

Correlation between vortex pinning and defect landscape in TLAG - $\text{YBa}_2\text{Cu}_3\text{O}_{7-\delta}$ nanocomposite films

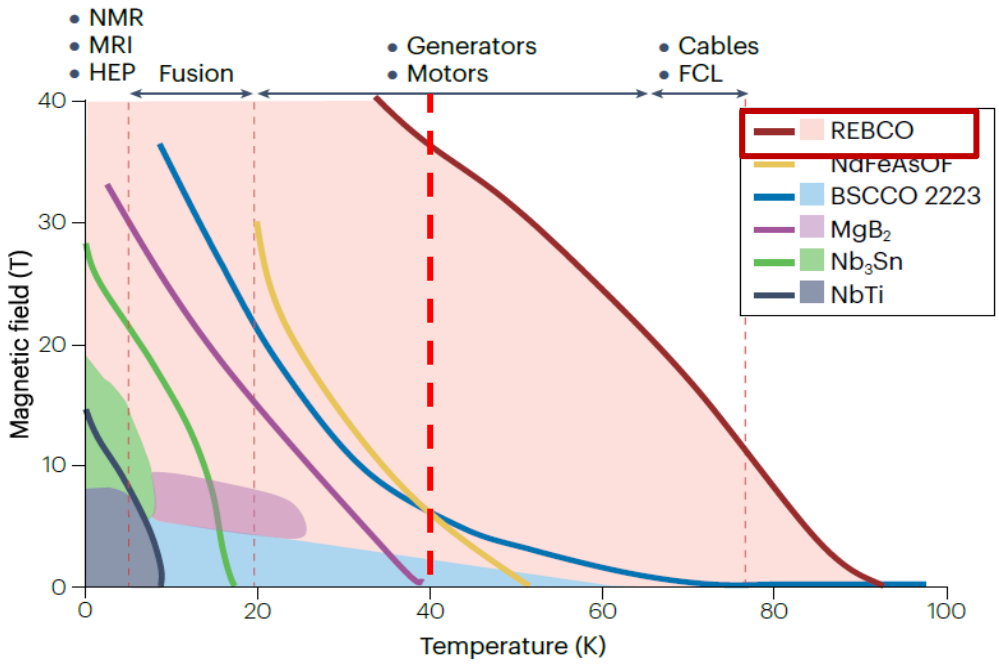
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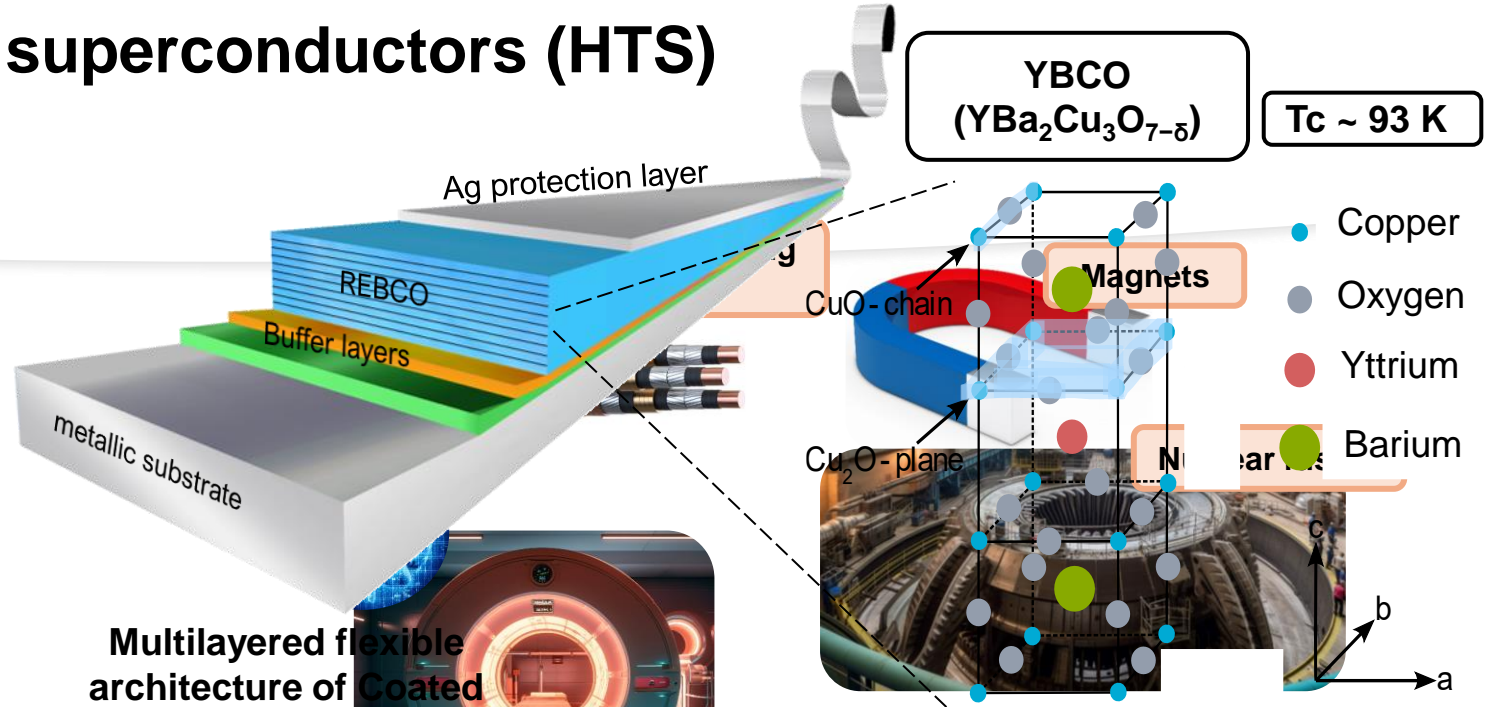
Introduction - High temperature superconductors (HTS)

