Mechanisms of novel transient liquid assisted growth for ultrafast production of $YBa_2Cu_3O_{7-x}$ thin films

L.Soler[1], J.Jareño[1], J.Banchewski,[1] R.Guzmán[1], S.Rasi[2], J.Farjas[2], P.Roura[2], C. Mocuta[3], S.Ricart[1], X.Obradors[1] and T.Puig[1]

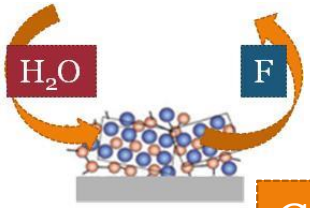
1) *Institut de Ciència de Materials de Barcelona (CSIC), Campus UAB*
2) *University of Girona, Girona,*
3) *Soleil synchrotron, París, France*

EUCAS 2017

TRANSIENT LIQUID ASSISTED GROWTH (TLAG)

CHEMICAL SOLUTION DEPOSITION (CSD)

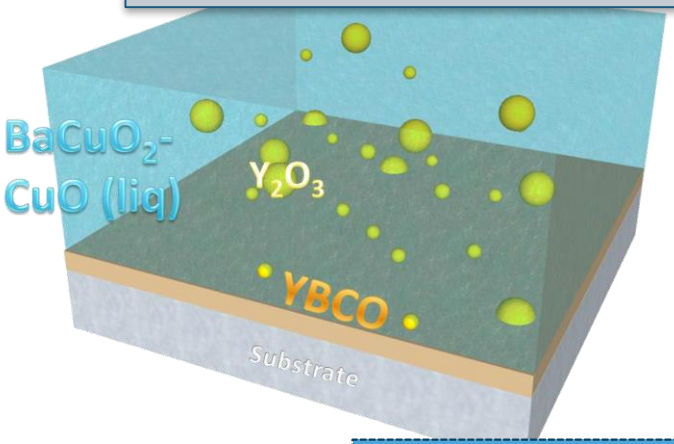
- Large-scale low cost
- TFA precursors: best route up to now for YBCO + nanocomposites



Gas-solid reaction diffusion

Growth rate limited 1-3 nm/s

LIQUID MEDIATED GROWTH



Liquid-solid reaction

•Y in the BaO-CuO melt to form YBCO

Diffusion of Y in the liquid is very fast (~10^{-10} m^2/s)

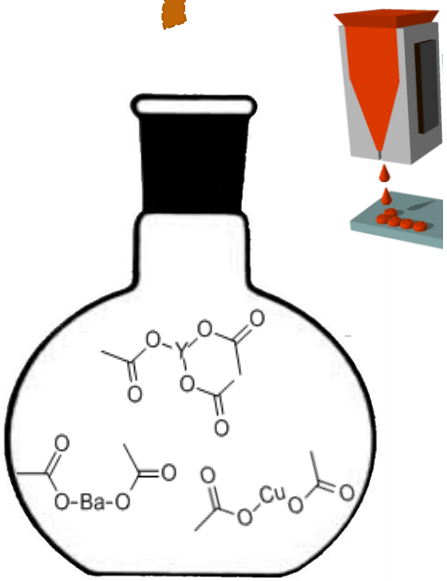
• Growth rate 20~50nm/s

TRANSIENT LIQUID ASSISTED GROWTH

❖**Temperature** and **PO2** control!

