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UNIVERSITÉ DE GENÈVE

Ionic liquid gating of $YBa_2Cu_3O_{7-x}$ grain boundaries

A. Fête, C. Senatore

3MO3 - Cuprate Thin films

EUCAS 2017

Outline

Brief introduction to grain boundaries in YBCO and ionic liquid gating

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Device structure and efficiency

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Results obtained on a 8° boundary

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Summary of the results obtained on 2°-3°-5° boundaries

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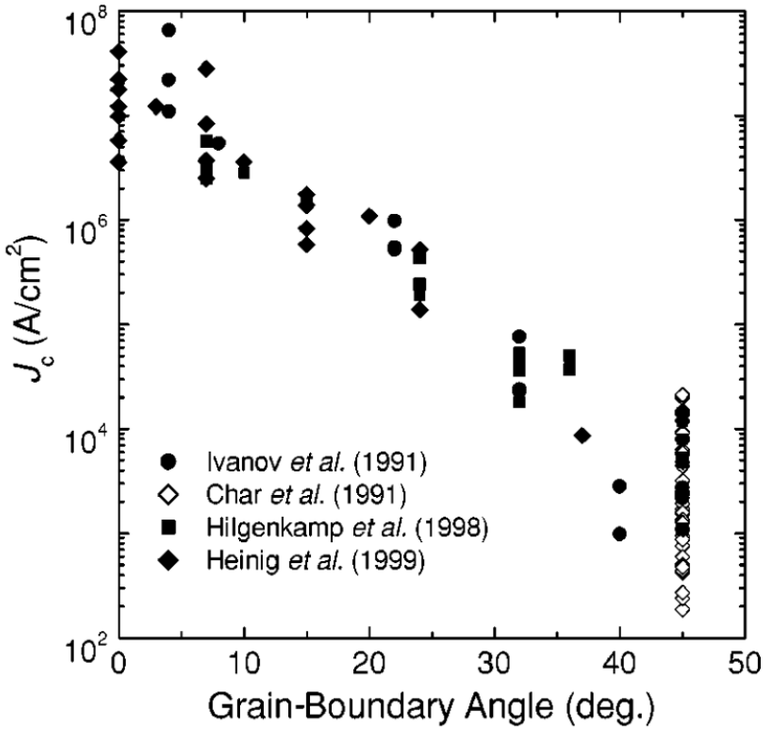
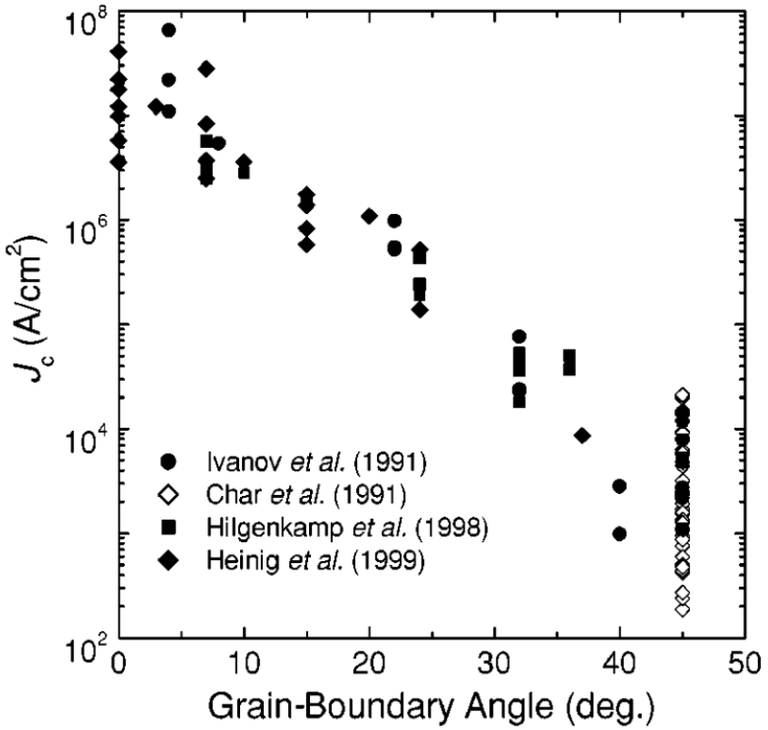
Conclusion and perspectives

Impact on SC transport



Hilgenkamp and Mannhart, RMP **74** 485 (2002)

Impact on manufacturing



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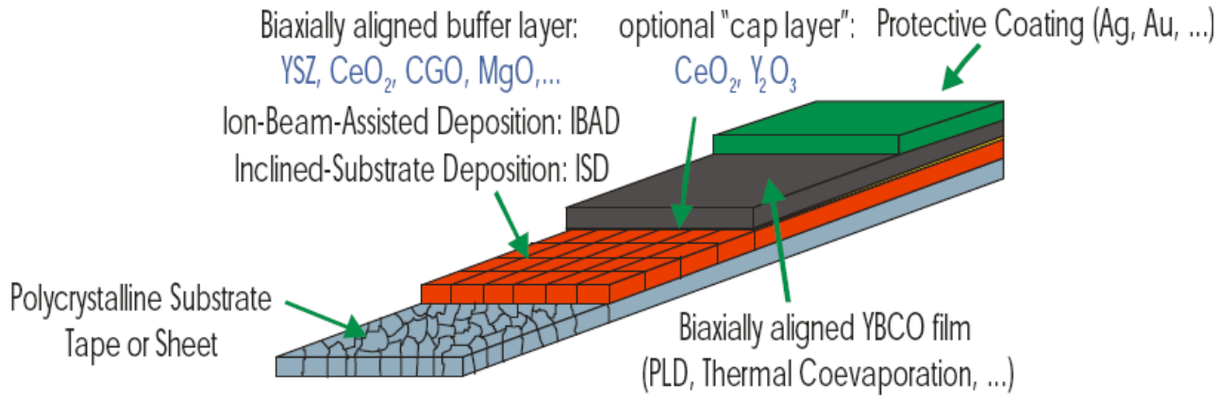
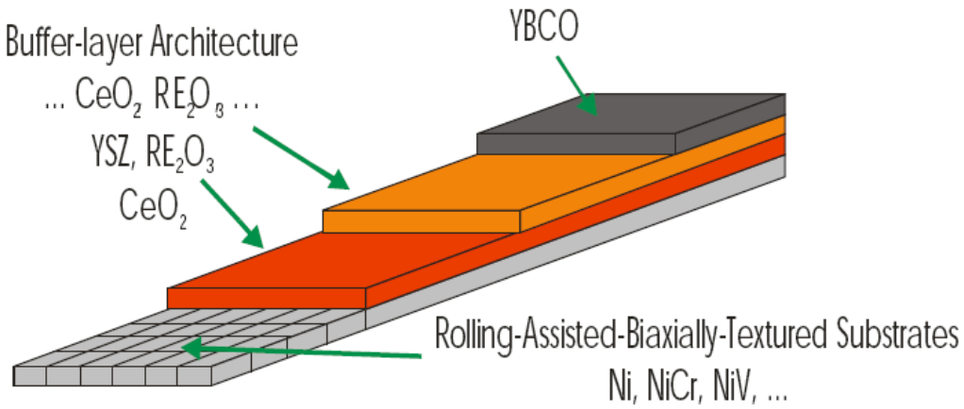
Forced Texturing
IBAD, ISD



Thermo-mechanical
Texturing of Substrates (TMT)
RABiTS

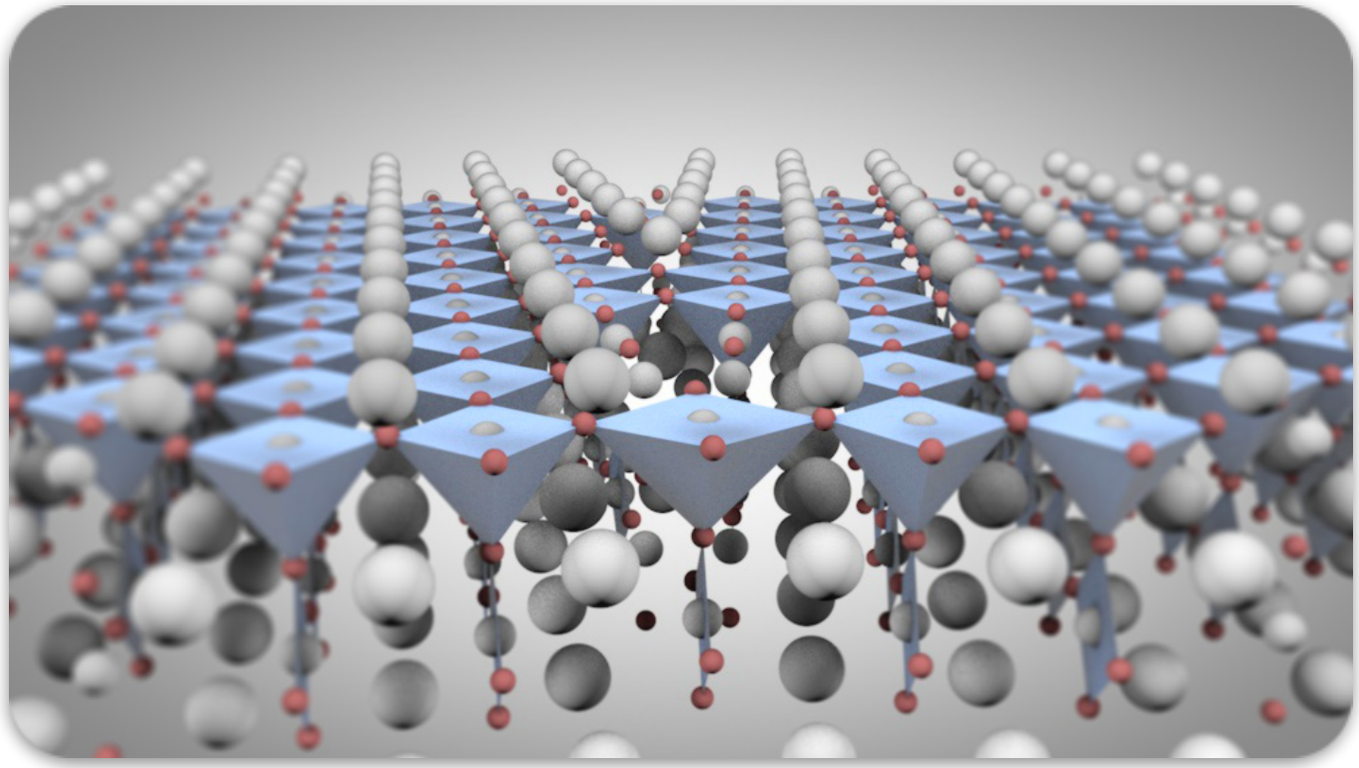


Driving question

***Q*:** What is the dominant mechanism limiting J_c^{GB} in YBCO?

strain field

variations of the charge carrier concentration



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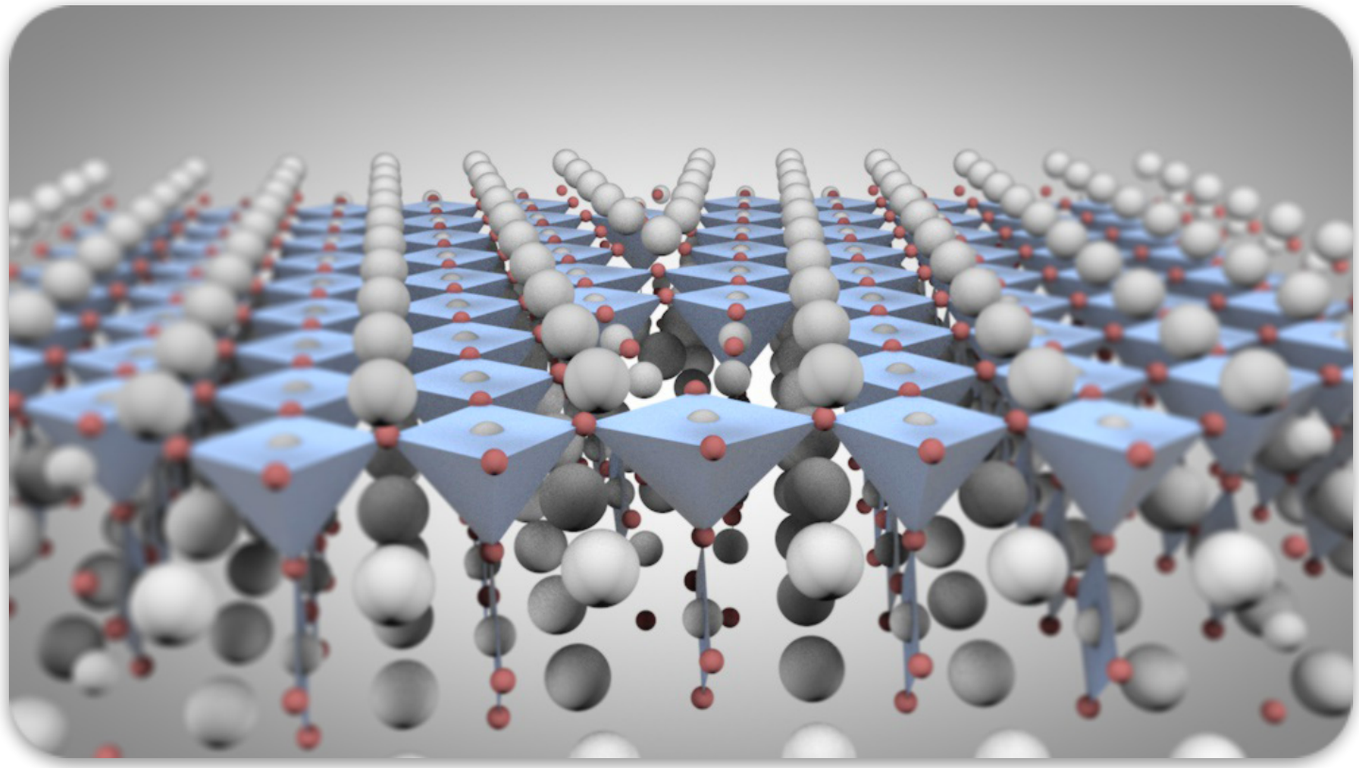
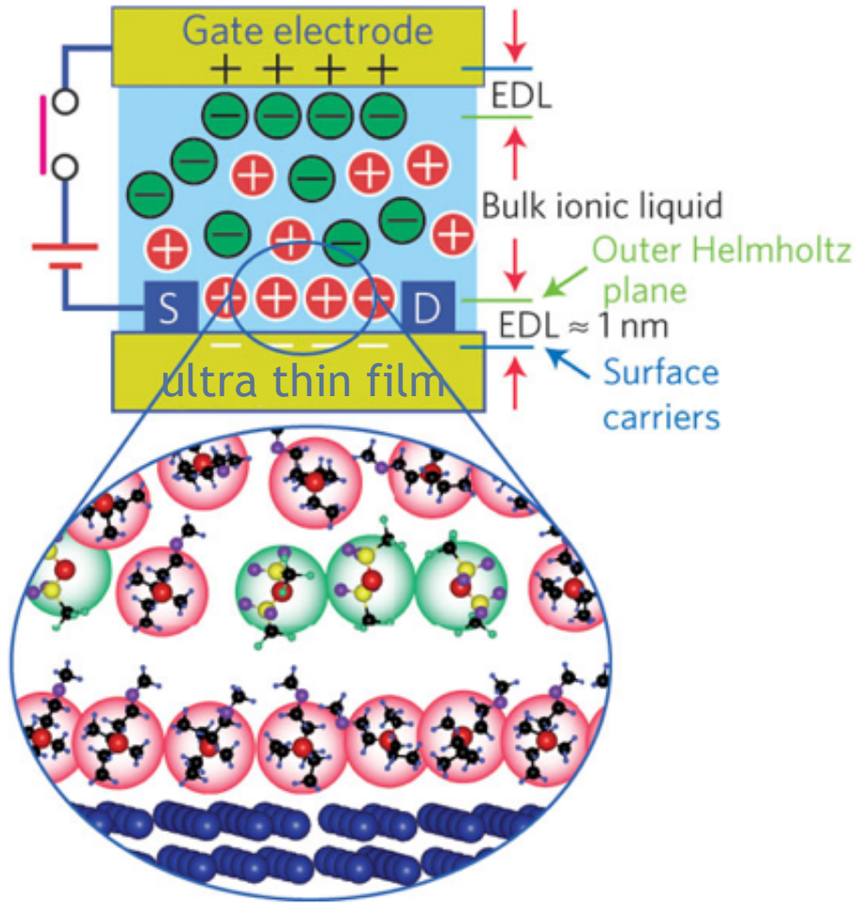