High temperature superconducting (HTS) materials:
T_c > 40 K

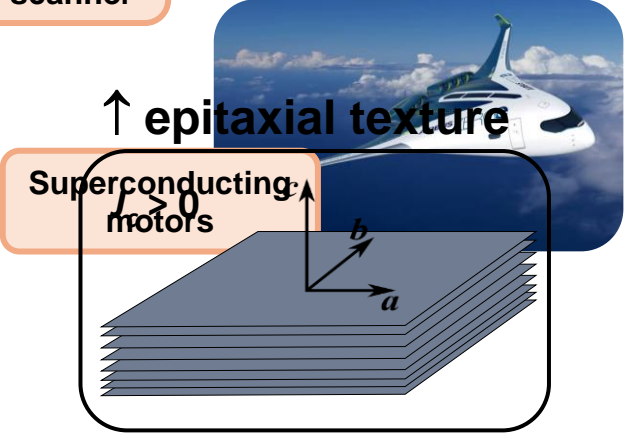
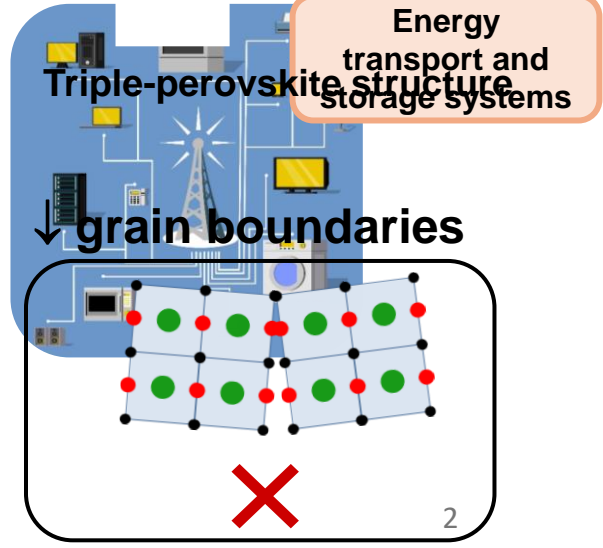


Performance of the superconducting material under $H \Rightarrow$ **critical current density (J_c)**

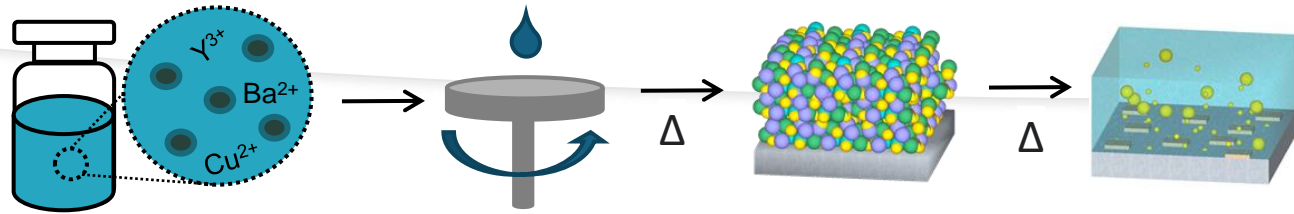
REBCO ($REBa_2Cu_3O_{7-\delta}$) materials have the **highest irreversibility field $H_{irr}(T)$**



Multilayered flexible architecture of Coated Conductors (CC)
MRI medical scanner



Transient Liquid Assisted Growth - Chemical Solution Deposition (TLAG-CSD)



● BaMO₃ (M=Zr, Hf)

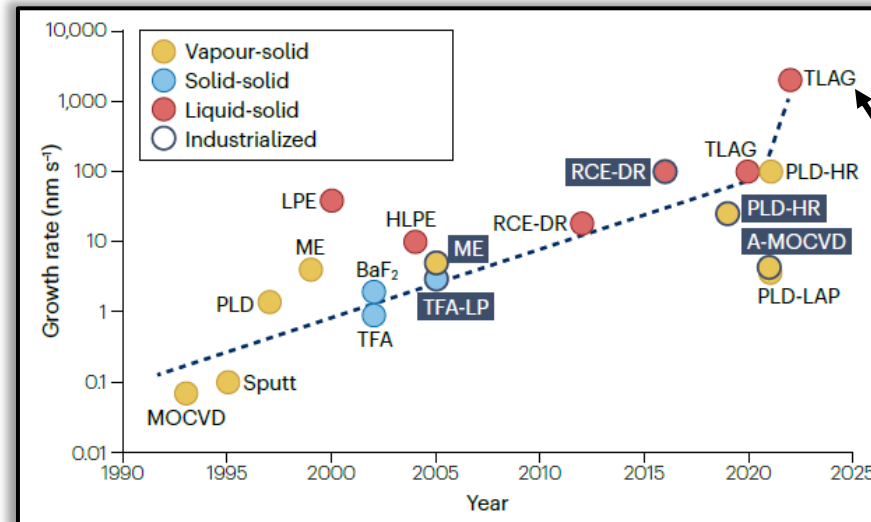
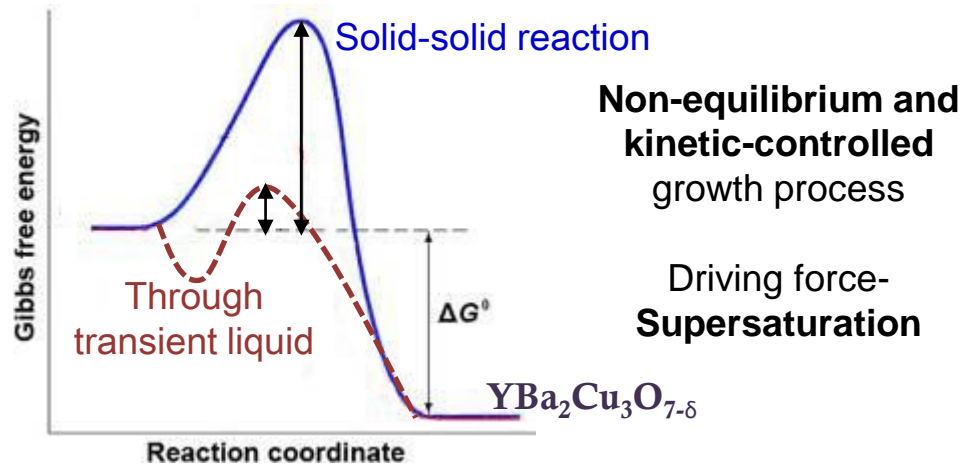
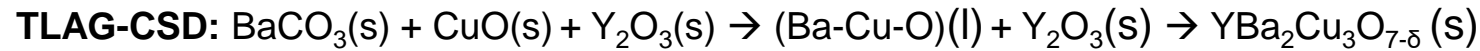
Metal-(Prop)₂
Precursor
Solution with NPs

