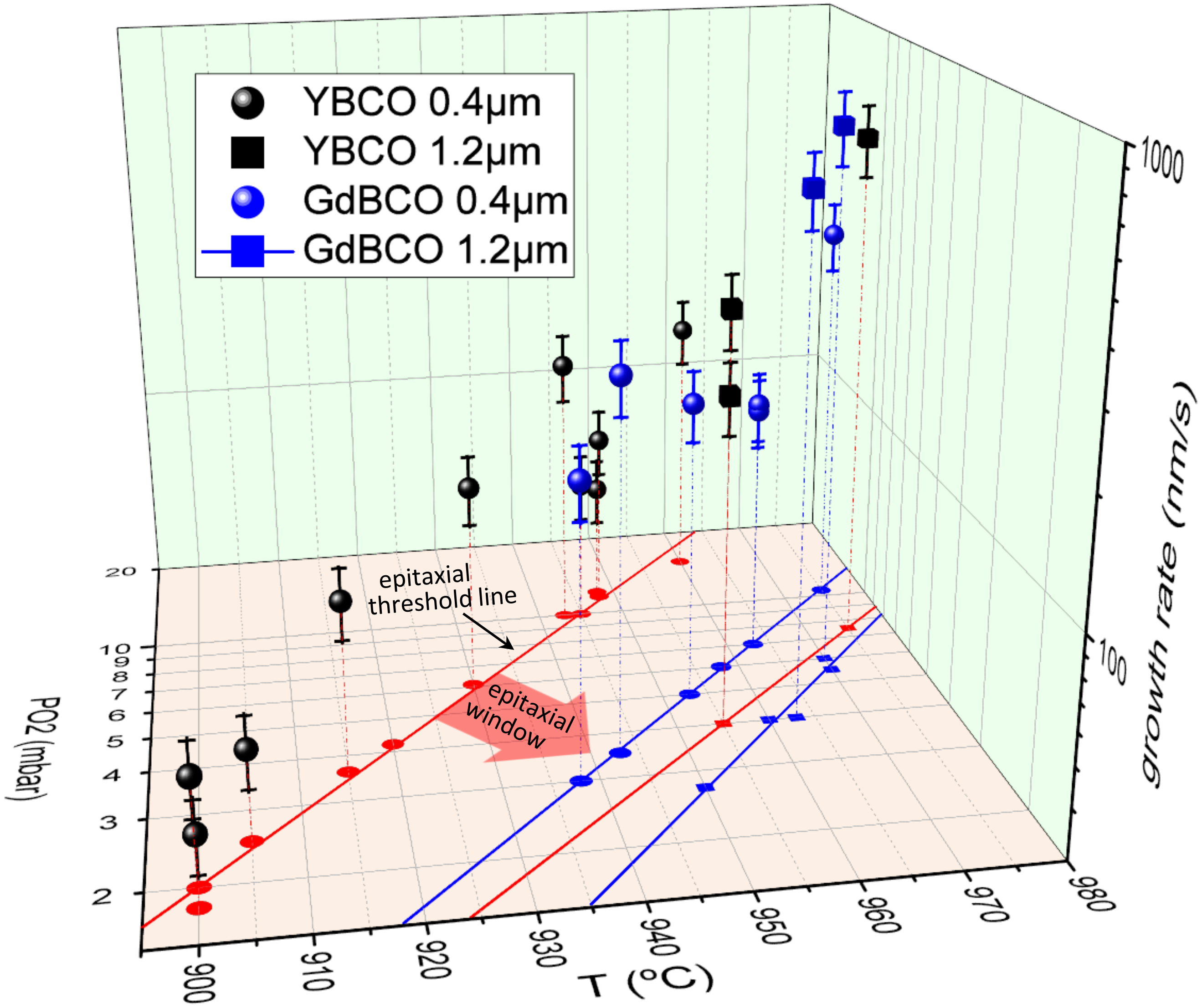


- Growth:



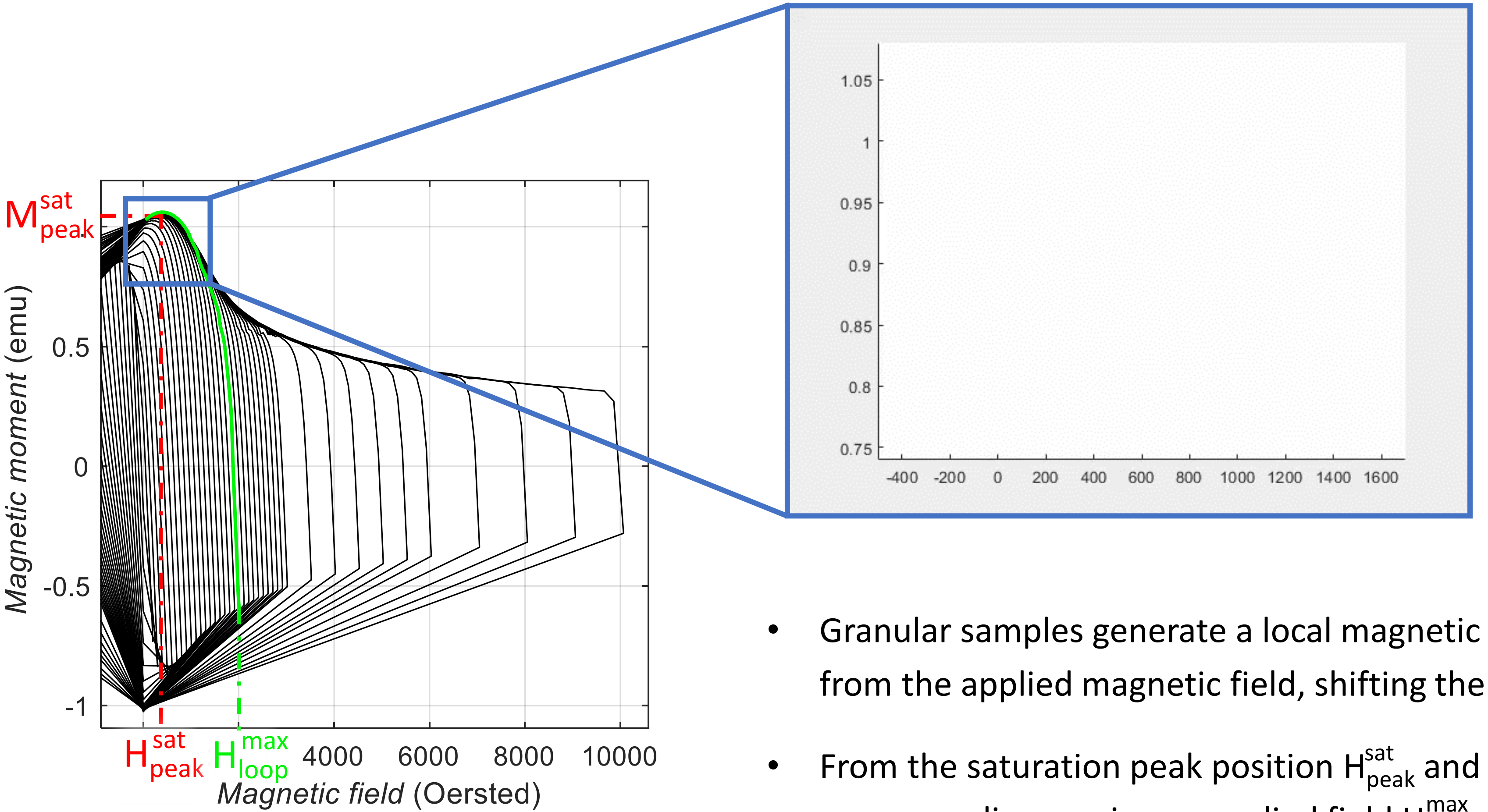
C. F. Sánchez-Valdés et al, Supercond. Sci. Technol. 28 (2015)
X. Obradors et al, Chem. Soc. Rev. 43 (2014)