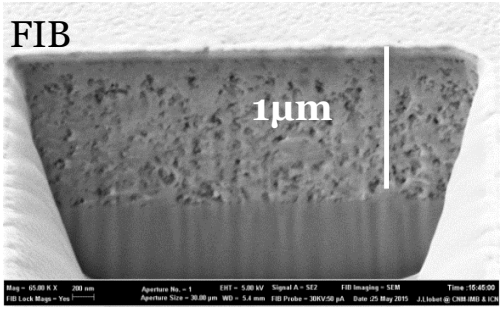
DEPOSITION AND PYROLYSIS

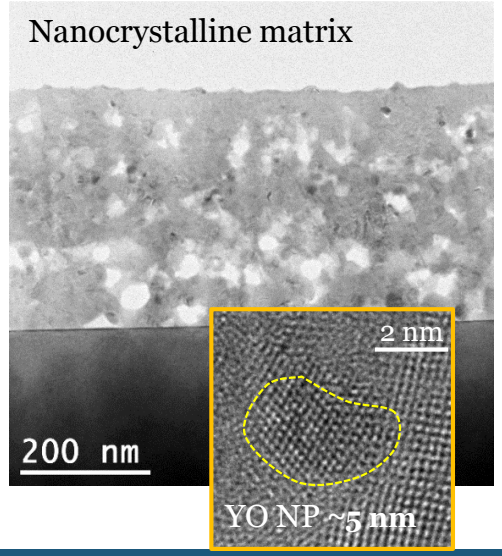
NUCLEATION AND GROWTH

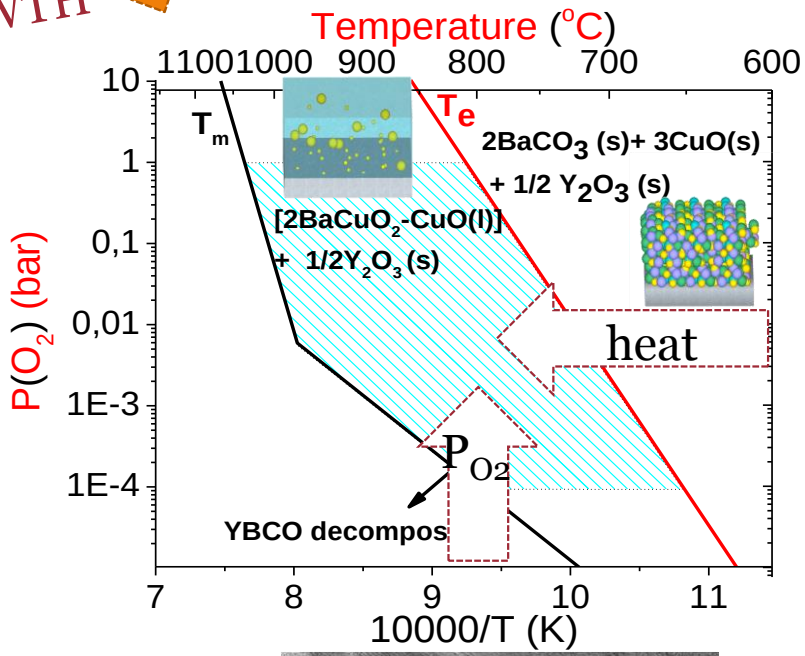


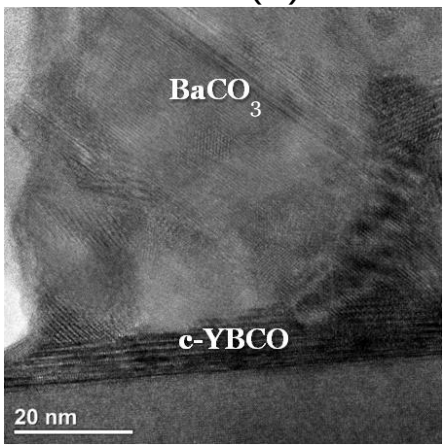
Solvent
Hprop/MeOH:

Fluorine free solution!







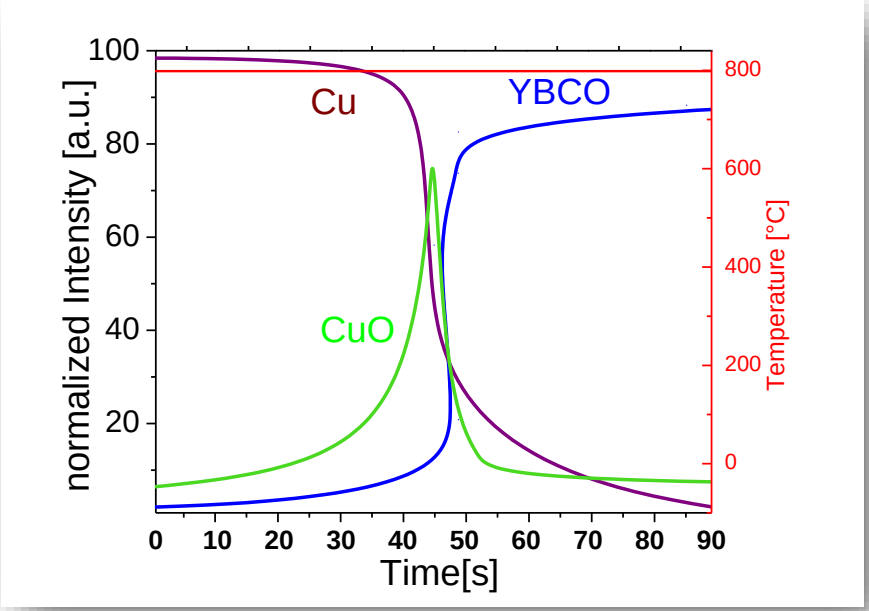


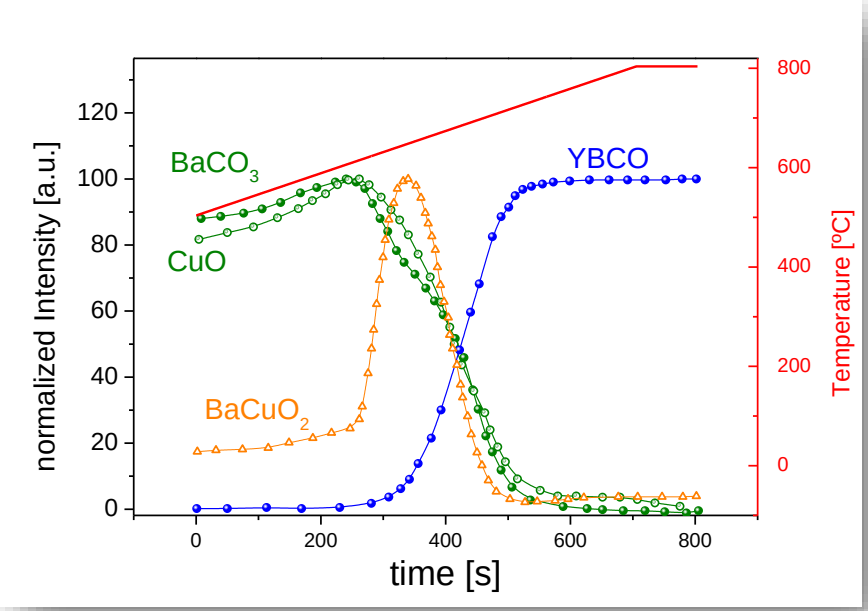
IN SITU GROWTH ANALYSIS :

SOLEIL SYNCHROTRON DiffAbs beamline

P_{O2}

heat





- Cu oxidation is the limitant reaction

Growth rate >26 nm/s!!

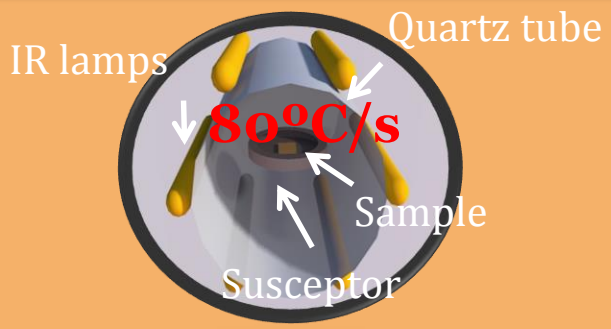
- $BaCO_3$ decomposition is the limitant reaction
- Crystalline $BaCuO_2$ intermediate as predicted by the phase diagram

Growth rate >50 nm/s!!