Deposition via
Spin coating

Amorphous
precursors

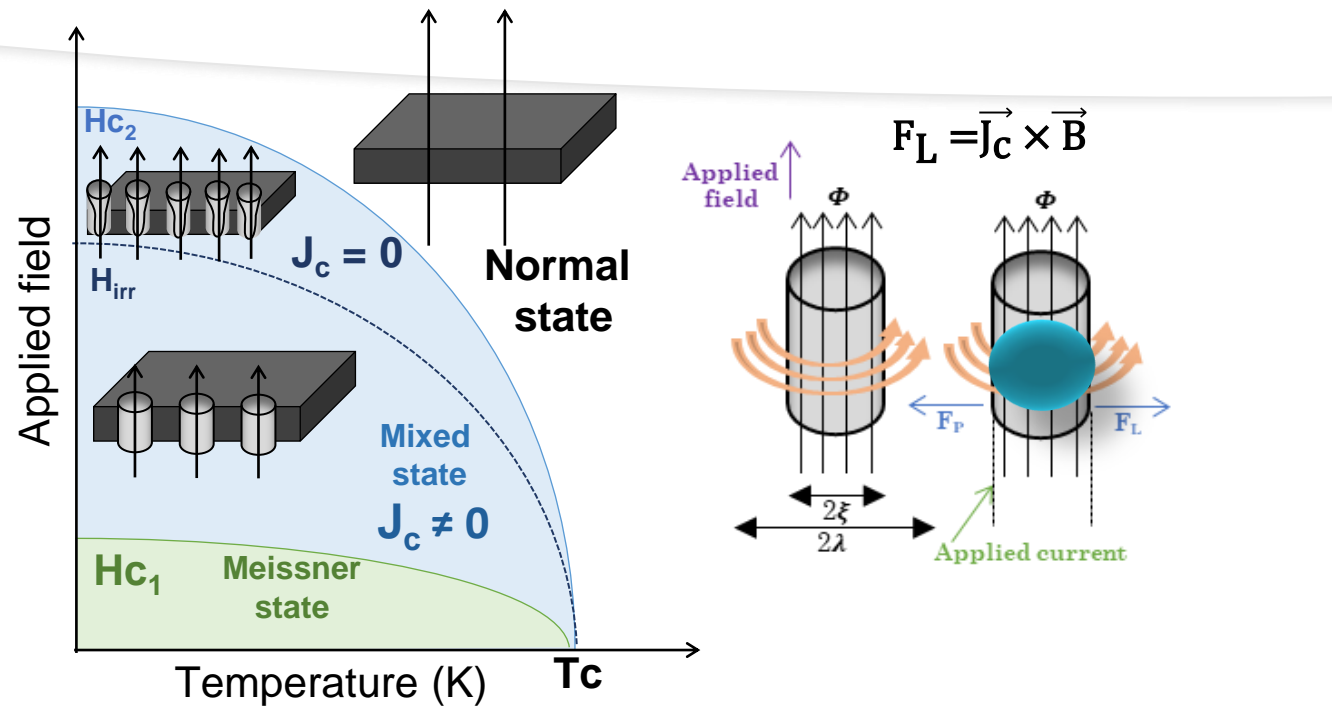
Crystallization of
YBCO from the
transient liquid

- High throughput
- Low cost/performance ratio
- High growth rate (upto 2000nm/s)
- High performance (2-5 MA/cm² at 77K)
- Uses simple reactor

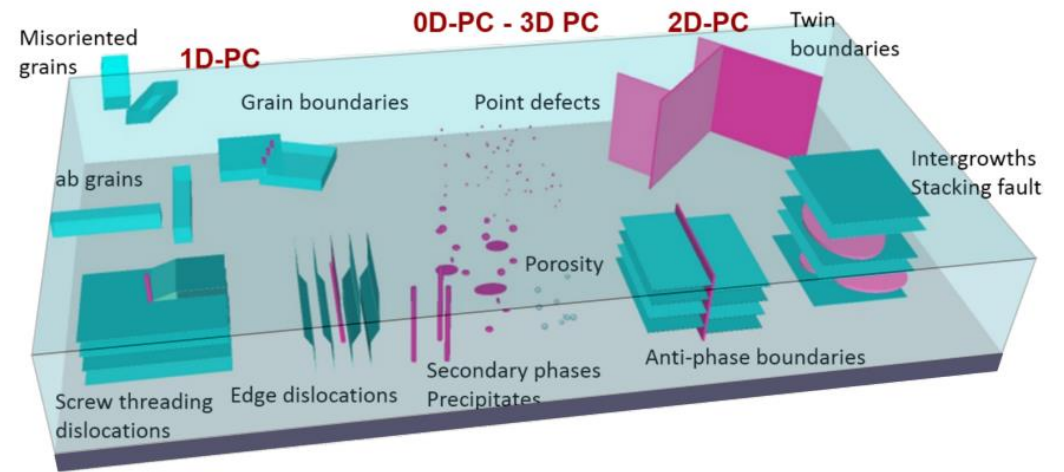


**TLAG-CSD Growth rate
100-2000 nm/s**

Motivation - Importance of vortex pinning in REBCO



Which are the microstructural defects that Efficiently pin vortices?