Growth rate dependence on TLAG conditions

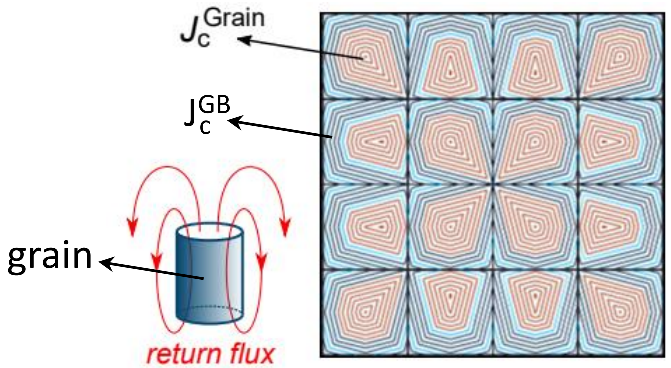


- Growth rate depends on the thermodynamic parameters: T, P_{O2}
- Growth rate increases at higher T and P_{O2}

Magnetic granularity analysis



Example of minor loops (hysteresis loop from different maximum applied magnetic fields until reaching saturation) for a thin superconductor film exhibiting magnetic granularity



Top view of a SC thin film with magnetic grains and percolation currents upon application of an external magnetic field

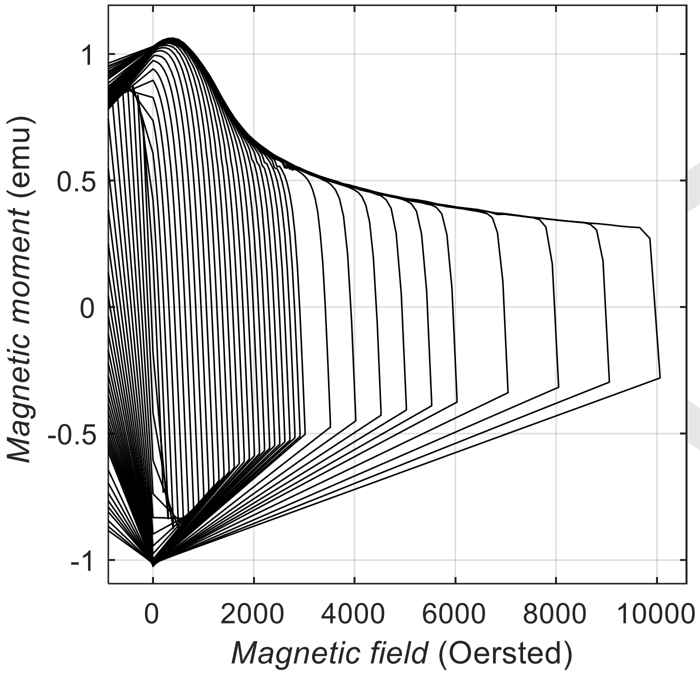
- Granular samples generate a local magnetic field at the grain boundaries different from the applied magnetic field, shifting the peak of the magnetization loop.
- From the saturation peak position H^{sat}_{peak} and corresponding maximum applied field H^{max}_{loop}, an average grain size and J_c^{Grain} is calculated:

$$\left\{\begin{array}{l} \text{grain size} = \dfrac{x\cdot t}{n}\,\dfrac{H^{max}_{loop}}{H^{sat}_{peak}} \\ J_c^{Grain} = \dfrac{H^{sat}_{peak}}{x\cdot t} \\ J_c^{GB} = 3\,\dfrac{M^{sat}_{peak}}{R} \end{array}\right.$$