Basics of field effect (FE)

Ionic liquid based
FE device



adapted from :
Ye *et al.* Nature Materials **9**, 125 (2010)

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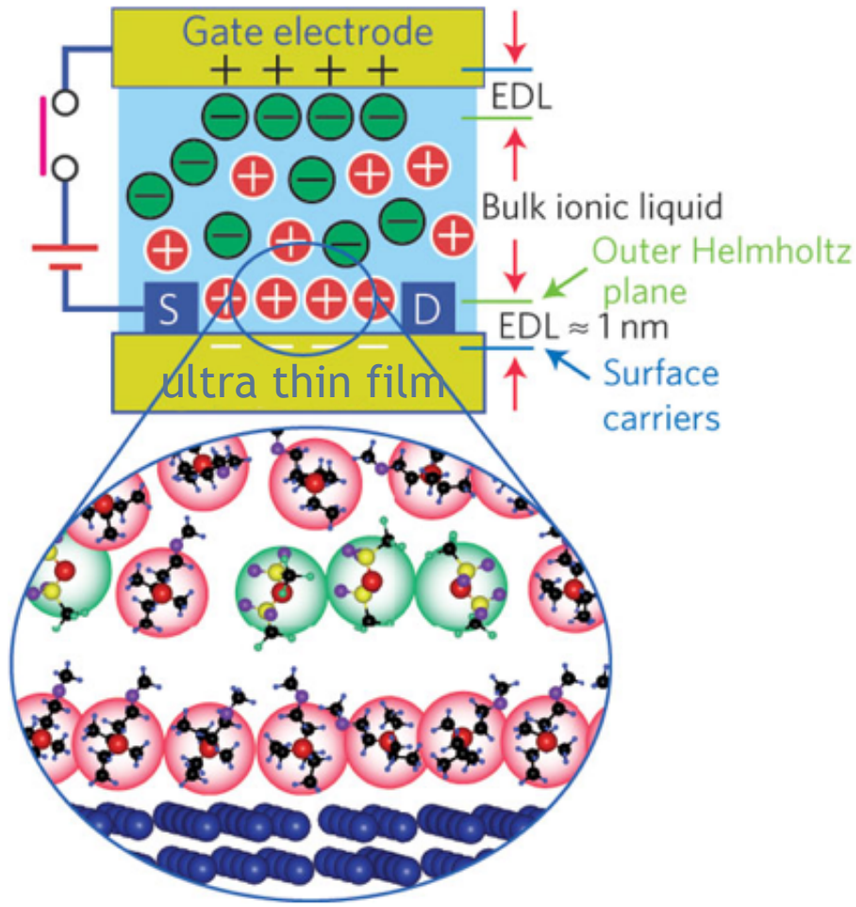
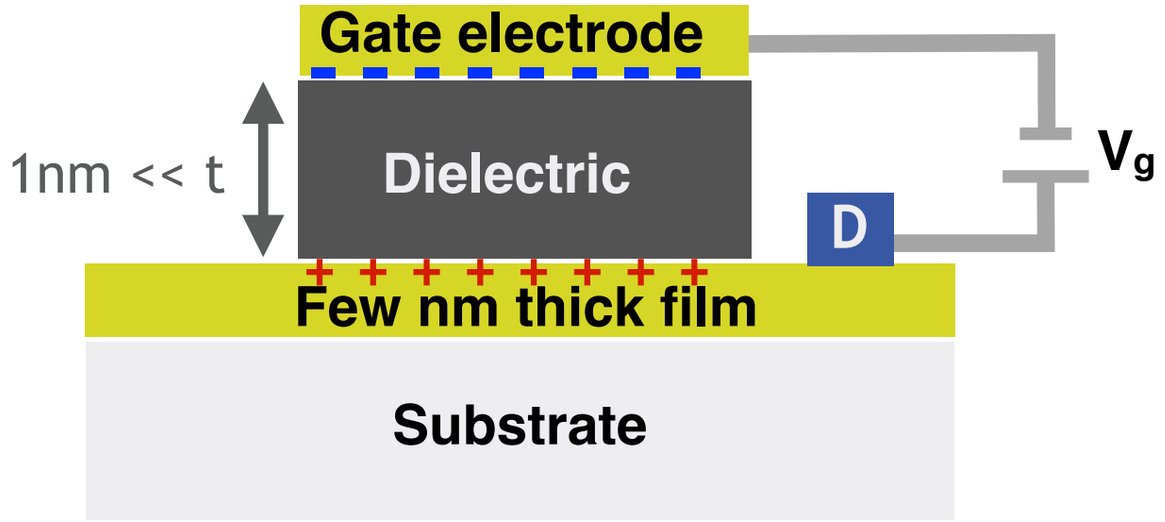


Standard FE device
(solid dielectric)



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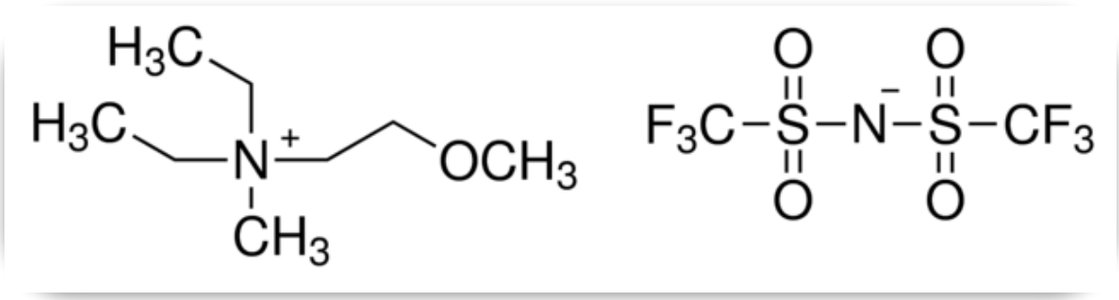
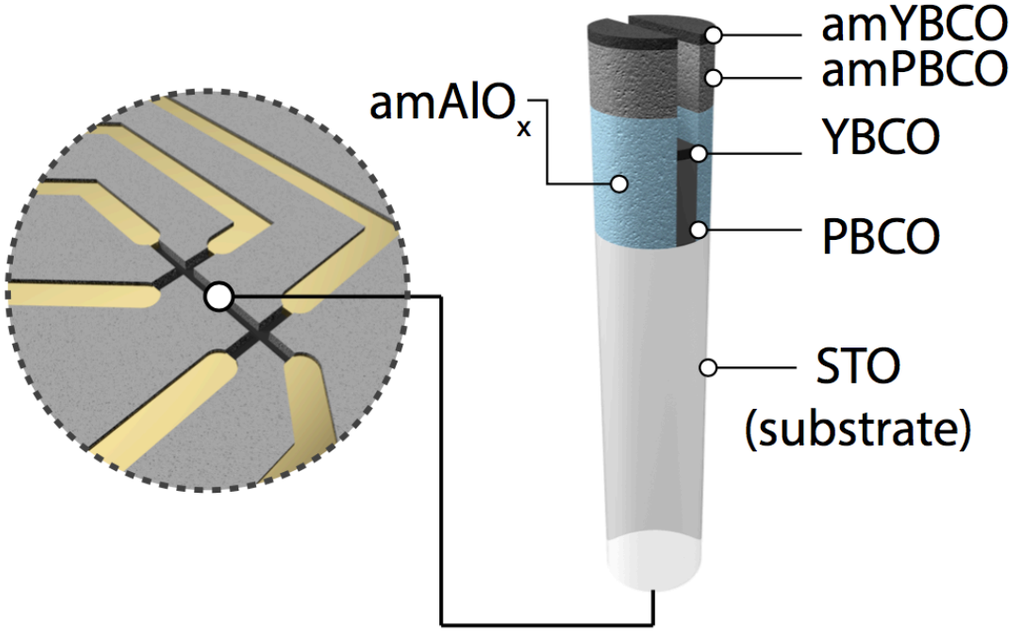
Device structure

DEME^{+} - TFSI^{-}





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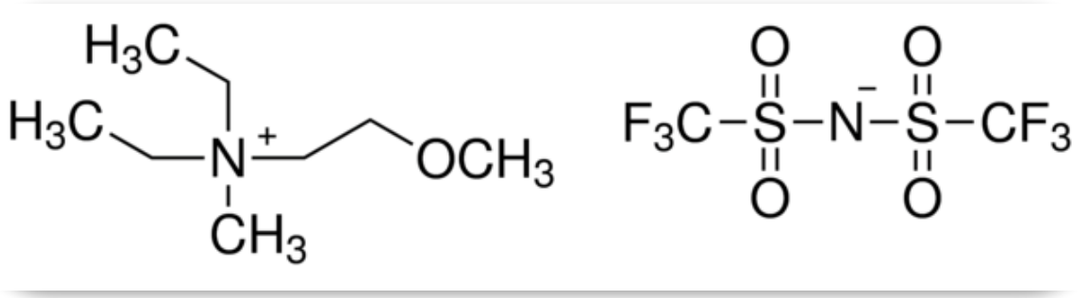