Vortex pinning ($\sim 2\xi$) to avoid current dissipation at high H&T
 $F_p > F_L$

Introduction of Artificial pinning centres
 ↓
NANOCOMPOSITES

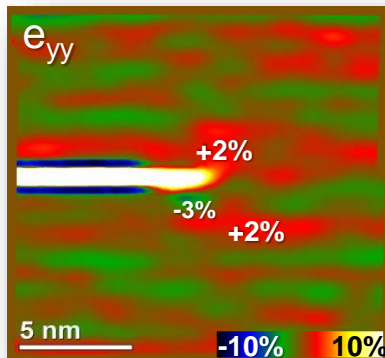
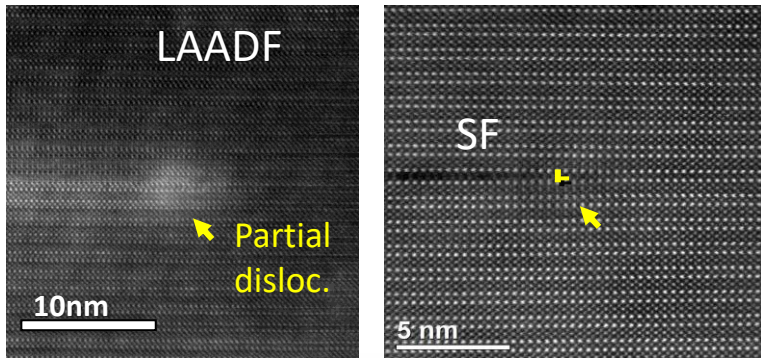
Vortex pinning analysis from physical properties & correlate with microstructure of TLAG-NANOCOMPOSITES

A.Palau, SUST. (2018)
 T. Puig, Nat. Rev. Phys. (2023)
 J. Driscoll, Nat. Rev. Mater. (2021)

Study of physical properties for the evaluation of vortex pinning

Nanostrain ϵ

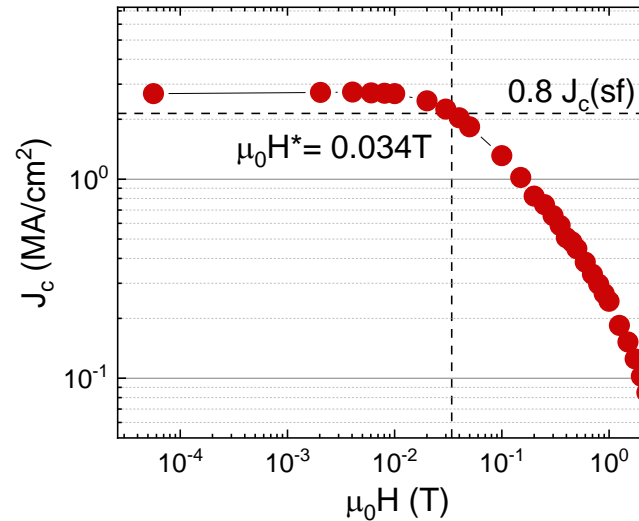
Strain accumulated at the partial dislocation surrounding the SF - **NANOSTRAIN**
 Also calculated from XRD - **Williamson - Hall** method



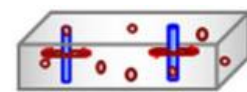
GPA TEM analysis

$\mu_0 H^*$

$$J_c(\mu_0 H^*) / J_c(sf) = 0.8$$



Transition between single-vortex pinning regime and vortex-vortex interaction regime



Single vortex pinning



Vortex-vortex interactions

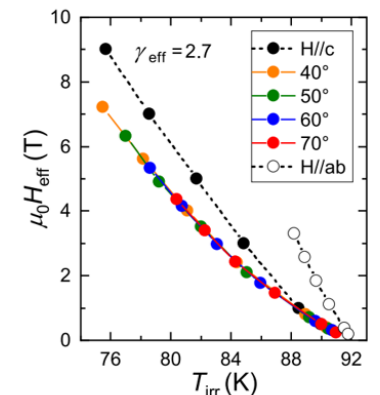
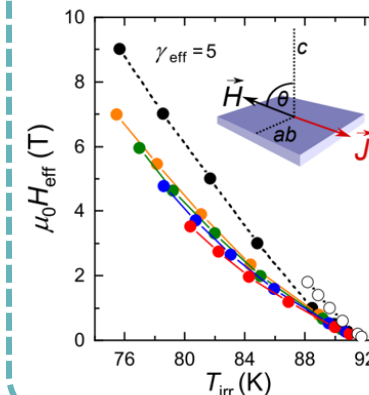
Effective Anisotropy factor γ_{eff}

$$\gamma = \sqrt{\frac{m_c}{m_{ab}}} = \frac{\lambda_c}{\lambda_{ab}} = \frac{\xi_{ab}}{\xi_c}$$