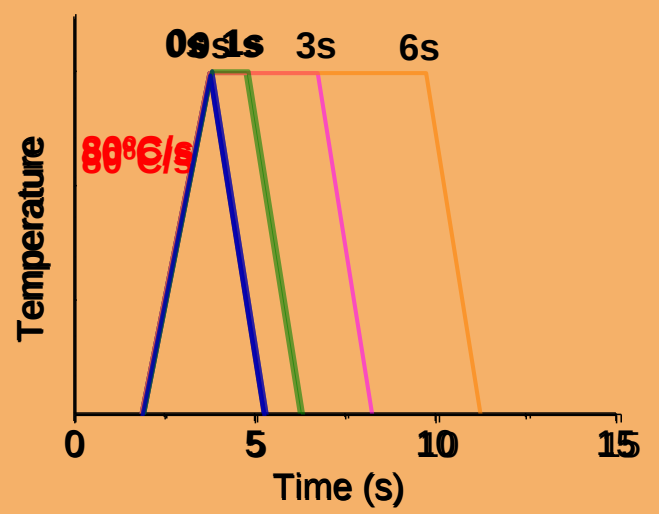
Poster: Silvia Rasi. "High growth rate of YBCO films by Transient Liquid Assisted Growth by oxygen partial pressure control"

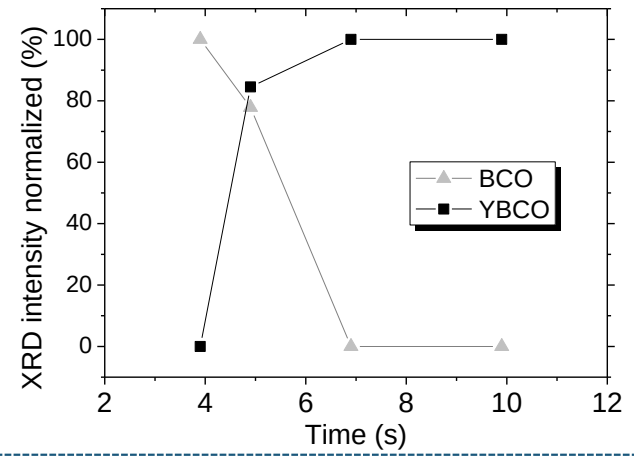
FAST GROWTH :

Rapid Thermal Annealing



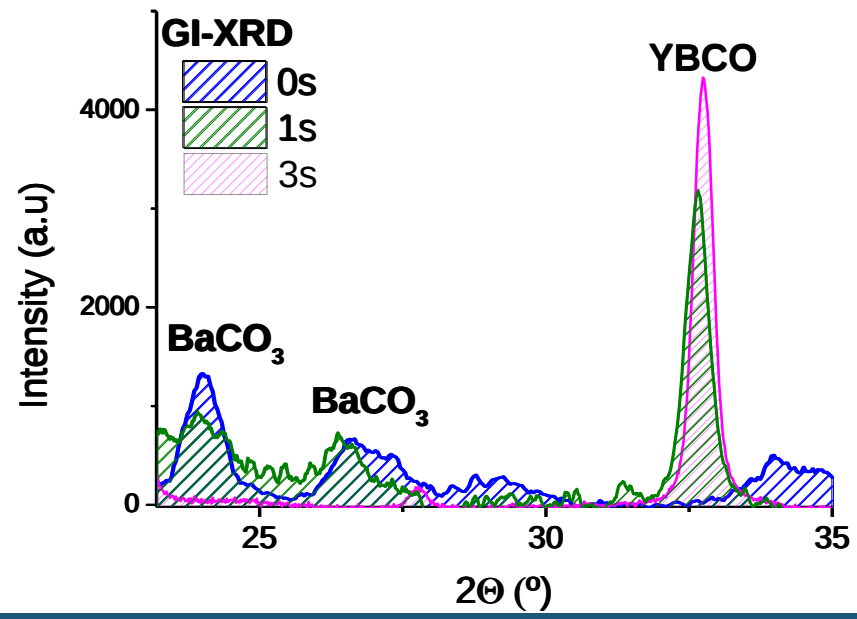
- Avoid coarsening
- Avoid low temperatures





Full conversion to YBCO with ~7 s!

Very fast growth rates can be achieved
GROWTH RATE:
~ 50 nm/s



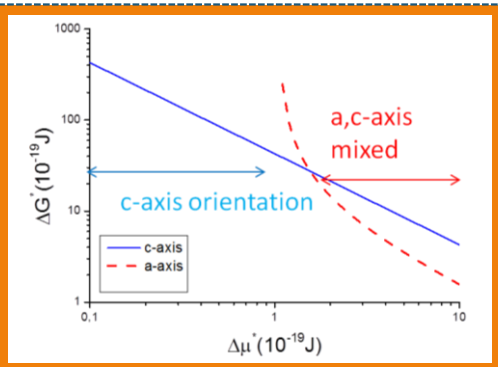
NUCLEATION CONTROL:

c-axis is promoted at lower supersaturation

The thermodynamic **driving force** for crystallization is the **supersaturation**

Crystallization from solution :

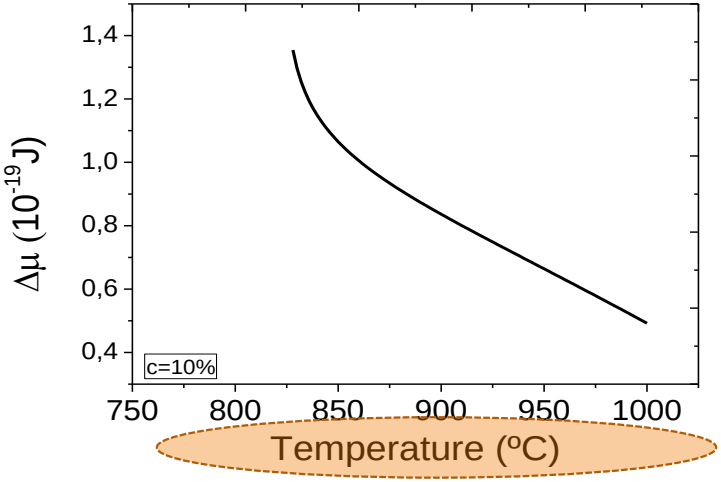
$$\Delta\mu = kT \ln \frac{c}{c_e}$$

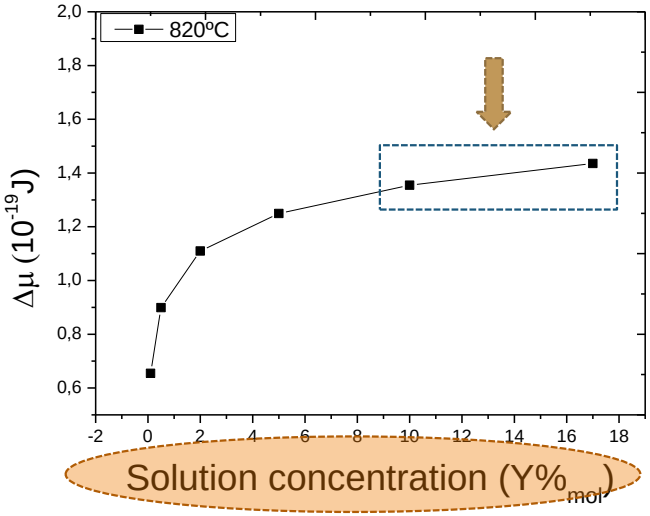


It can be tuned by:

C_e
Equilibrium concentration

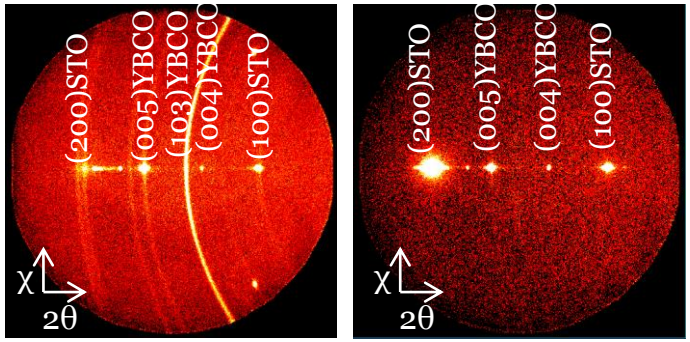
C
Disolved Y concentration

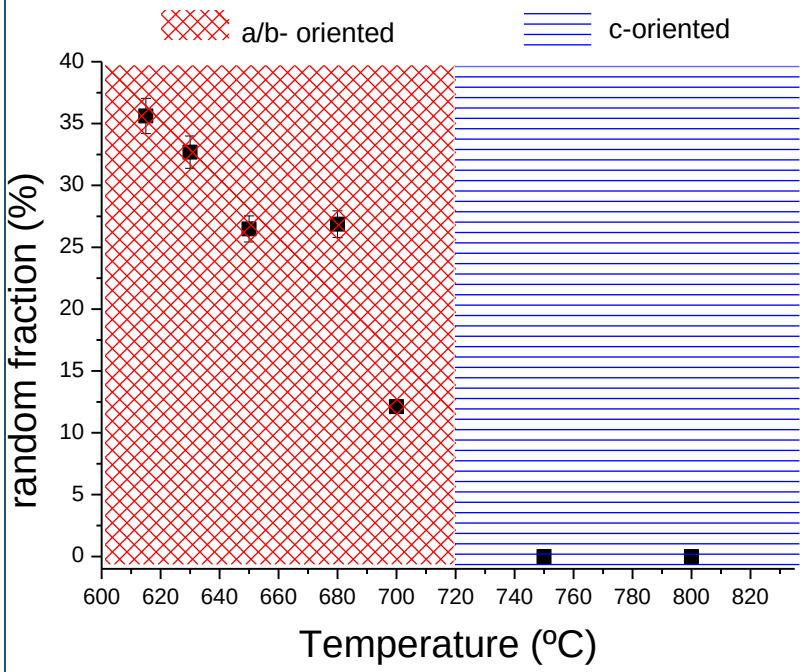


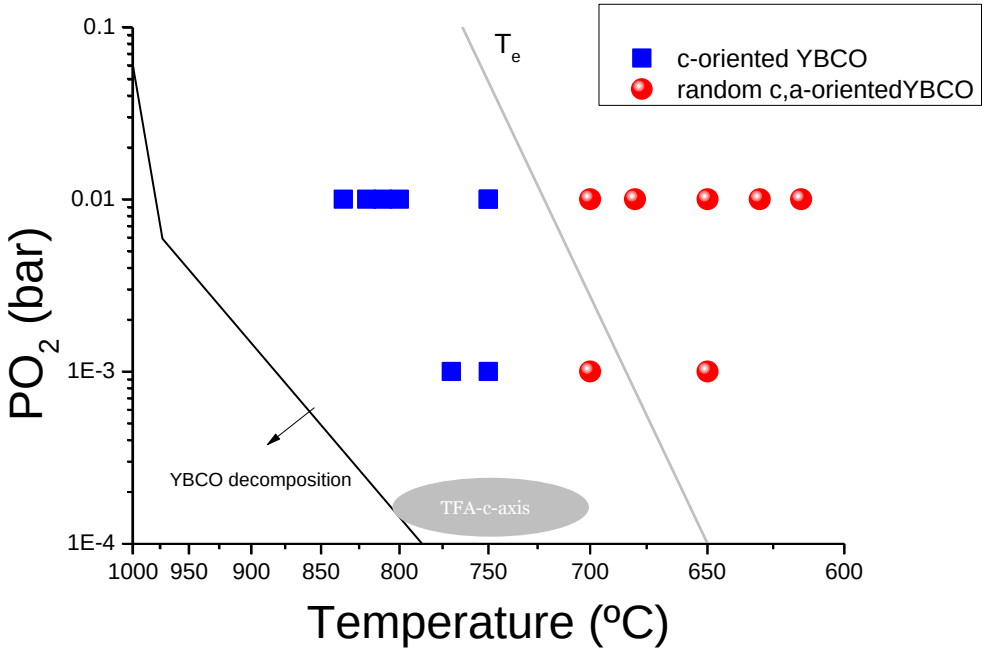


NUCLEATION CONTROL WITH TEMPERATURE:

2D-XRD





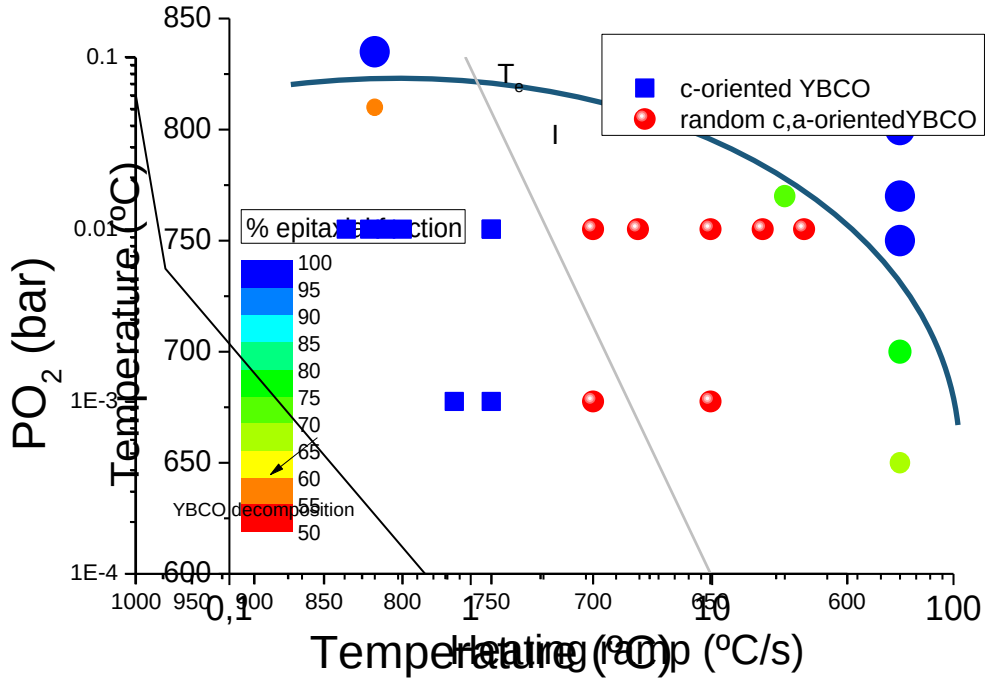


•Only c-axis nucleation is promoted at low supersaturation, high temperatures

THERMODYNAMICS ⟷ **NUCLEATION KINETICS**

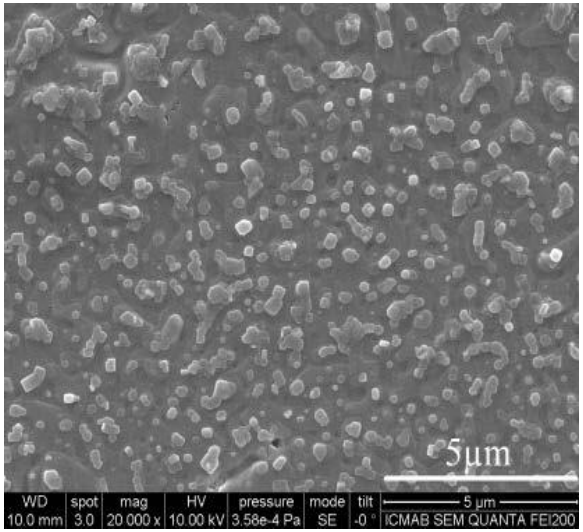
Kinetic effects of metastable intermediate phases have a strong influence on YBCO growth control

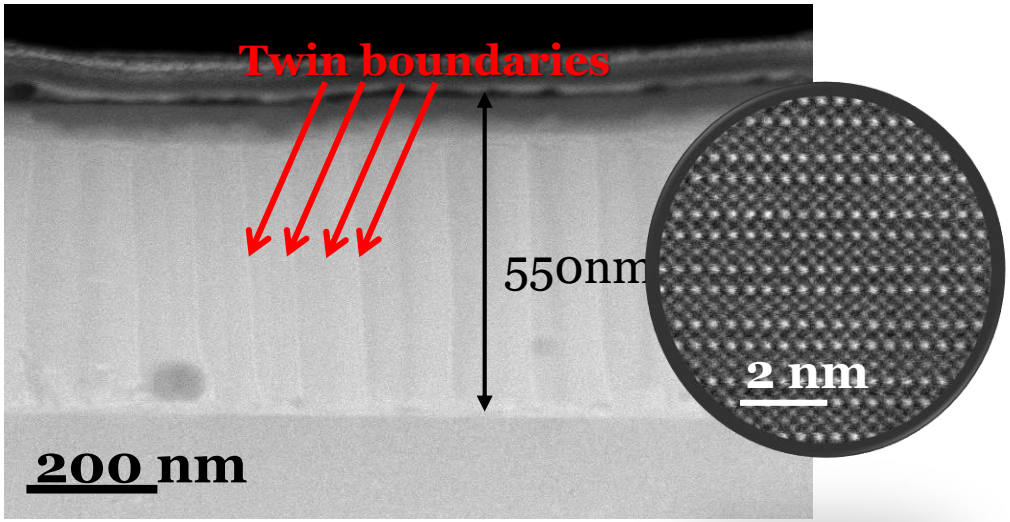
❖Heating ramp influence:



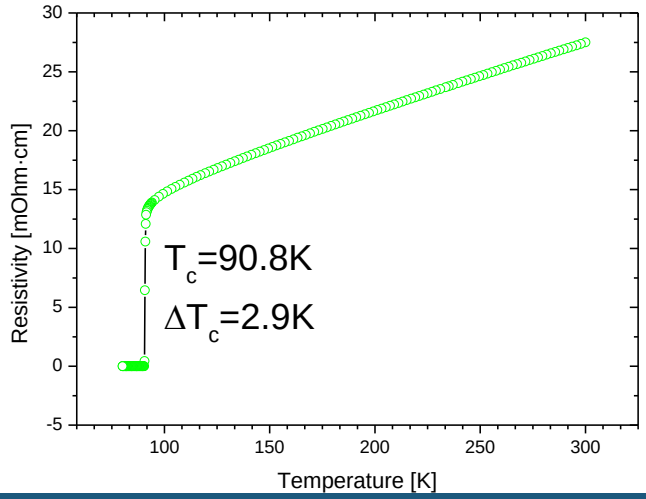
❖Reactivity with substrate is also a kinetic effect that needs to be controlled