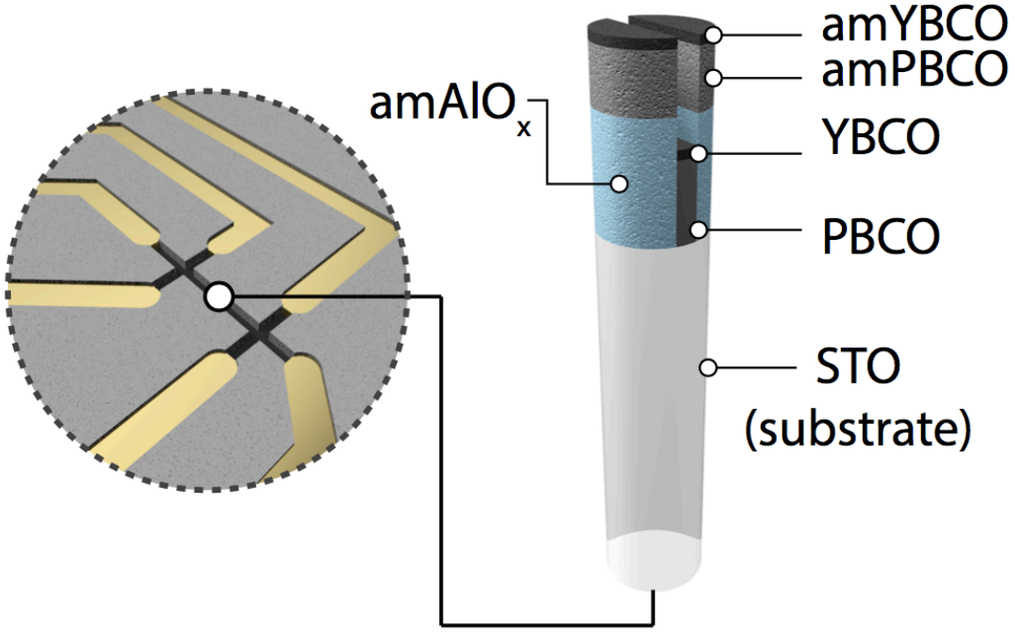

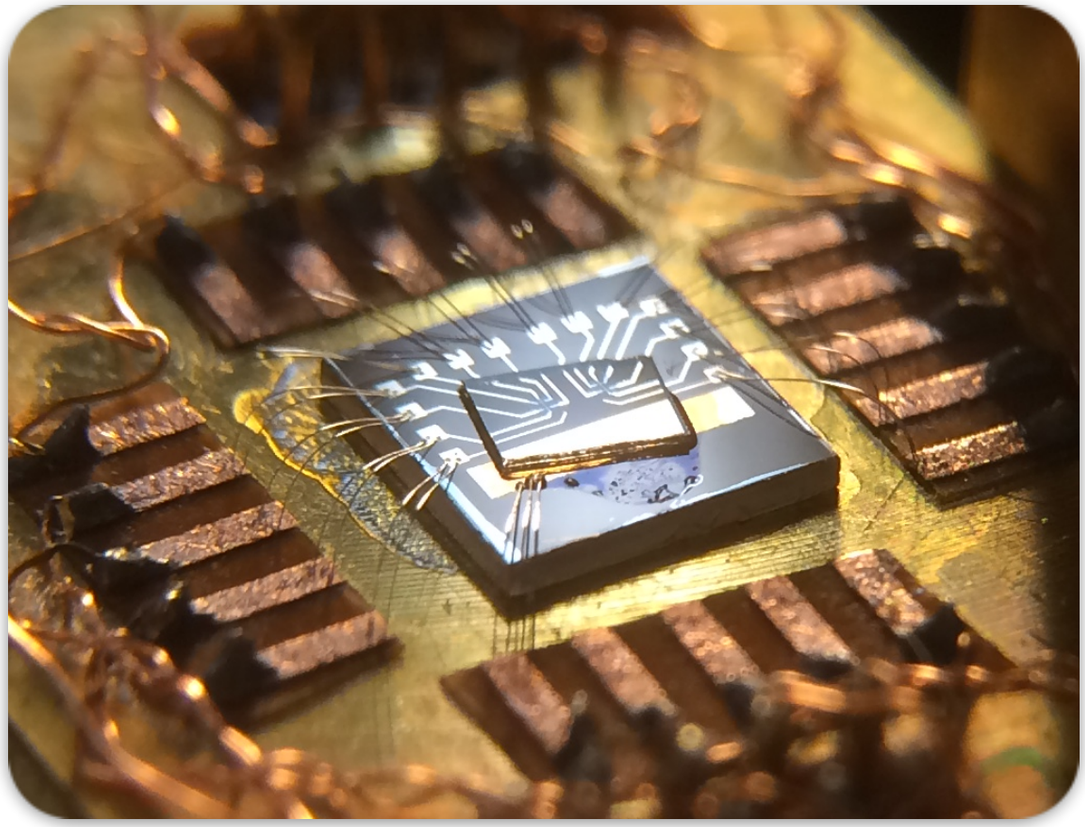

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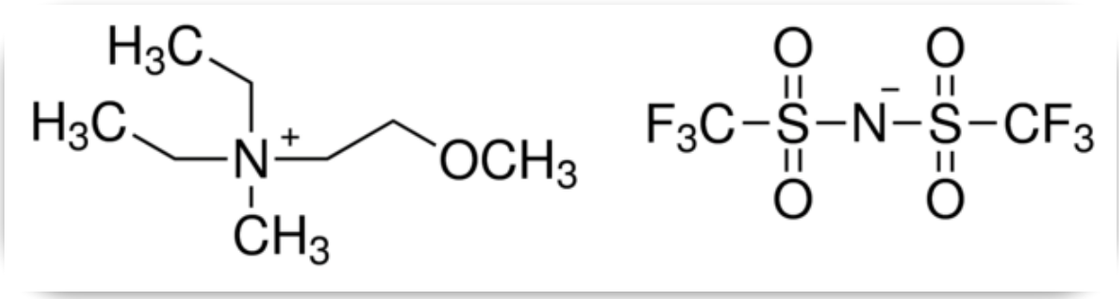
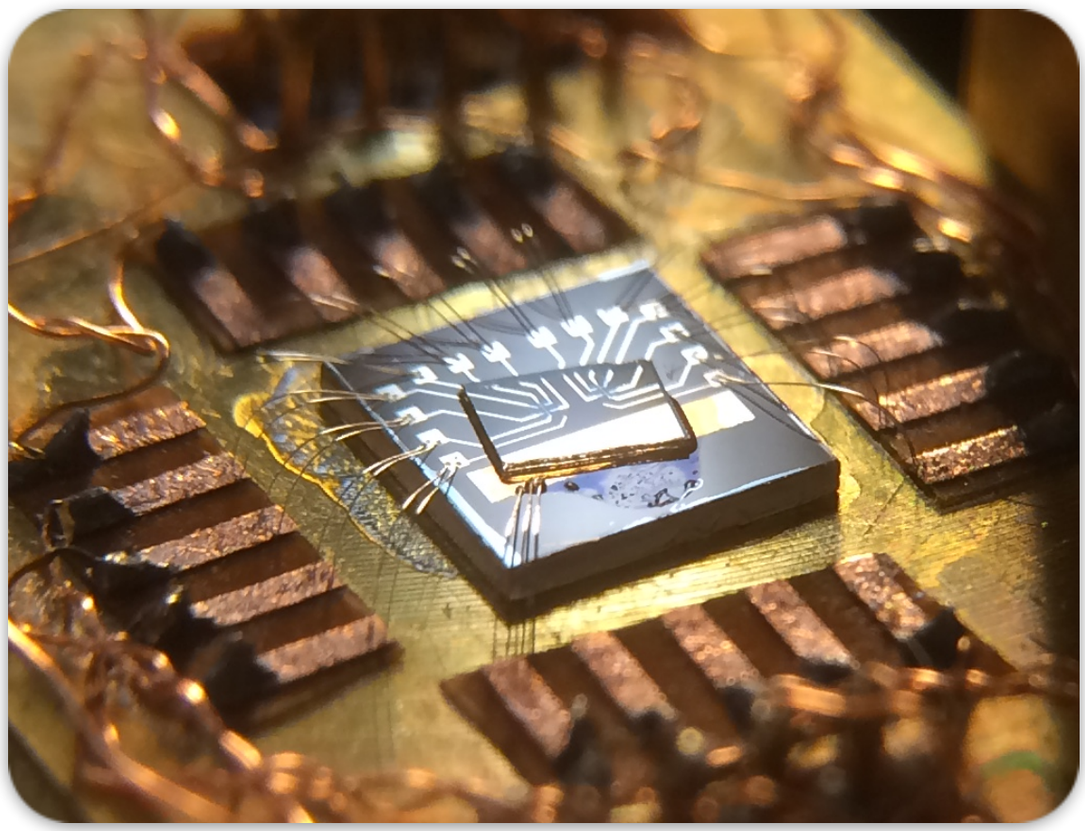




Sample preparation & characteristics

Our ultra-thin films :

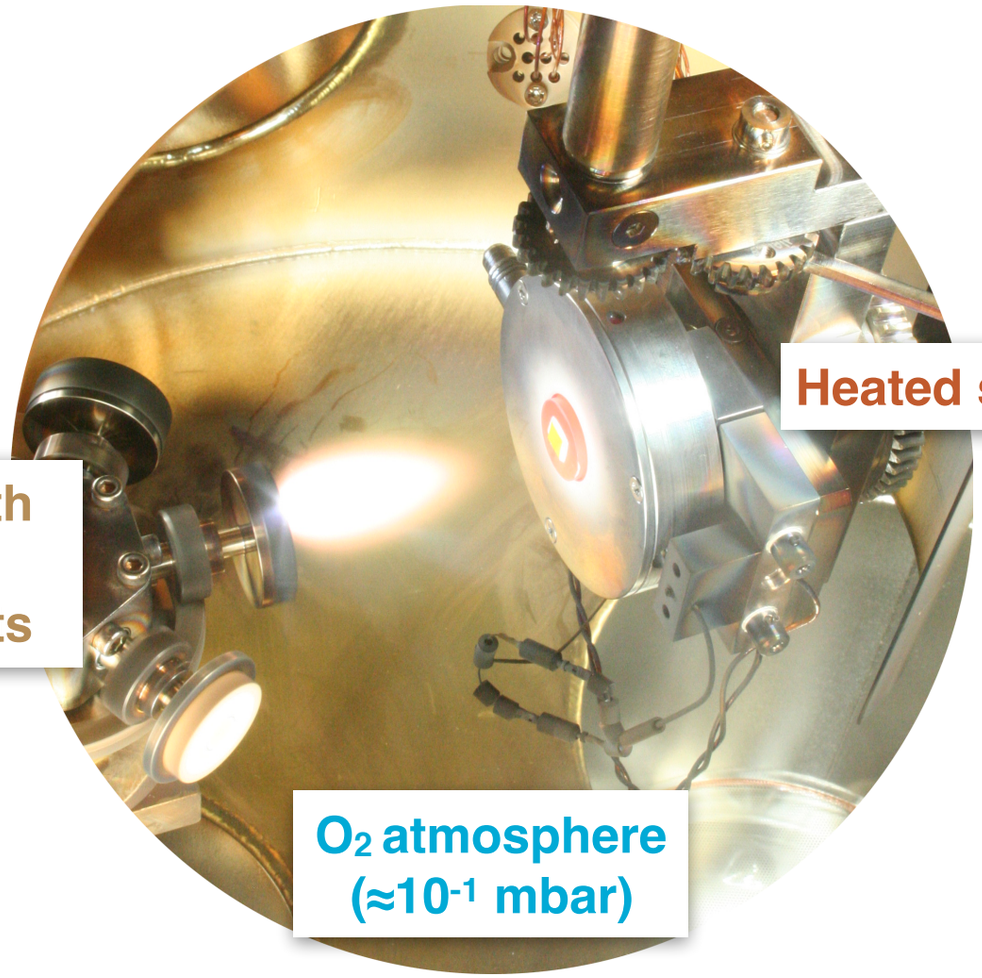
on $SrTiO_3$ substrate ([001]-tilt bi-crystals)

buffer layer : 20uc PBCO
SC layer : 5uc of YBCO

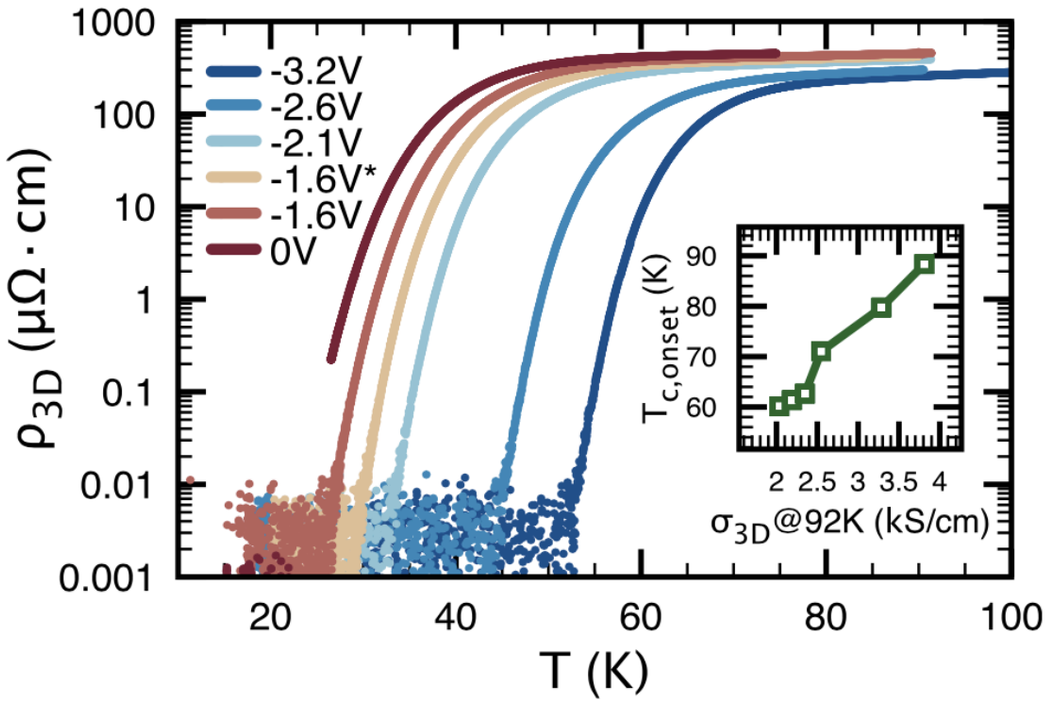
$T_c(R=0) \approx 60K$, capped

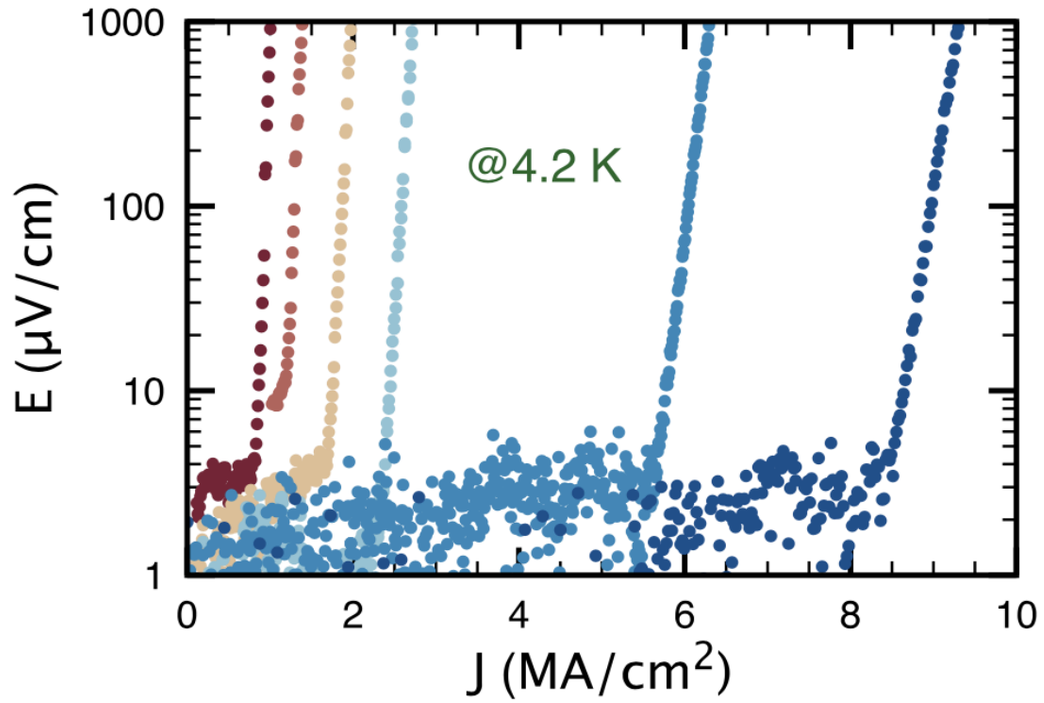
$T_c(R=0) \approx 45K$, uncapped and patterned