Blatter scaling of irreversibility lines

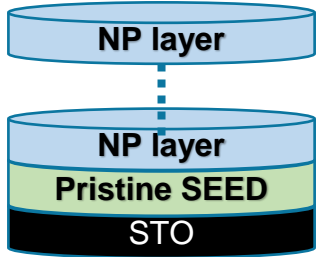
$$H_{eff} = \epsilon(\theta) H,$$

$$\epsilon_{eff}(\theta) = [\cos^2\theta + \gamma_{eff}^{-2} \sin^2\theta]^{1/2}$$



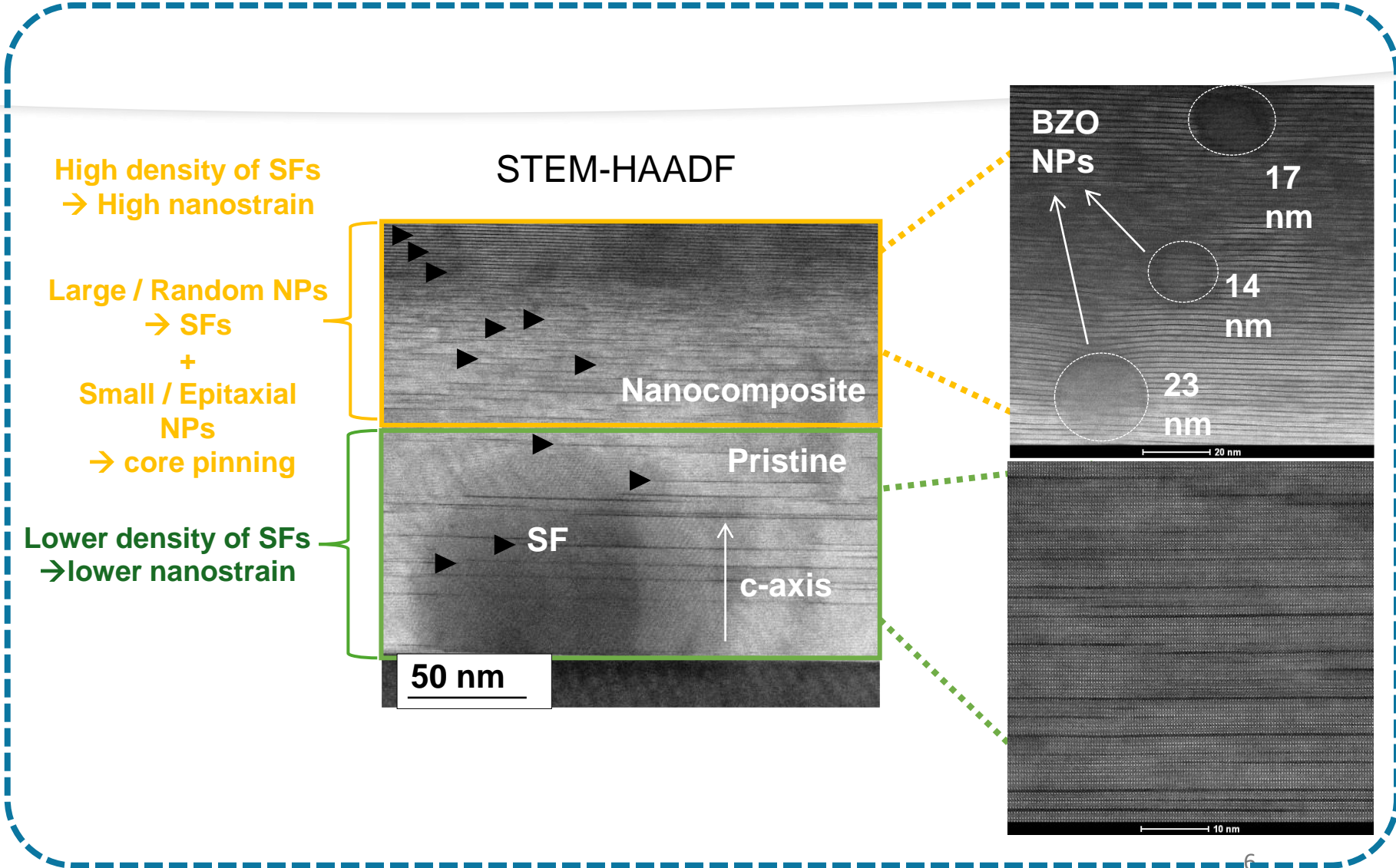
Microstructure of TLAG films

Main multilayered film architecture



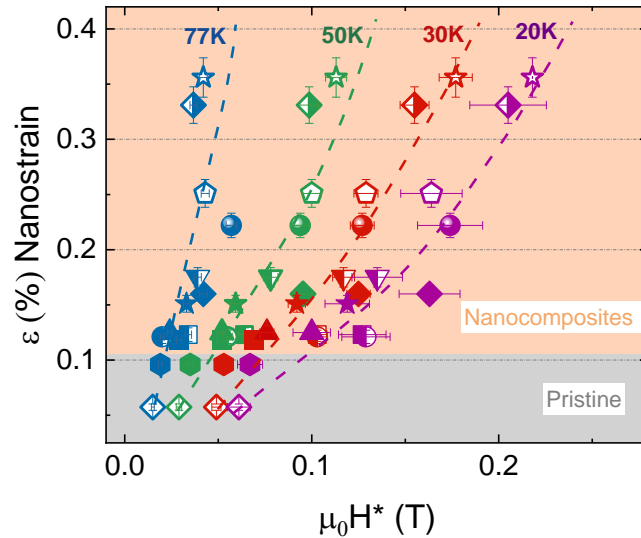
STO = SrTiO₃
 Pristine = without NPs
 NP = Nanocomposite layer

How does this microstructure reflect in physical properties?