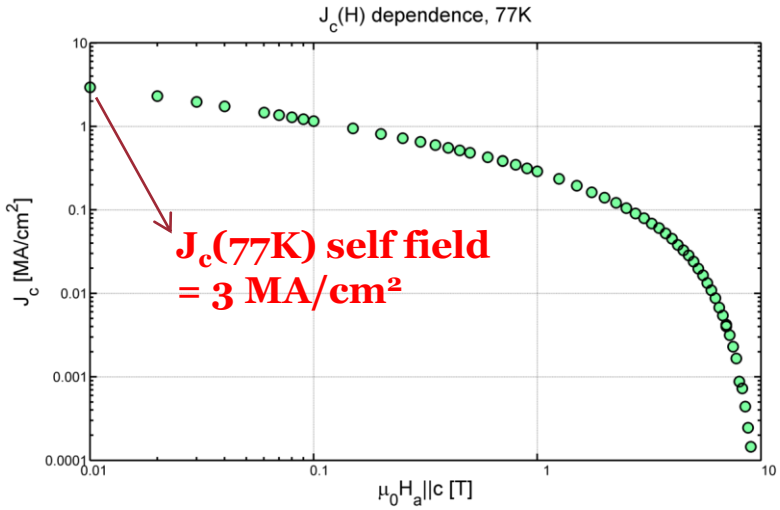
CHARACTERIZATIONS





Higly epitaxial and extremely low porosity. J_c(77K)= 3 MA/cm²

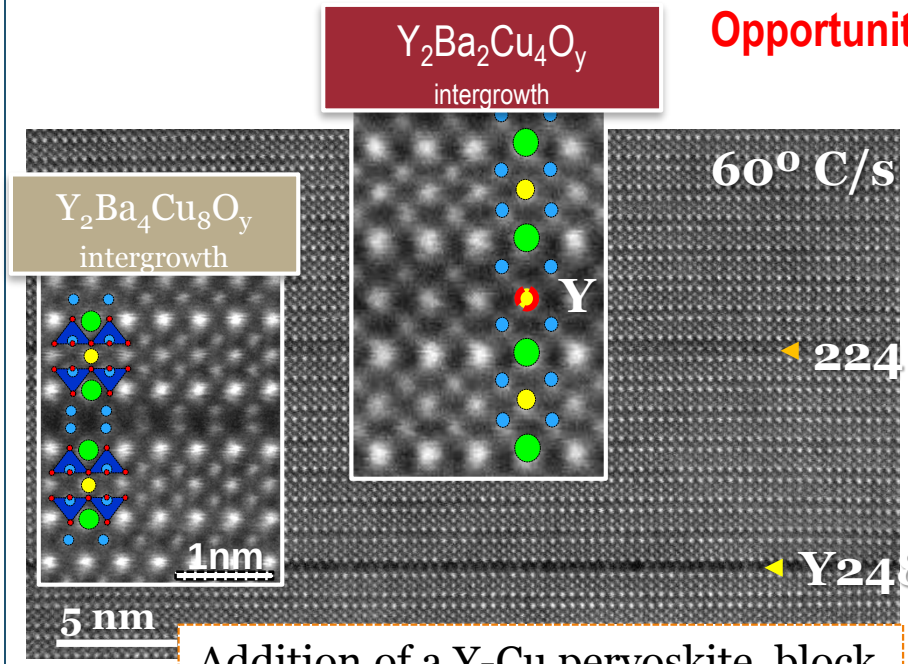




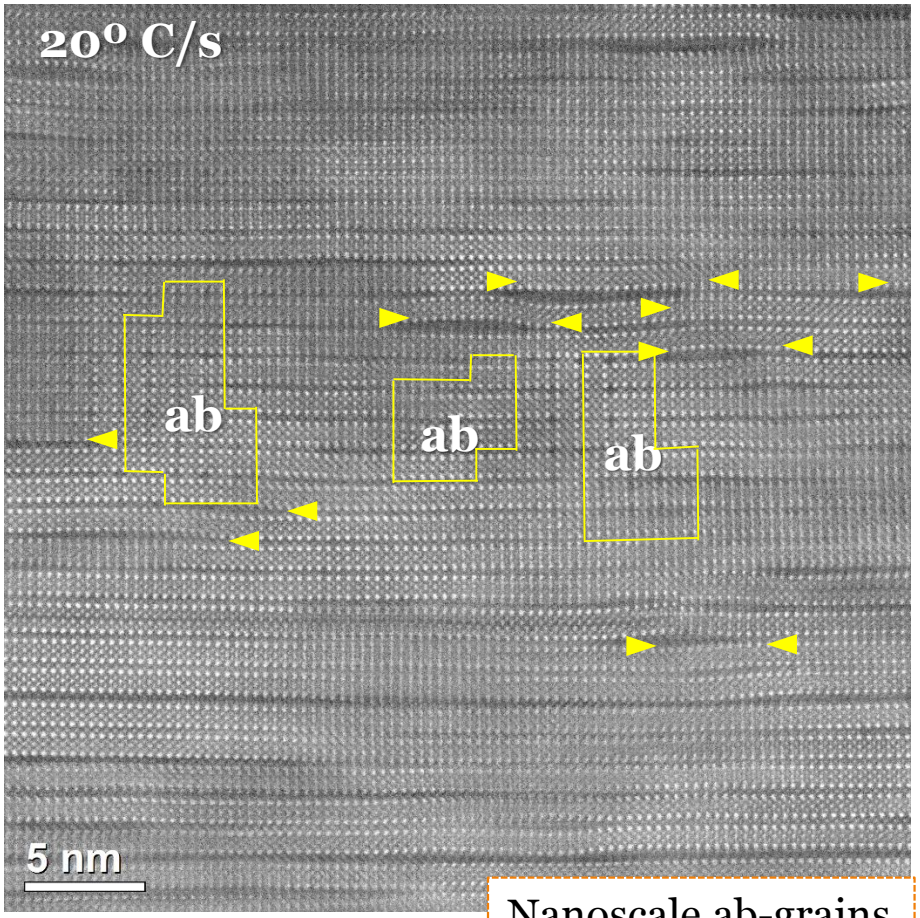
NEW DEFECTS IN CSD-TLAG FILMS

Growth process can strongly modify the nano(microstructure) of these films

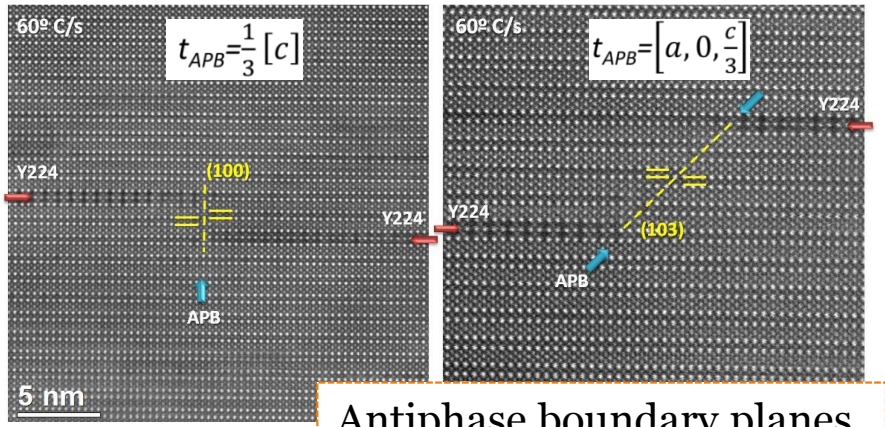
Opportunities for new defects



Addition of a Y-Cu pervoskite block



Nanoscale ab-grains

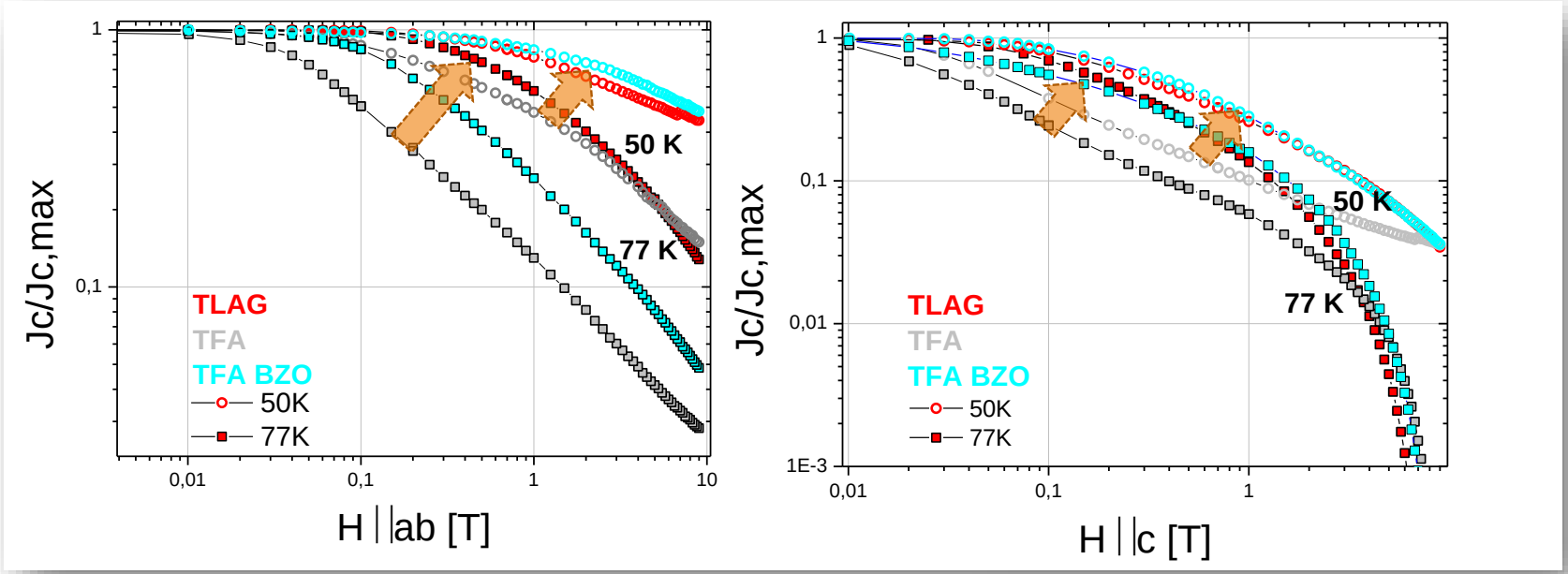


Antiphase boundary planes

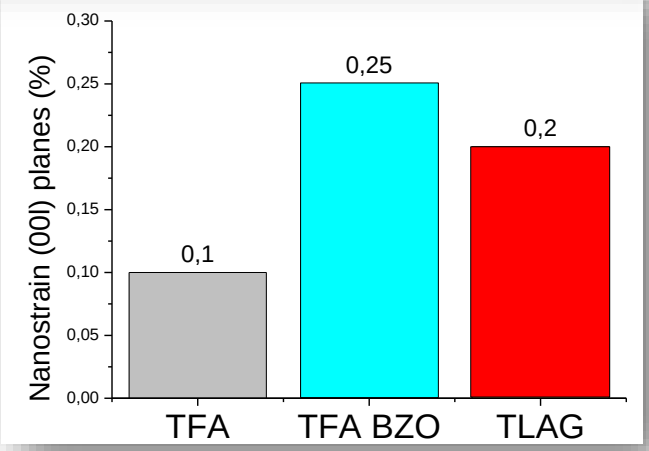