$T_c(R=0) \approx 20K$ with ionic liquid (device ready)



Tuning in GB free samples





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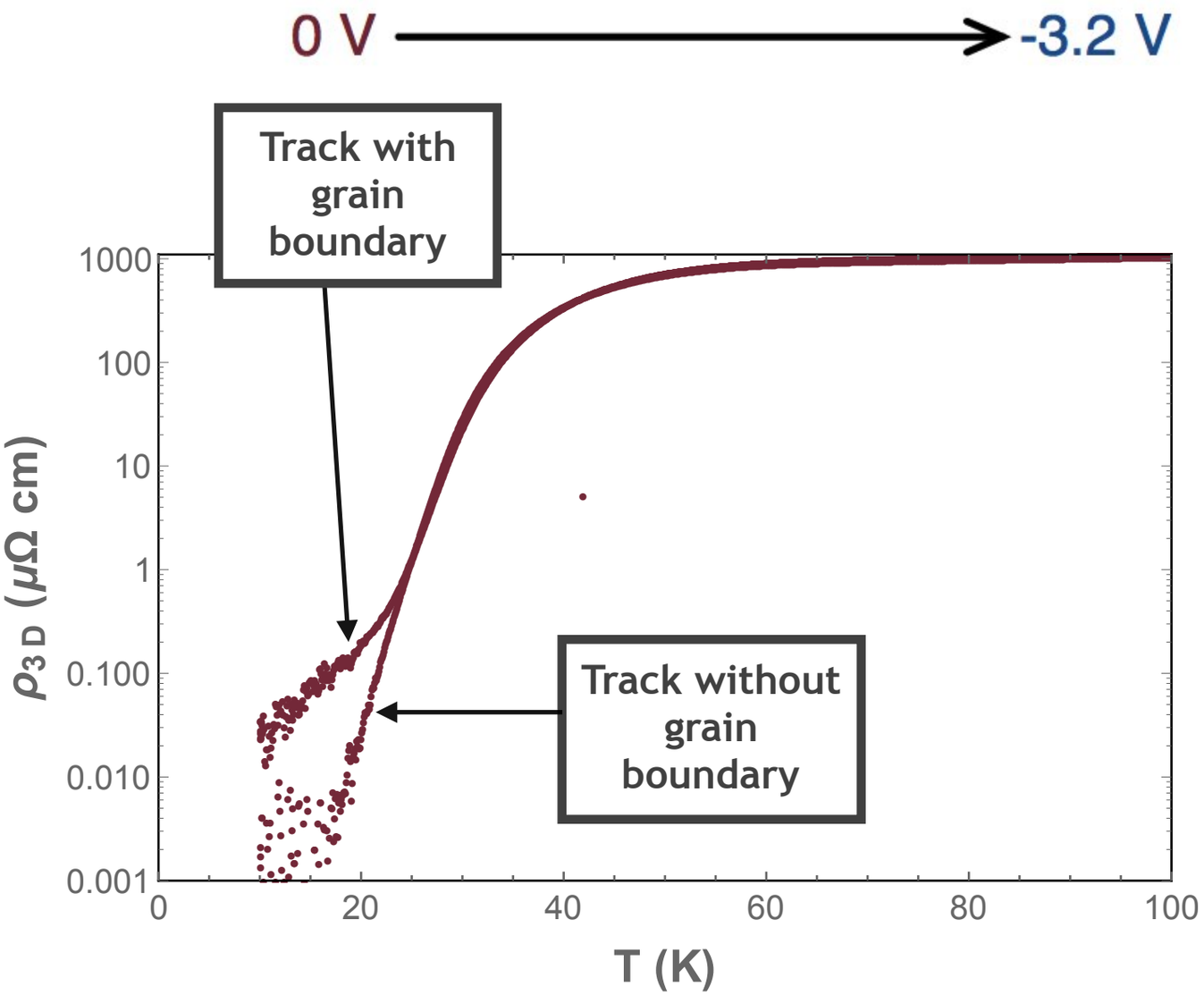
Tuning of a [001] tilt 8° GB

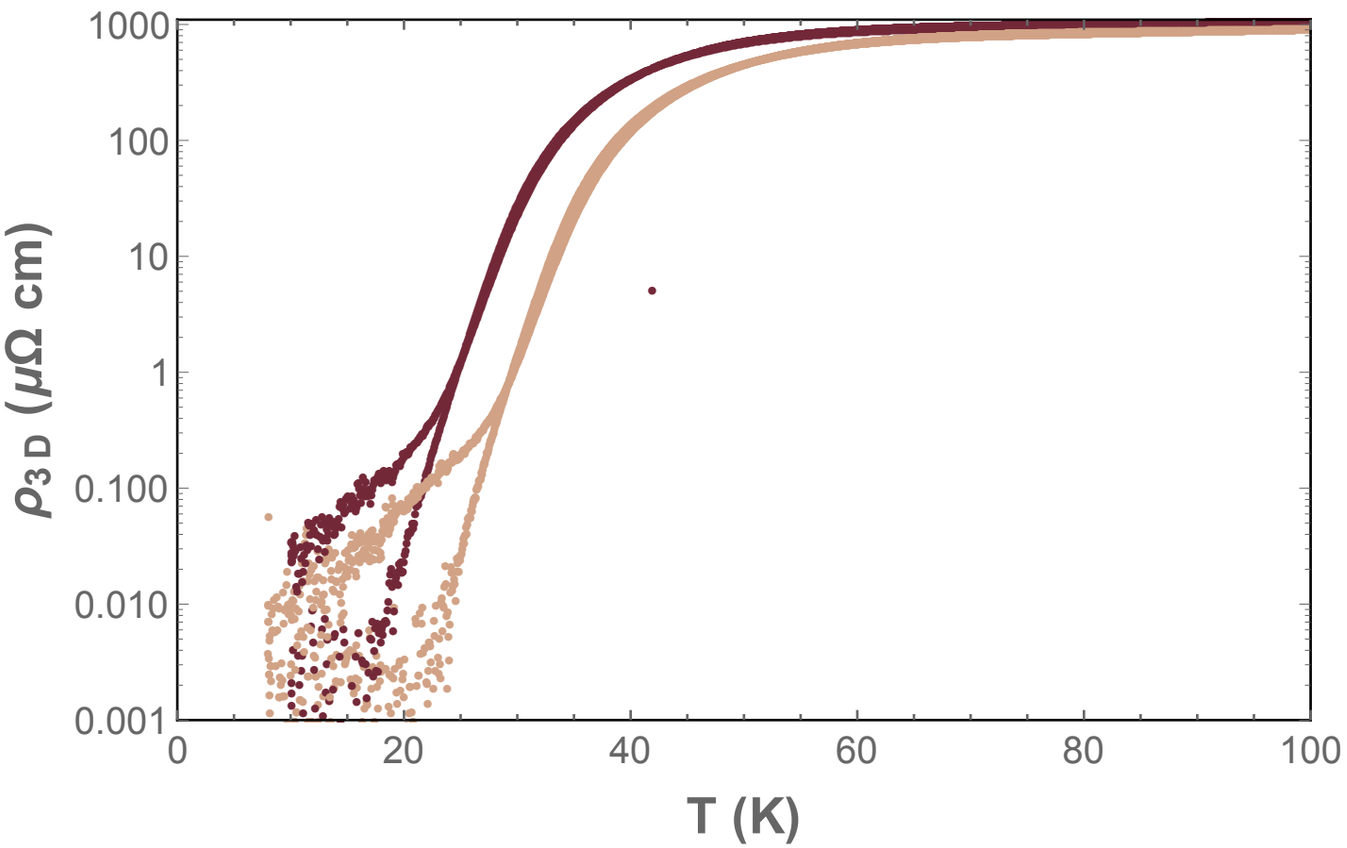
Cooling in remanent field (approx. 7mT)



Tuning of a [001] tilt 8° GB

Cooling in remanent field (approx. 7mT)

0 V → -3.2 V



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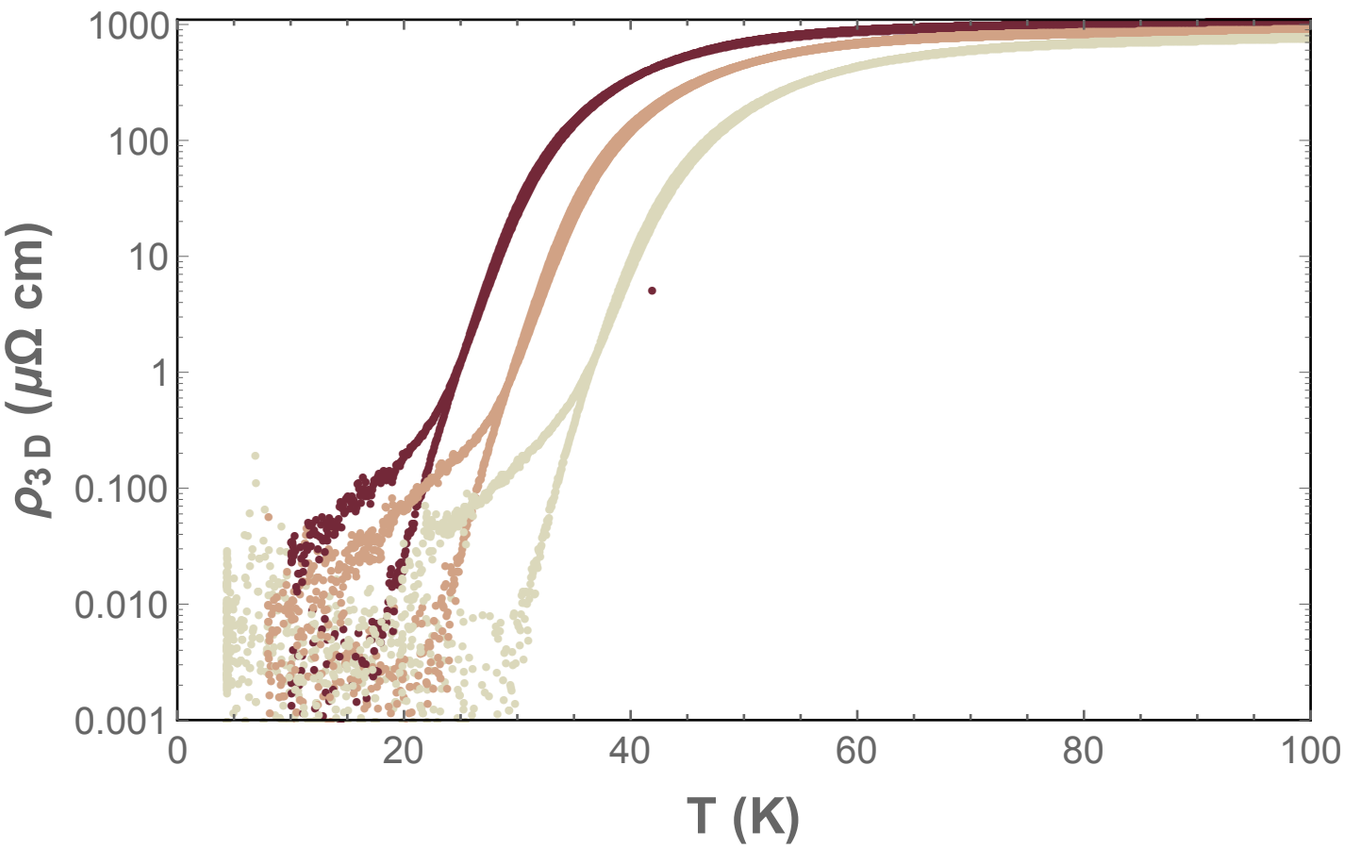