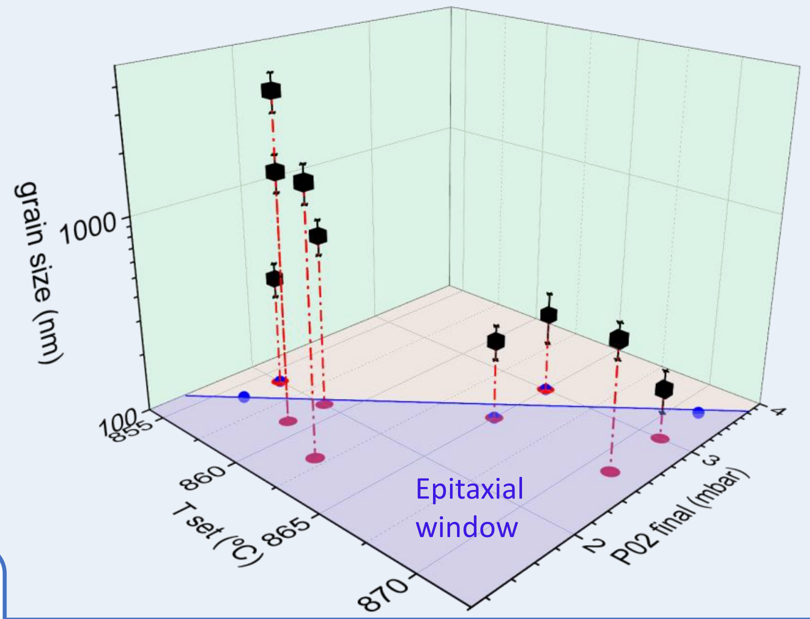
t = thickness
R = effective radius of SC film
x, n = functions of the model

A. Palau et al, Phys. Rev. B (2007)
E. Bartolome et al, Phys. Rev. B (2007)

Magnetic granularity analysis of TLAG films

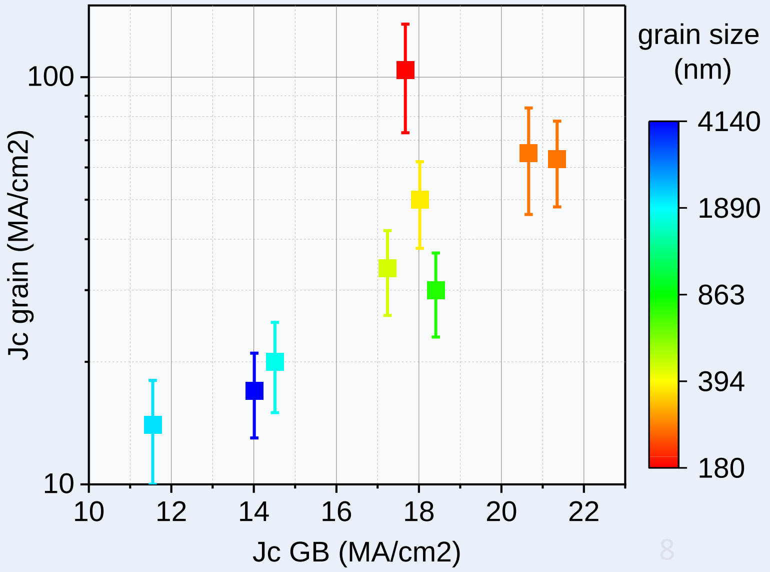


At higher T and P_{O2}, so higher growth rates and supersaturation, the grains are smaller and the nucleation density is higher



High growth rates favour better samples

Samples with smaller grain sizes have higher Jc(grain) and Jc(grain boundary)



Conclusions

- TLAG-CSD is a non-equilibrium ultrafast process enabling high throughput, low cost and high performance REBCO films.
- In-situ resistivity experiments enable the determination of the growth rate dependence on temperature and oxygen partial pressure in TLAG films. We have demonstrated that growth rate increases at higher T, P_{O2}.
- Magnetic granularity studies indicate that higher growth rates favour higher grain and intergrain critical current densities.

FUTURE

- Study the vortex-pinning analysis of samples grown at different growth rates (T, P_{O2} varying conditions), to correlate it with its defect microstructure. This will allow us to determine the defects appear at different conditions and their correlation with Jc(B, T), enabling to identify the best pinning conditions.