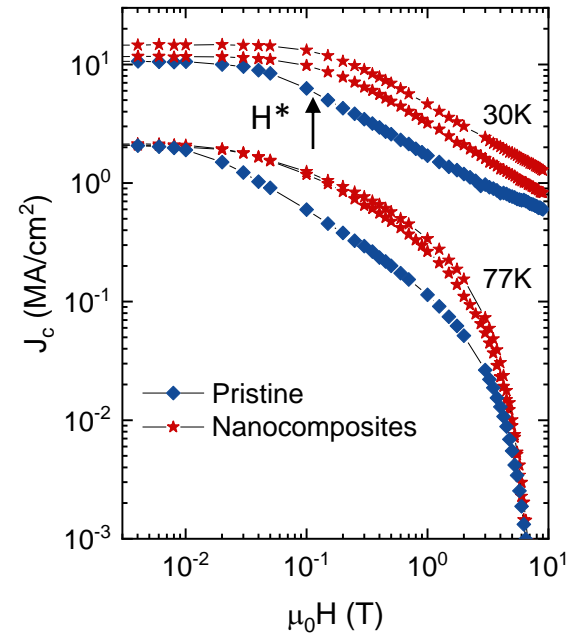
Study of physical properties for the evaluation of vortex pinning

Nanostrain ε



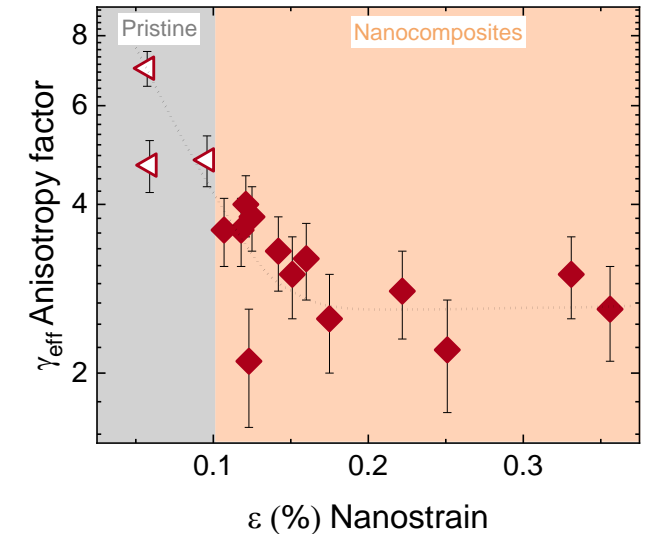
Strong correlation between **Nanostrain and H^*** for a wide range of samples (pristine, NCs (6- 24%)) with several thickness

$\mu_0 H^*$



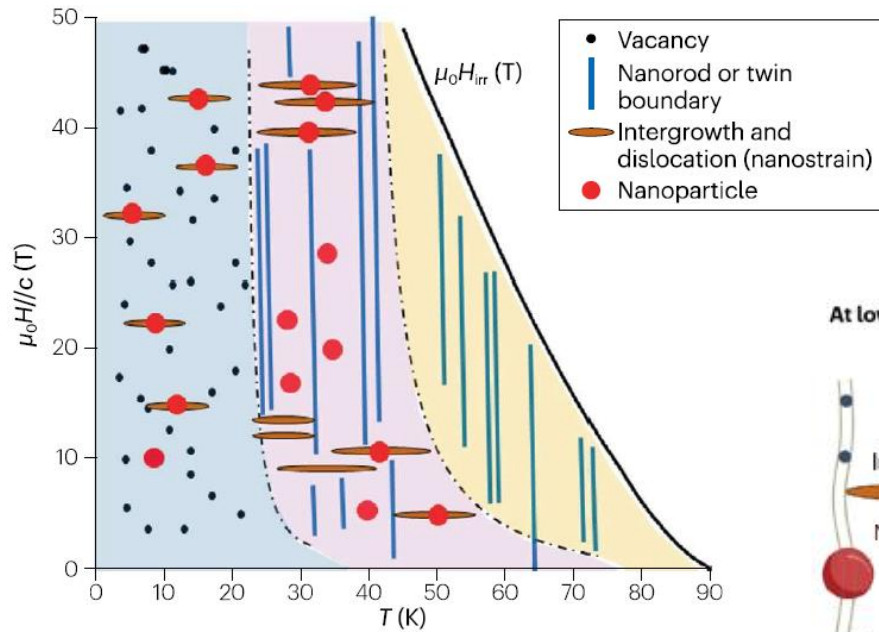
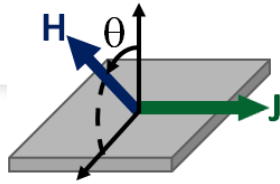
Enhancement of H^* in Ncs as a result of single vortex pinning by NPs

Effective Anisotropy factor γ_{eff}

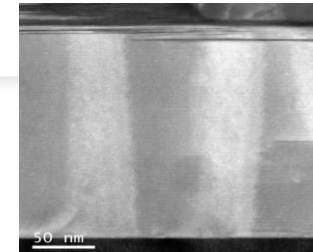


Reduced effective anisotropy γ_{eff} in nanocomposites compared to pristine films

Angular dependent study of J_c

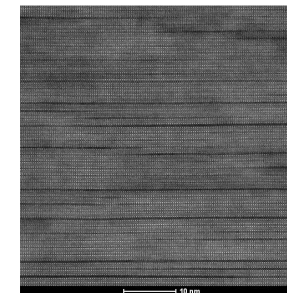
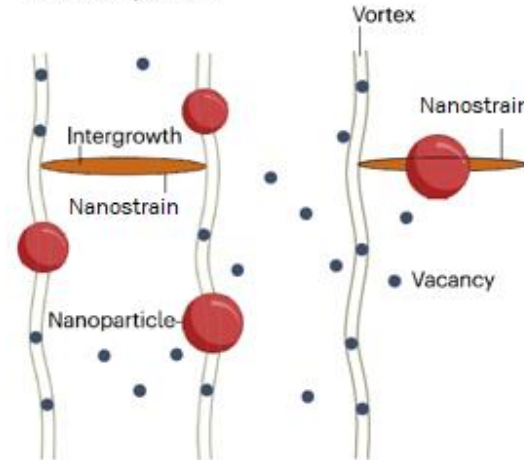