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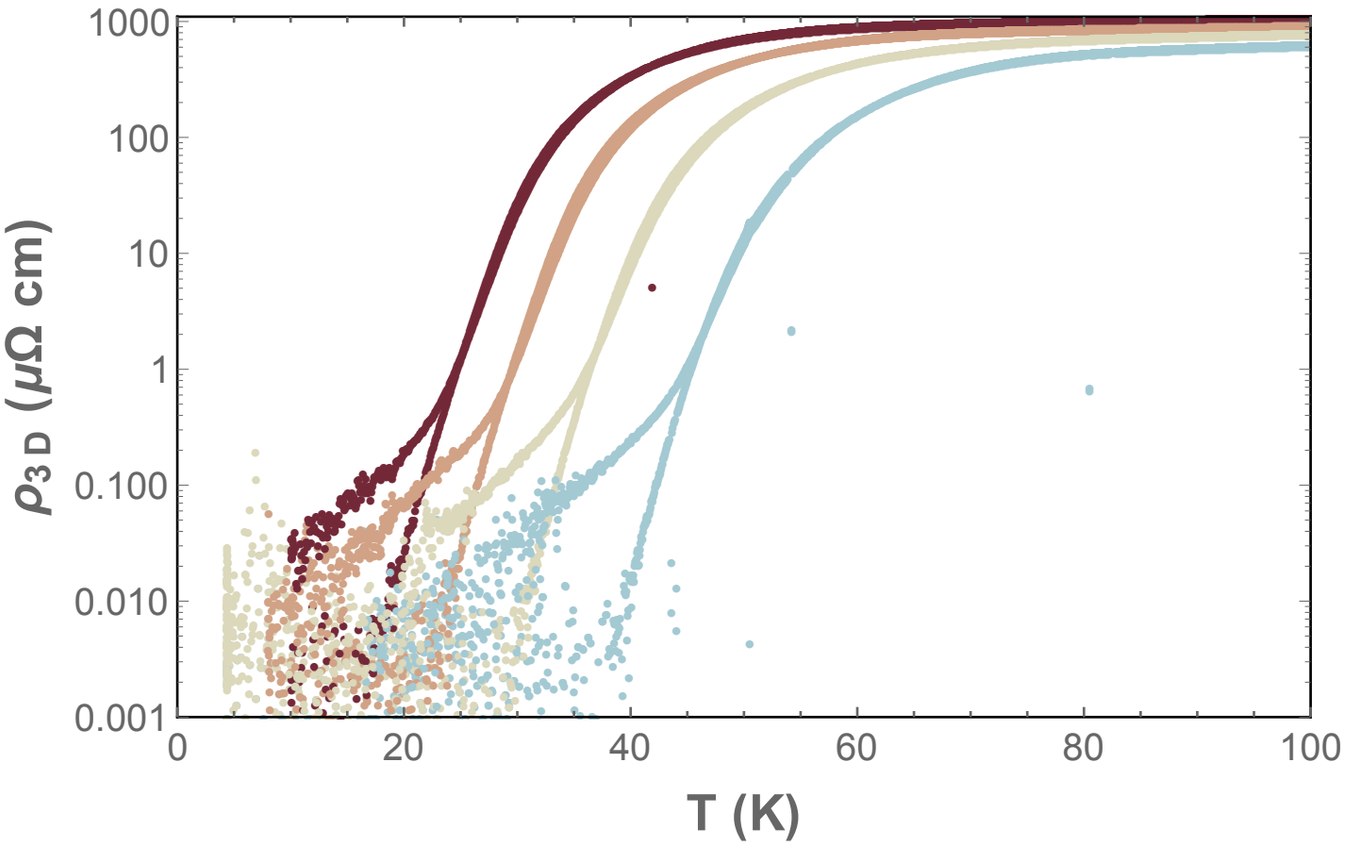

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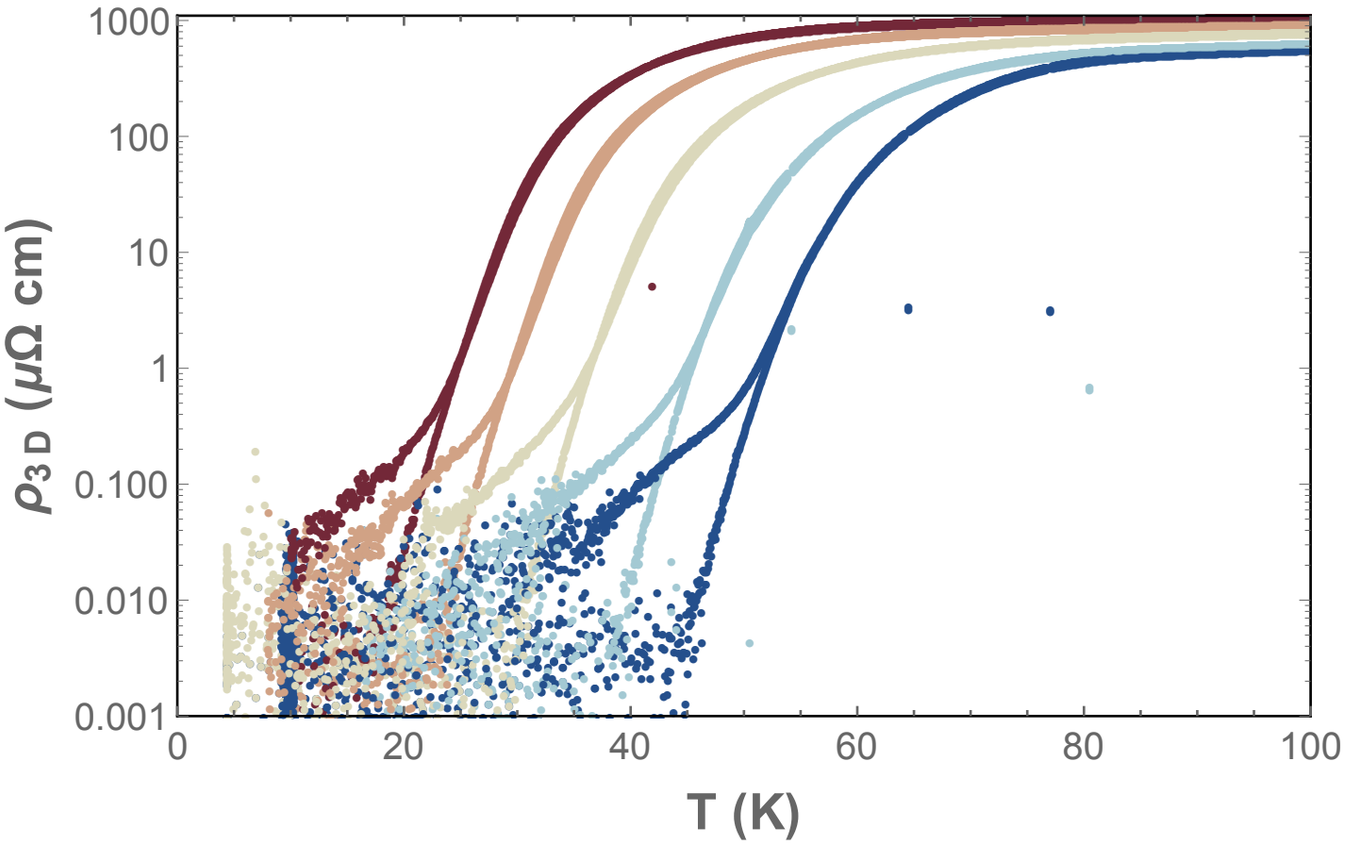

A clear increase of T_c with doping is observed on both the intra- and inter-grain channels

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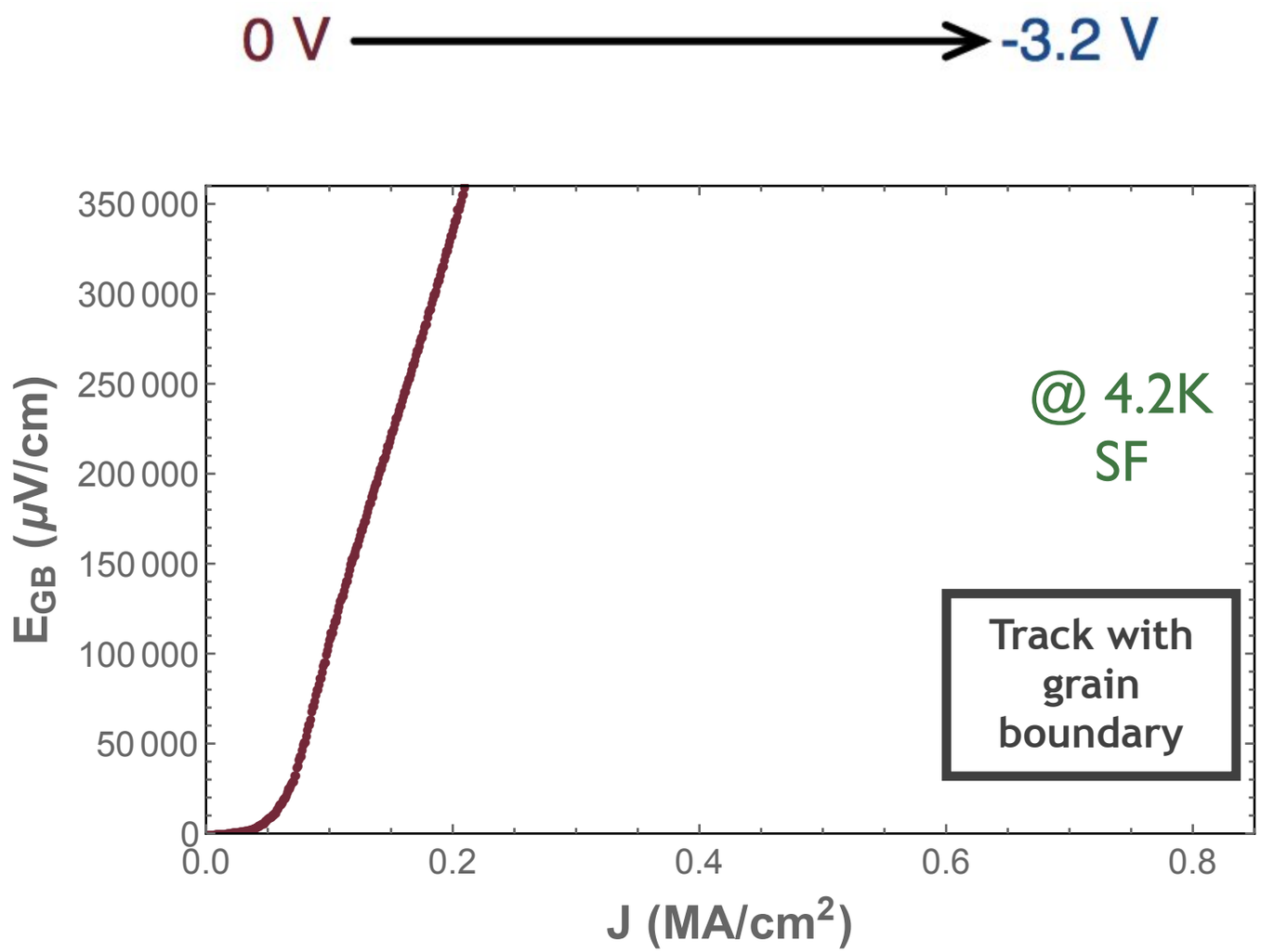

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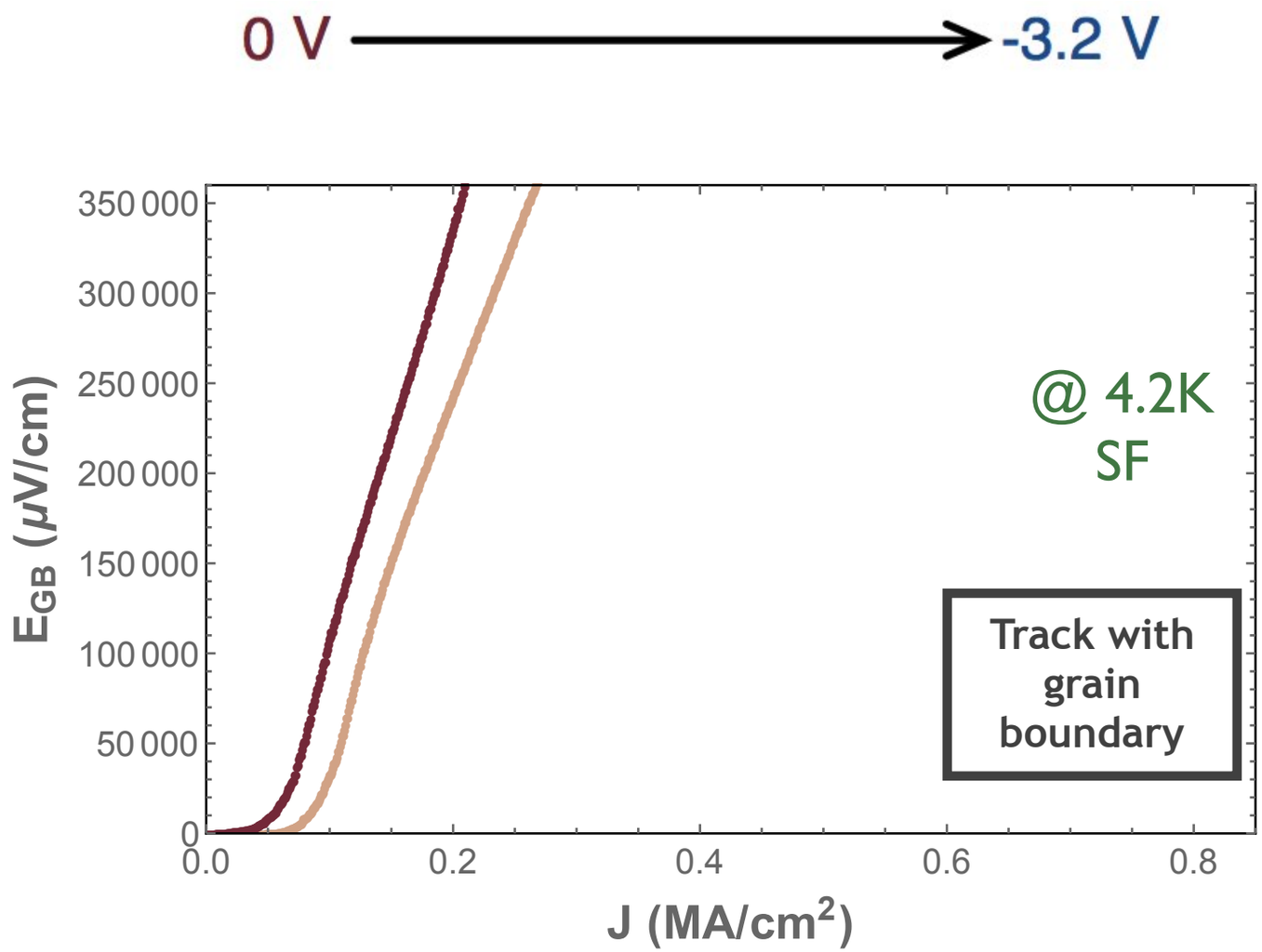