NEW DEFECTS IN CSD-TLAG FILMS

Growth process can strongly modify the nano(microstructure) of these films

Opportunities for new defects and vortex pinning

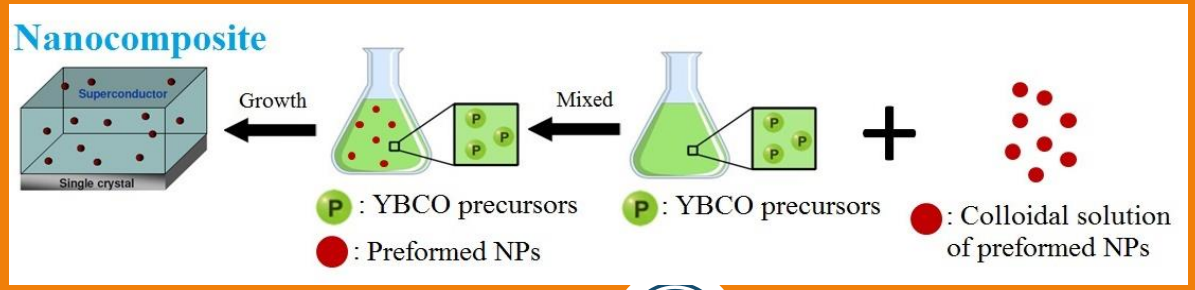


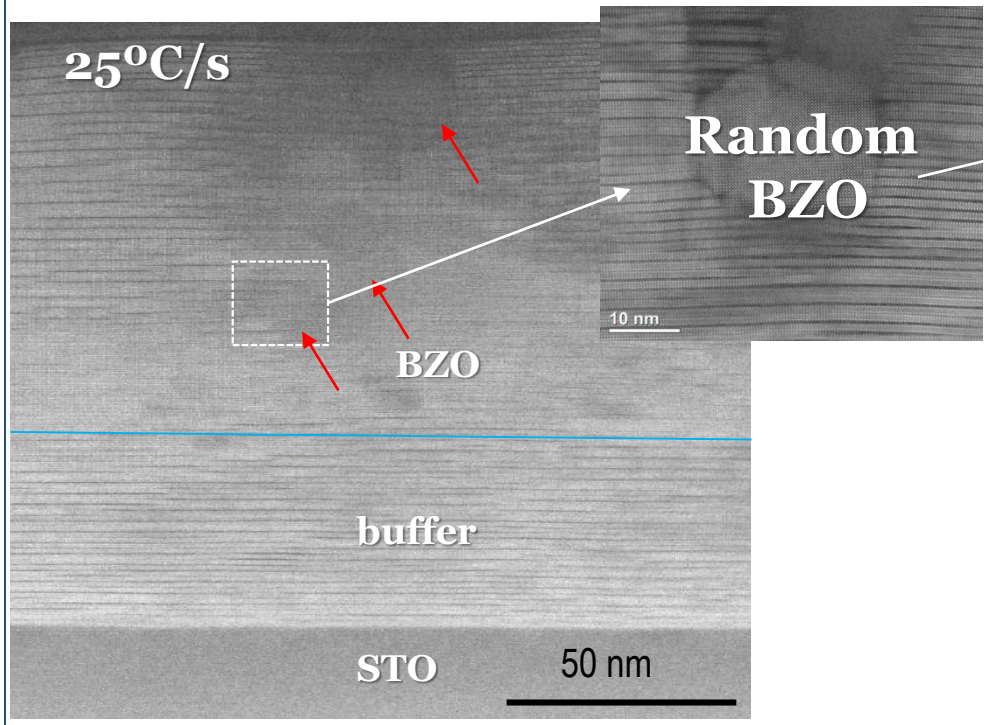
Nanocomposite behavior!

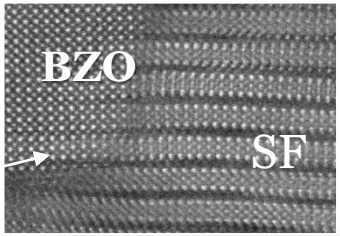


NANOCOMPOSITE TLAG FILMS WITH PREFORMED BZO NP

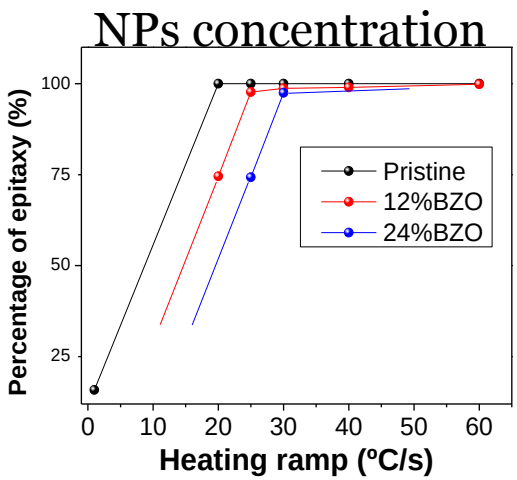
Colloidal solutions: through preformed nanoparticles colloidal solutions







New opportunities for vortex pinning!



❖Need good control of reactivity with substrate

CONCLUSIONS