At high temperature

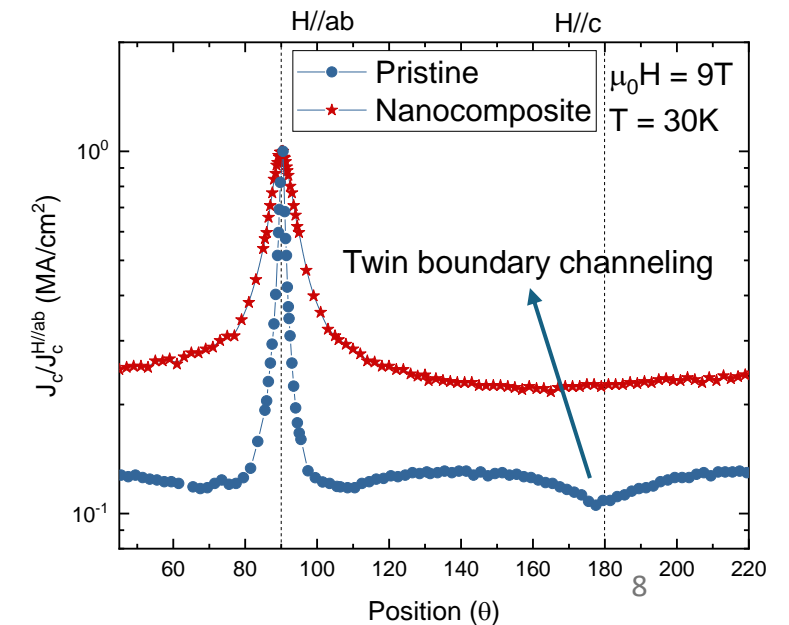
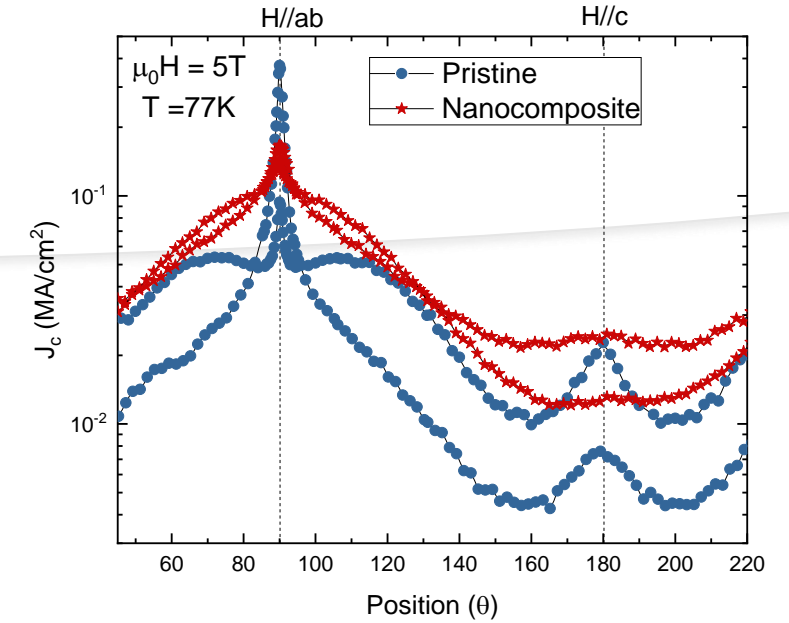