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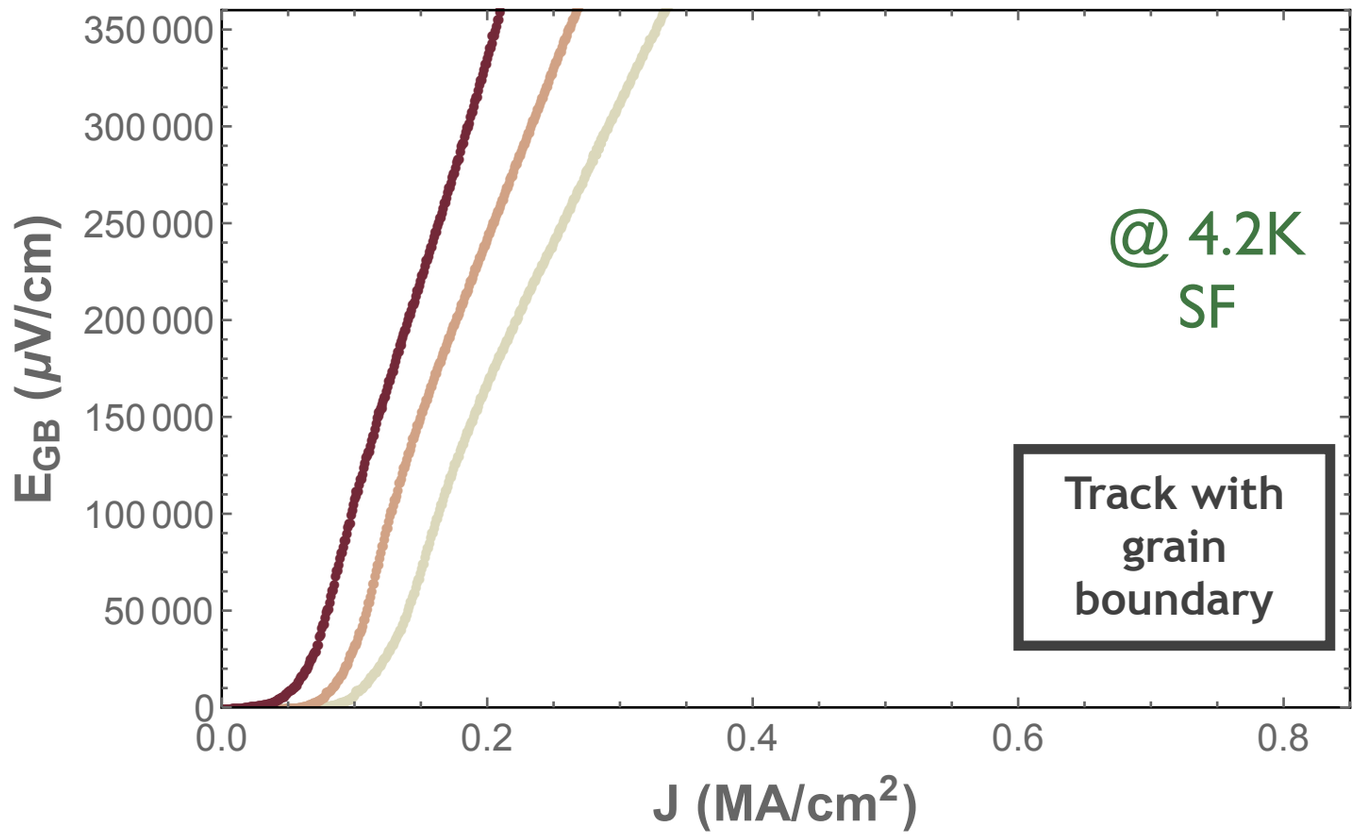

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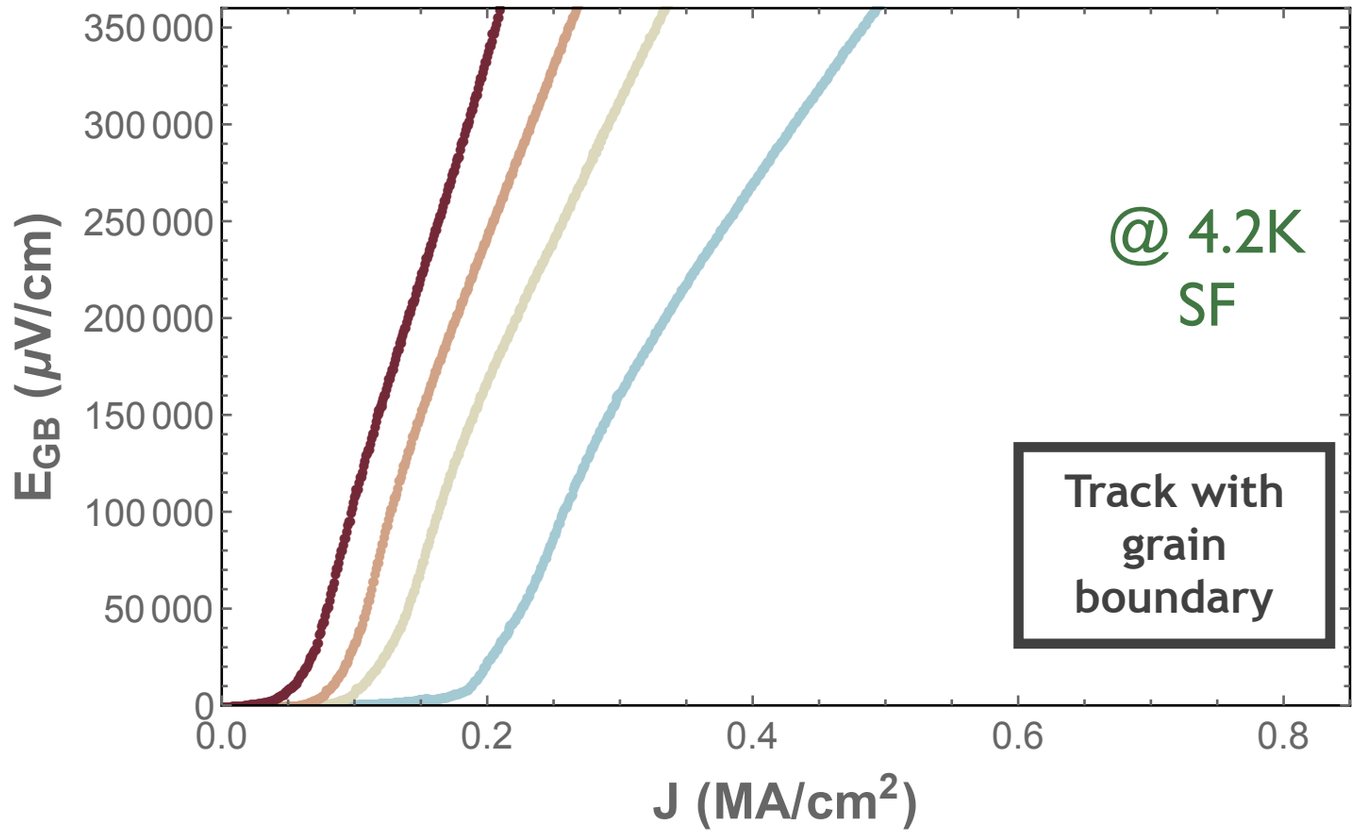

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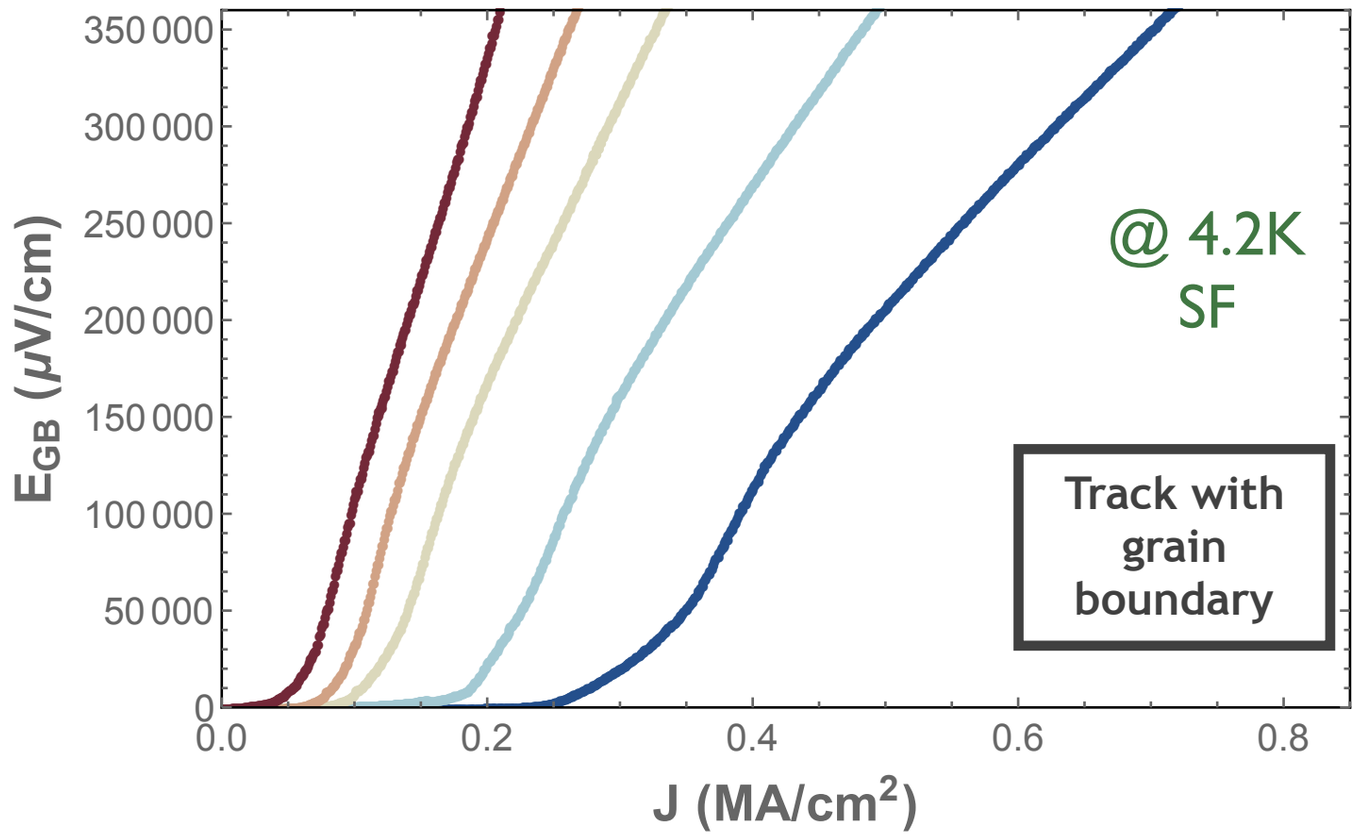
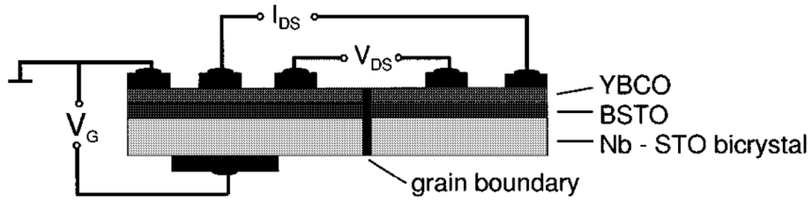


$J_{c,sf}$ is increased by a factor ≈5 !