Chemical Solut Depositon

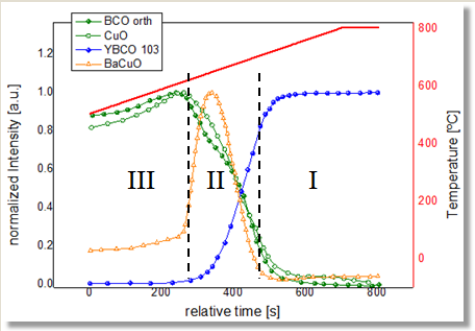
CSD-
Transient Liquid
Assisted Growth

quid-assisted growth

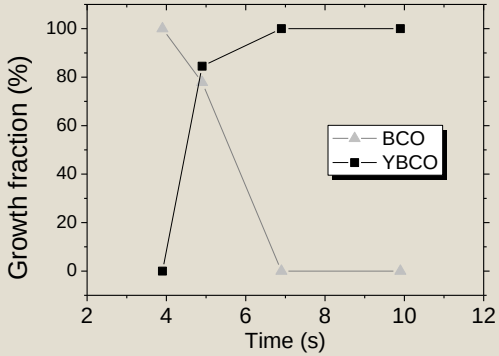
✓**Very fast growth rate**
✓Highly simplified reactor
✓More enviromentally friendly

✓**Large-scale**
✓**Low cost investment**
✓High deposition rates on large areas

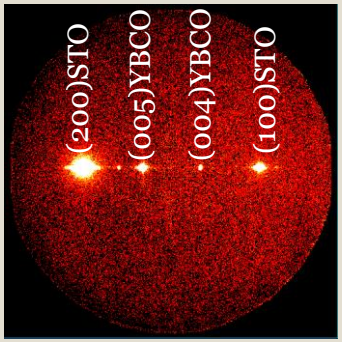
✓**Metastable liquid phase achieved from metalorganic precursors**



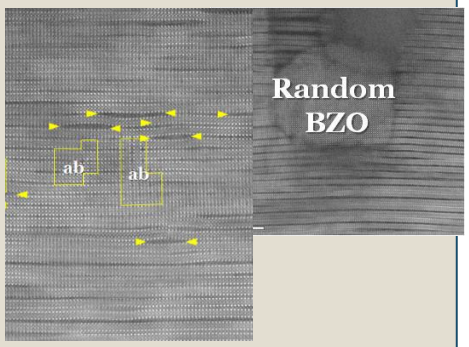
✓**Growth rate 25-50nm/s**



✓**Nucleation control**



✓**New defects landscape**



lsoler@icmab.es