Twin boundary

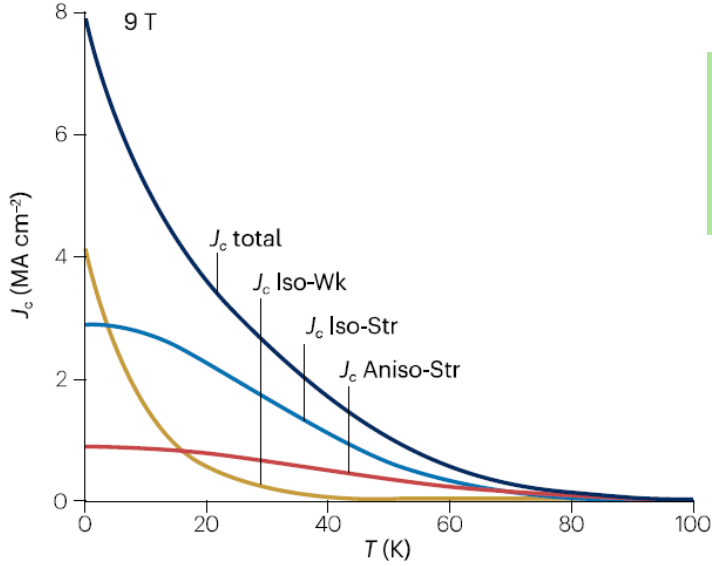
At low temperature



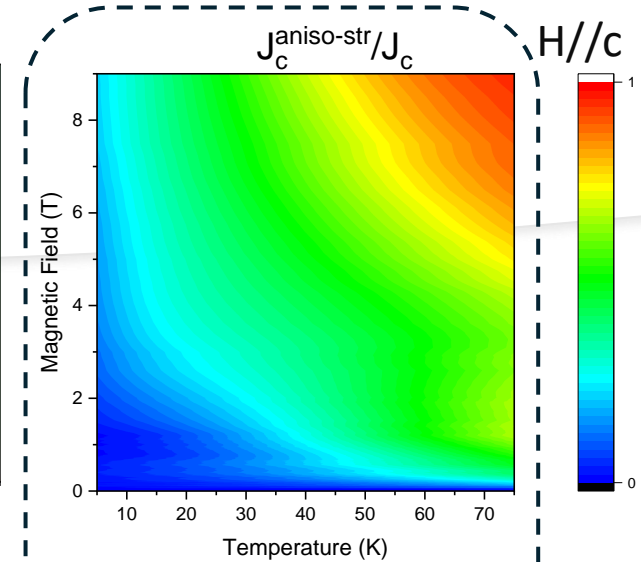
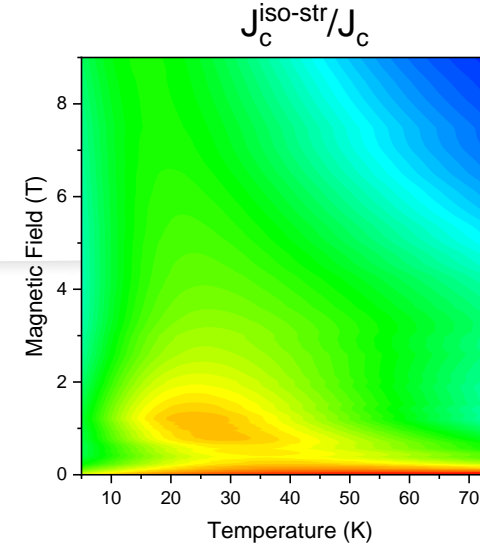
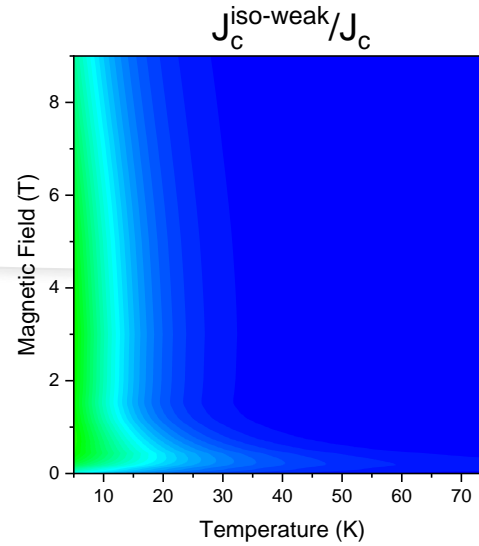
SFs



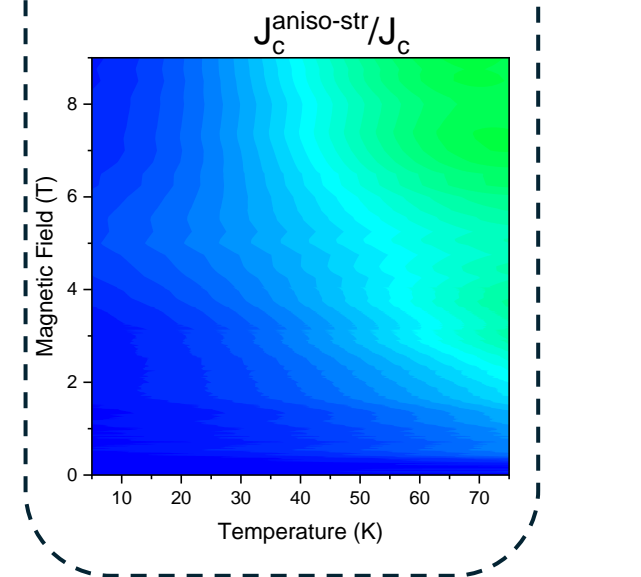
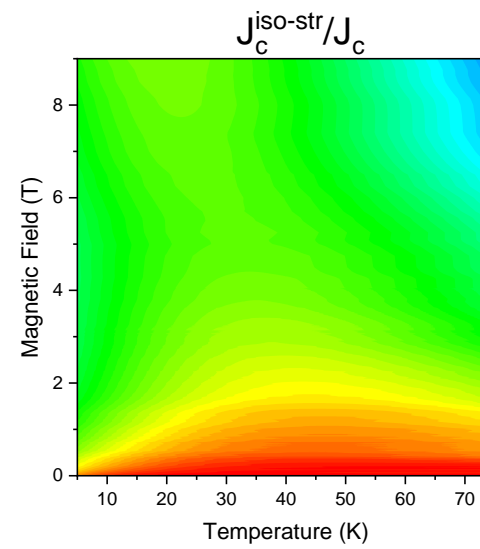
Pinning Model Analysis



Pristine



Nanocomposite



$$J_c(T) = J_c^{iso-wk}(T) + J_c^{iso-str}(T) + J_c^{aniso-str}(T)$$

$$J_c^{wk}(T) = J_c^{wk}(0) e^{-\frac{T}{T_0}}$$

$$J_c^{str}(T) = J_c^{str}(0) e^{-3\left(\frac{T}{T^*}\right)^2}$$

- ↑ isotropic pinning contribution in NCs
- ↑ nanostrain and nanoparticle pinning

Summary and Conclusions

TLAG - nanocomposites demonstrates the capacity to artificially modify the pinning landscape of TLAG films and thereby improve the performance under applied magnetic field

In comparison with pristine, TLAG nanocomposites have reduced effective anisotropy γ_{eff} , increased nanostrain and H^* values

In addition to act as core pinning centres, nanoparticles generate new defects (SFs) in the films which are also helping for pinning the vortices

The overall isotropic contribution of J_c has increased in nanocomposites



Thank You for Your Attention!

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