Tuning of a [001] tilt 8° GB



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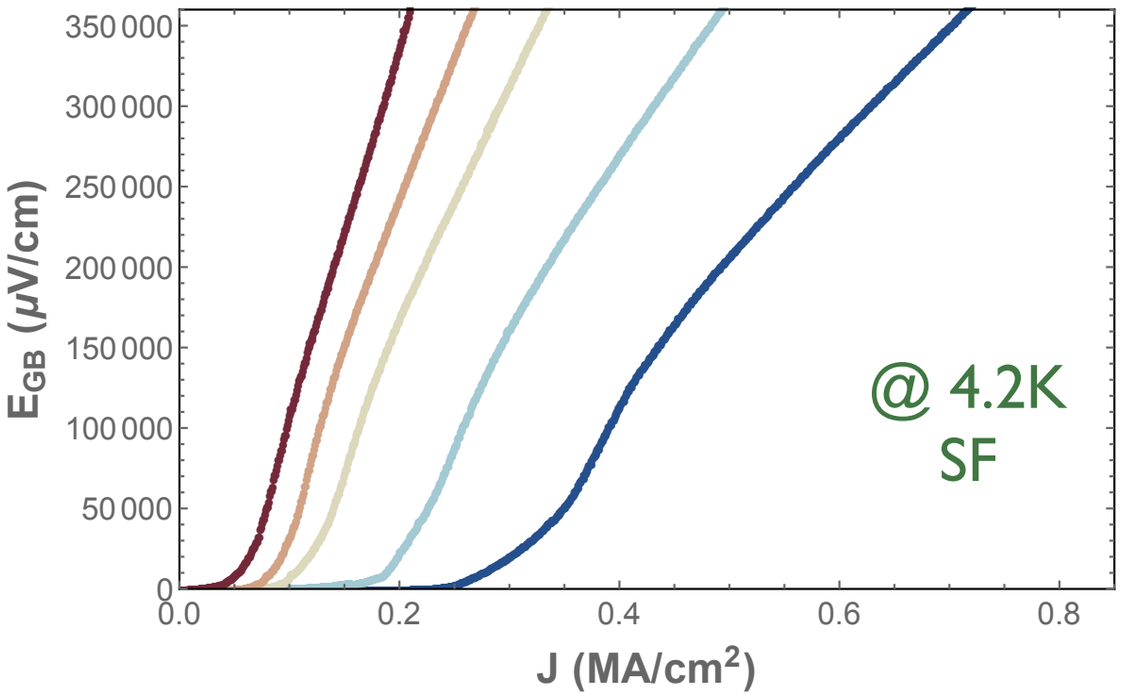

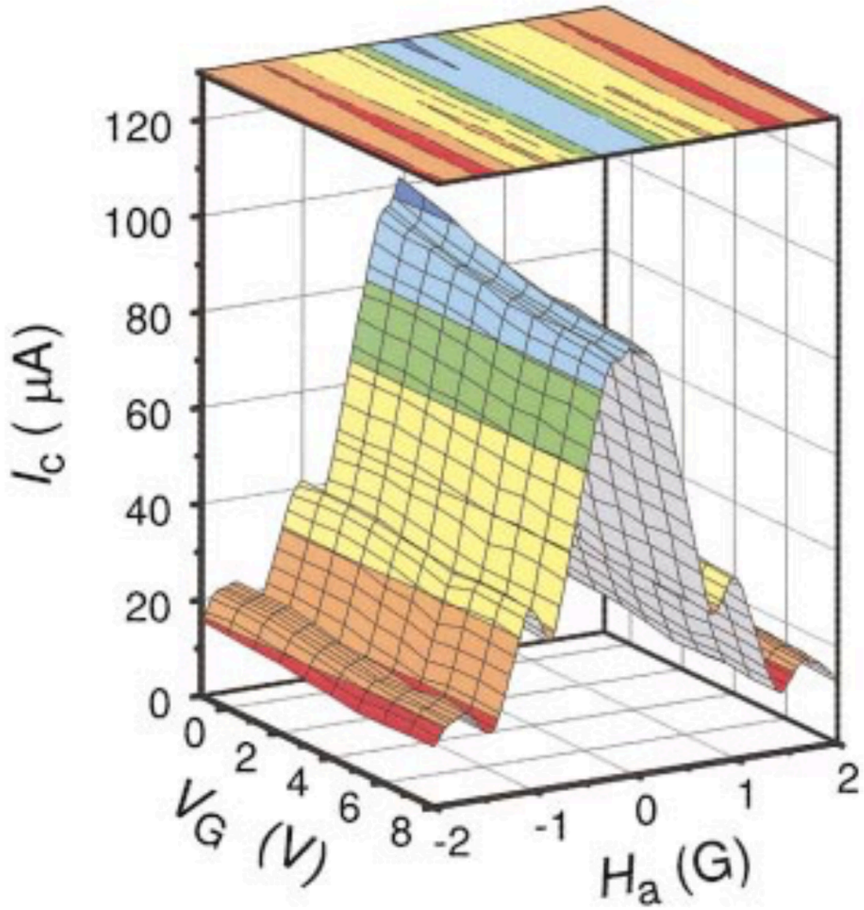

⟶

+360% increase in J_c

B. Mayer, J. Mannhart, H. Hilgenkamp, APL, **68** 3031 (1996)

+10%-20% increase in J_c

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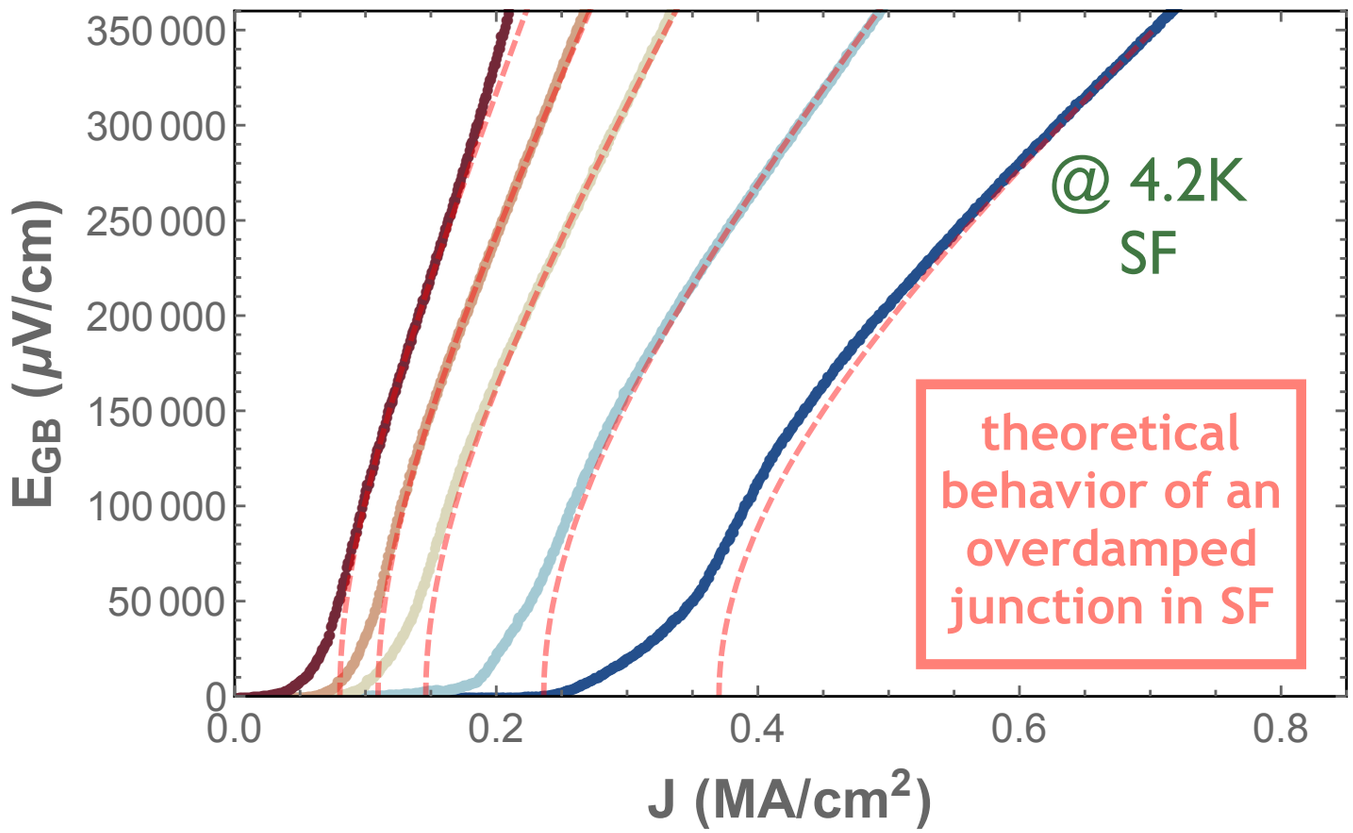
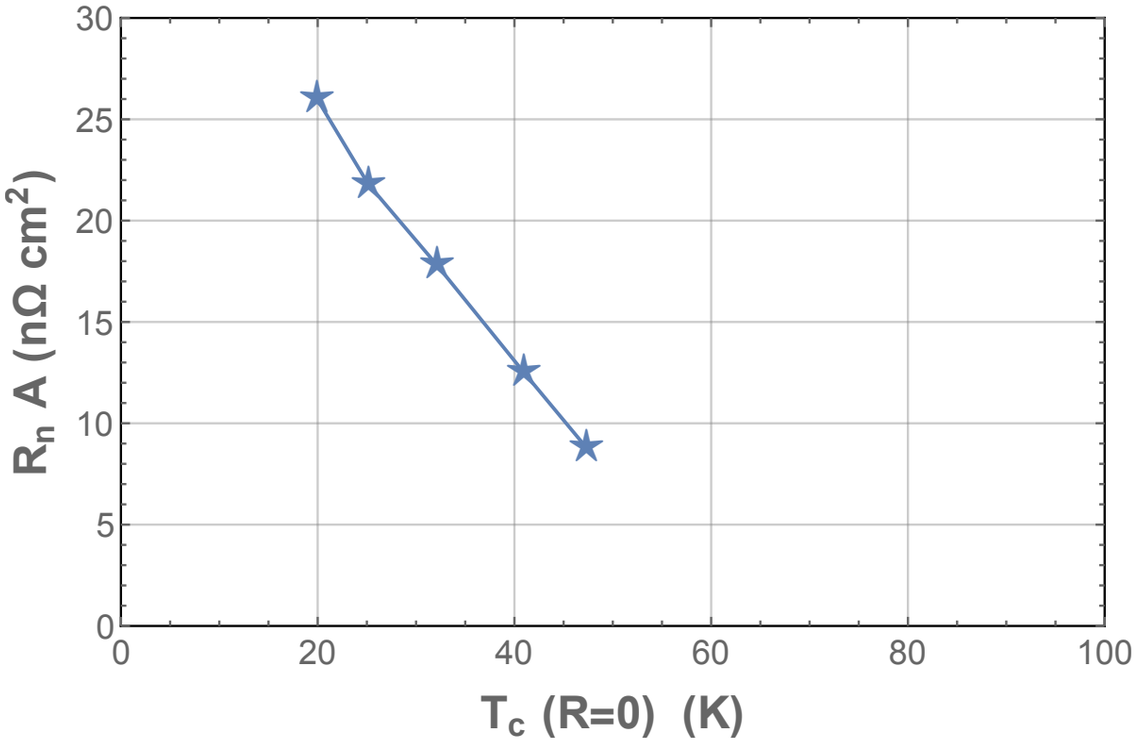
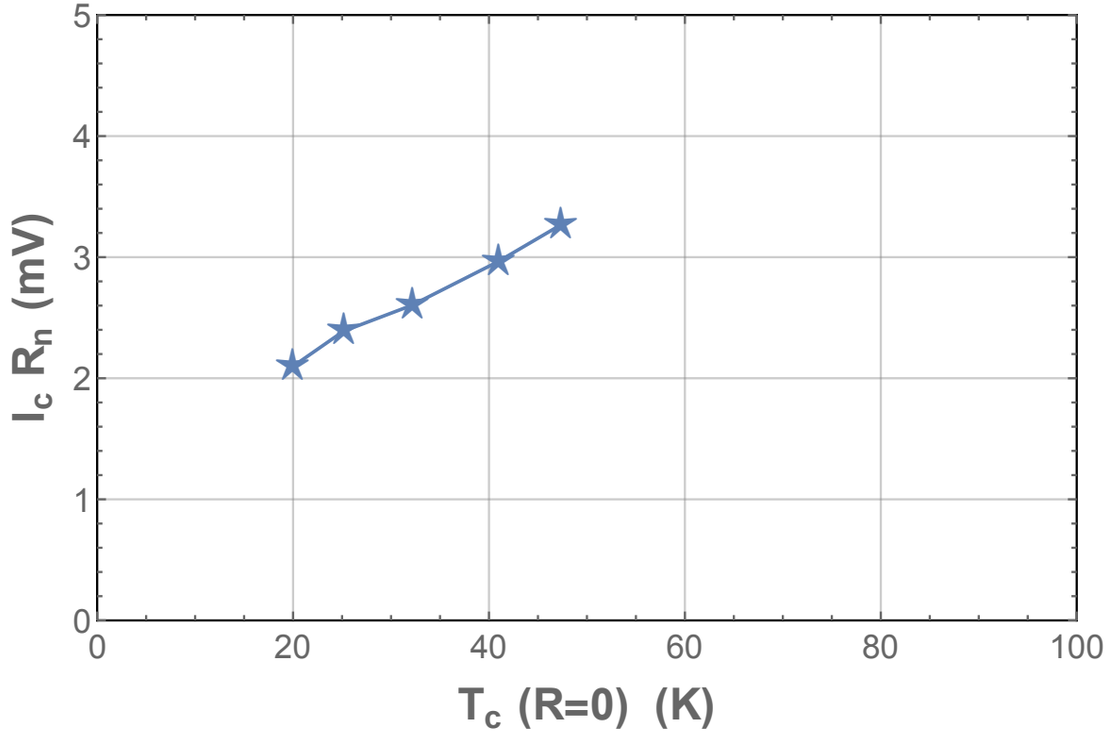


Tuning of a [001] tilt 8° GB

Extrapolating our results (not recorded in absolute zero field) within the RCSJ model gives :





The parameters of the junction are strongly improved

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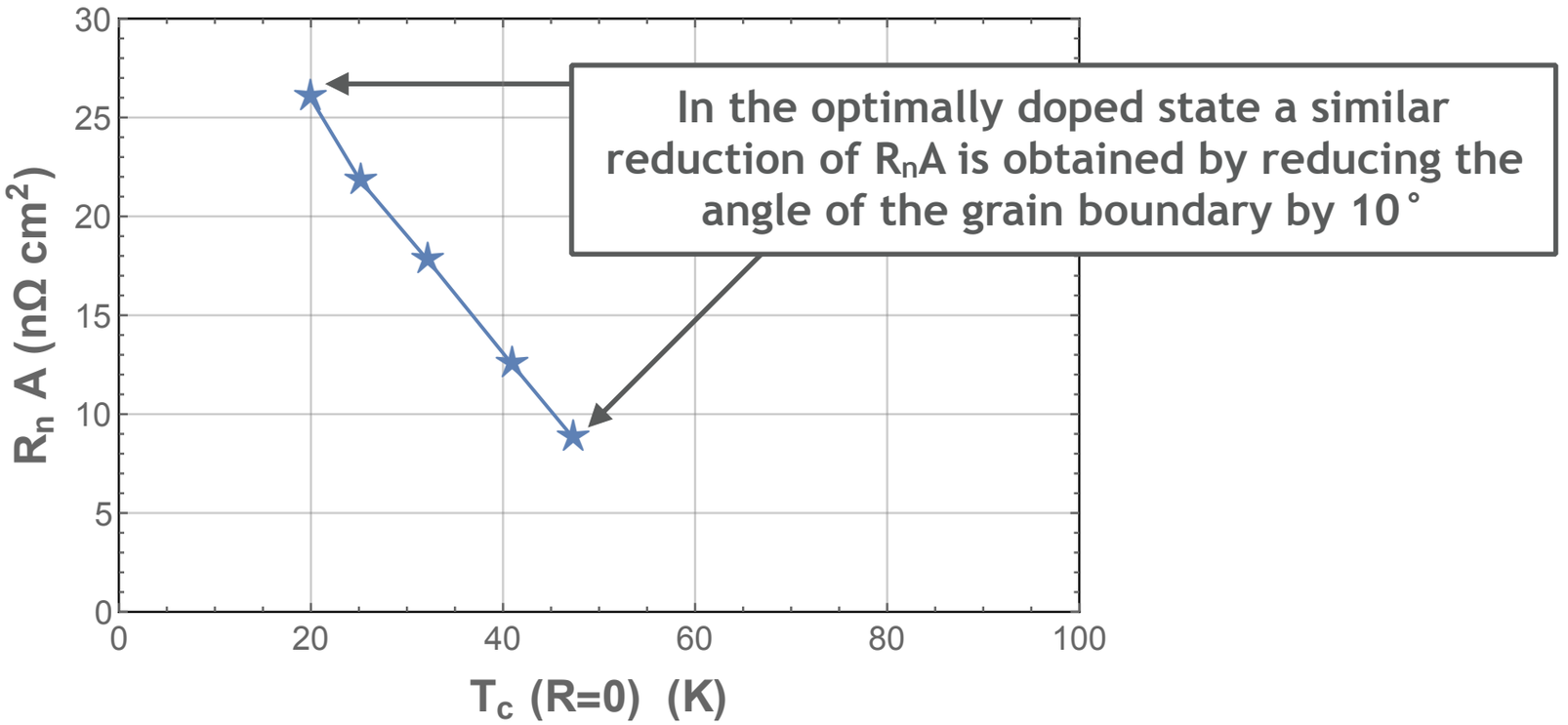

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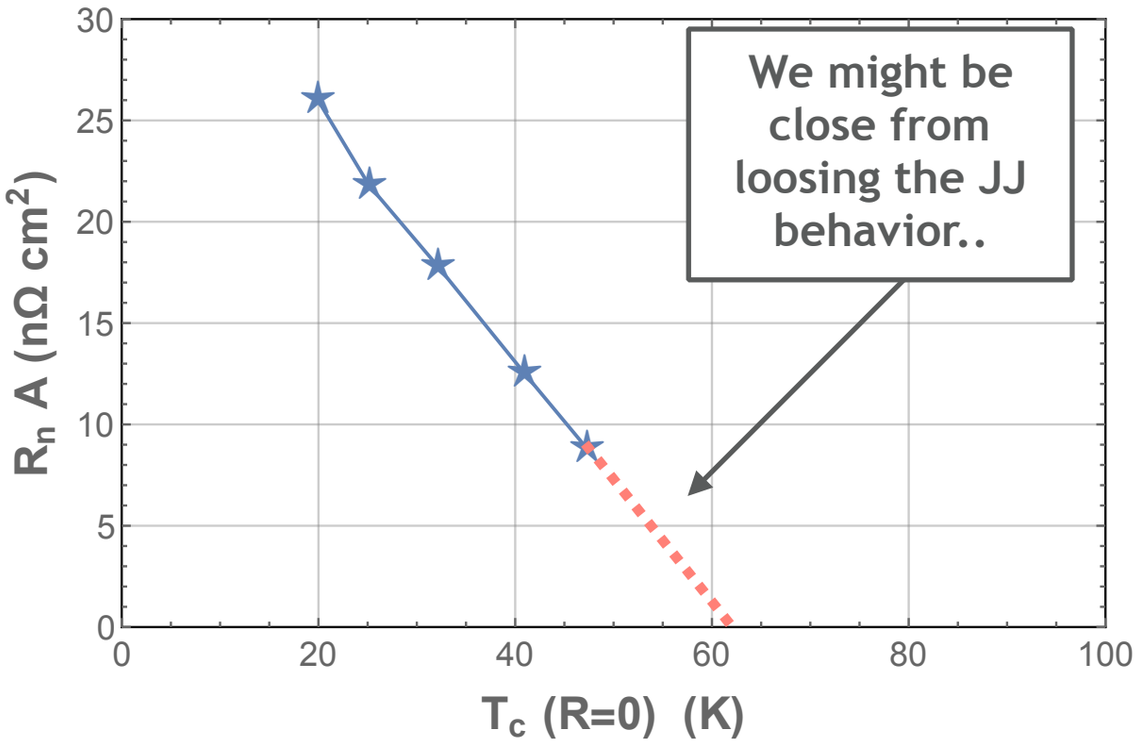
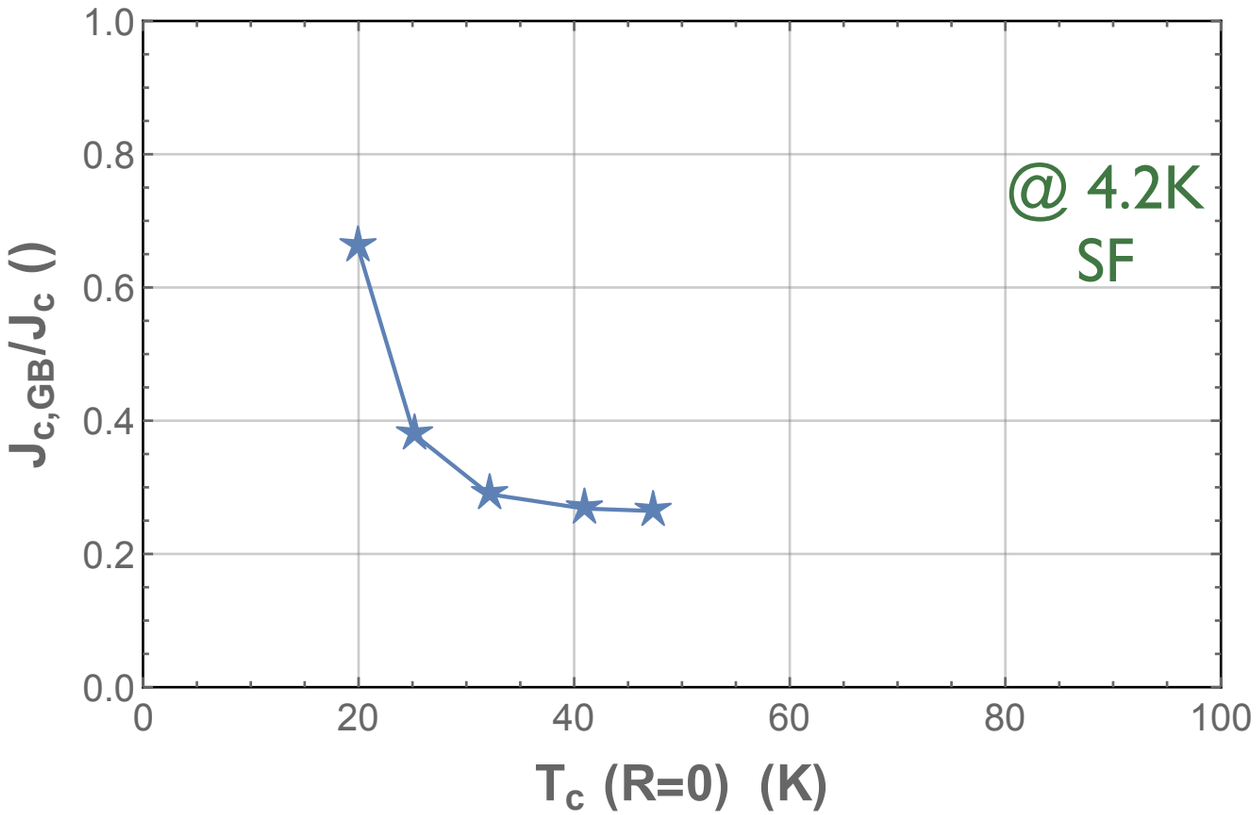


The parameters of the junction are strongly improved

Tuning of a [001] tilt 8° GB

Yet $J_{c,GB}/J_c$ displays a surprising behavior



Tuning of a [001] tilt 8° GB

But $J_{c,GB}$ and J_c have different relation to the superfluid density :
(estimated by $1/\lambda^2$, λ: London penetration depth)

$J_{c,GB} \propto 1/\lambda^2$ while $J_c \propto (1/\lambda^2)^{3/2}$

Tunneling of the SC condensate

valid for a thin film (thickness<λ)

Talantsev and Tallon
Nat. Comm., **6**, 7820 (2015)

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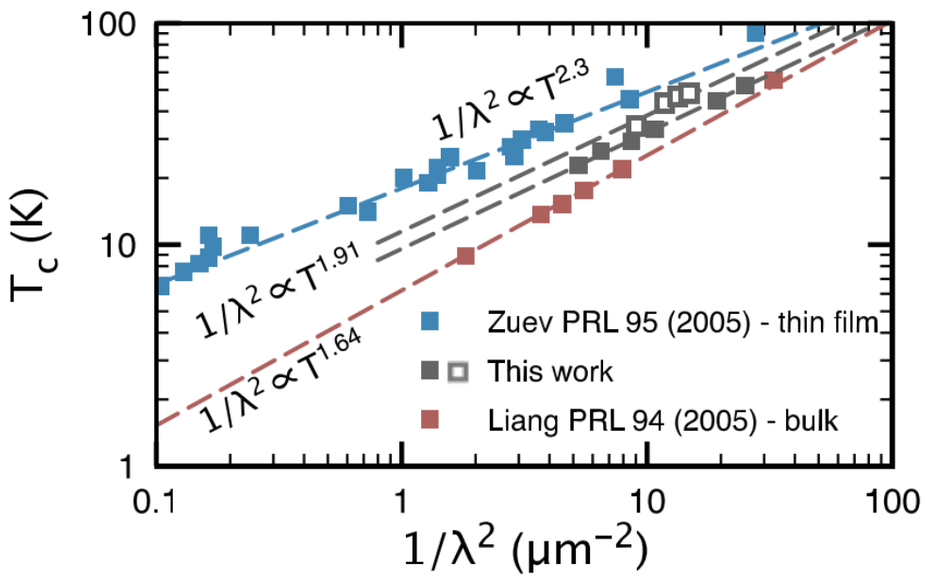
From a previous study :



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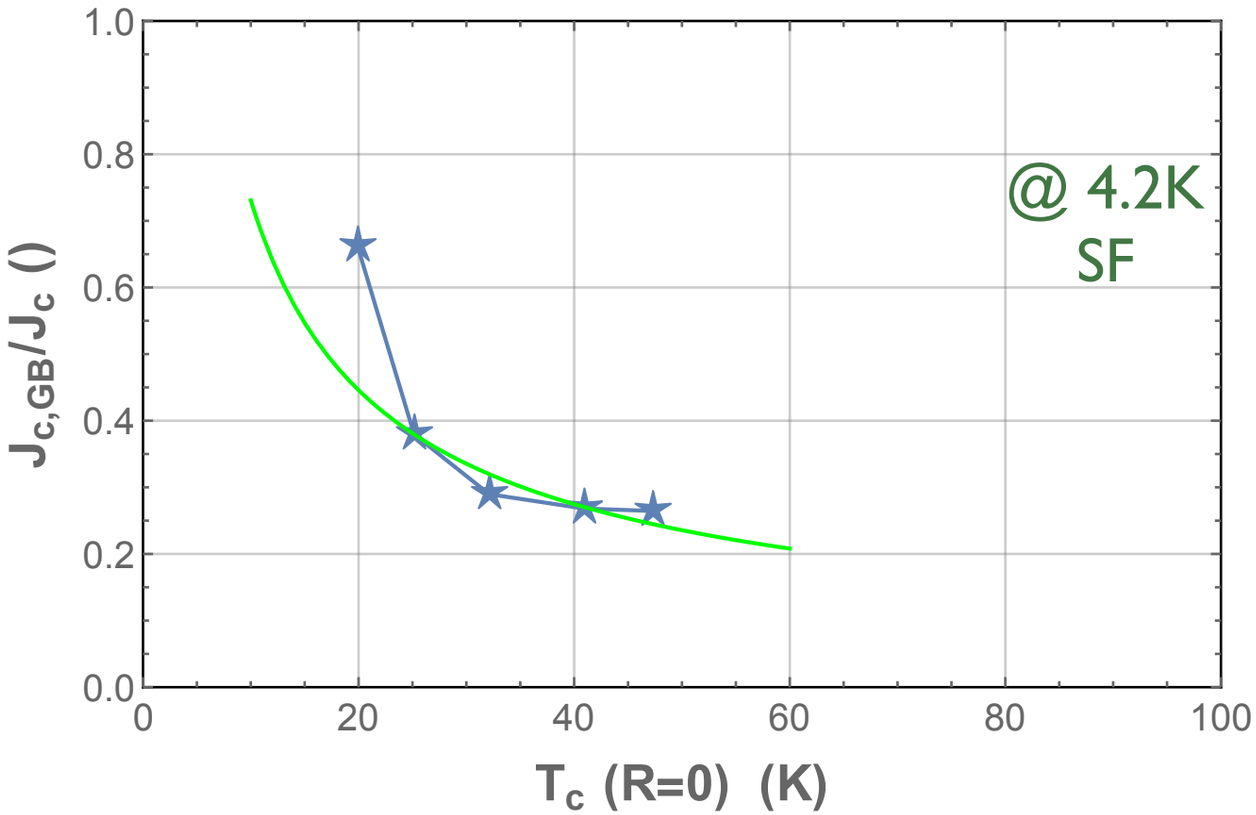
Tuning of a [001] tilt 8° GB

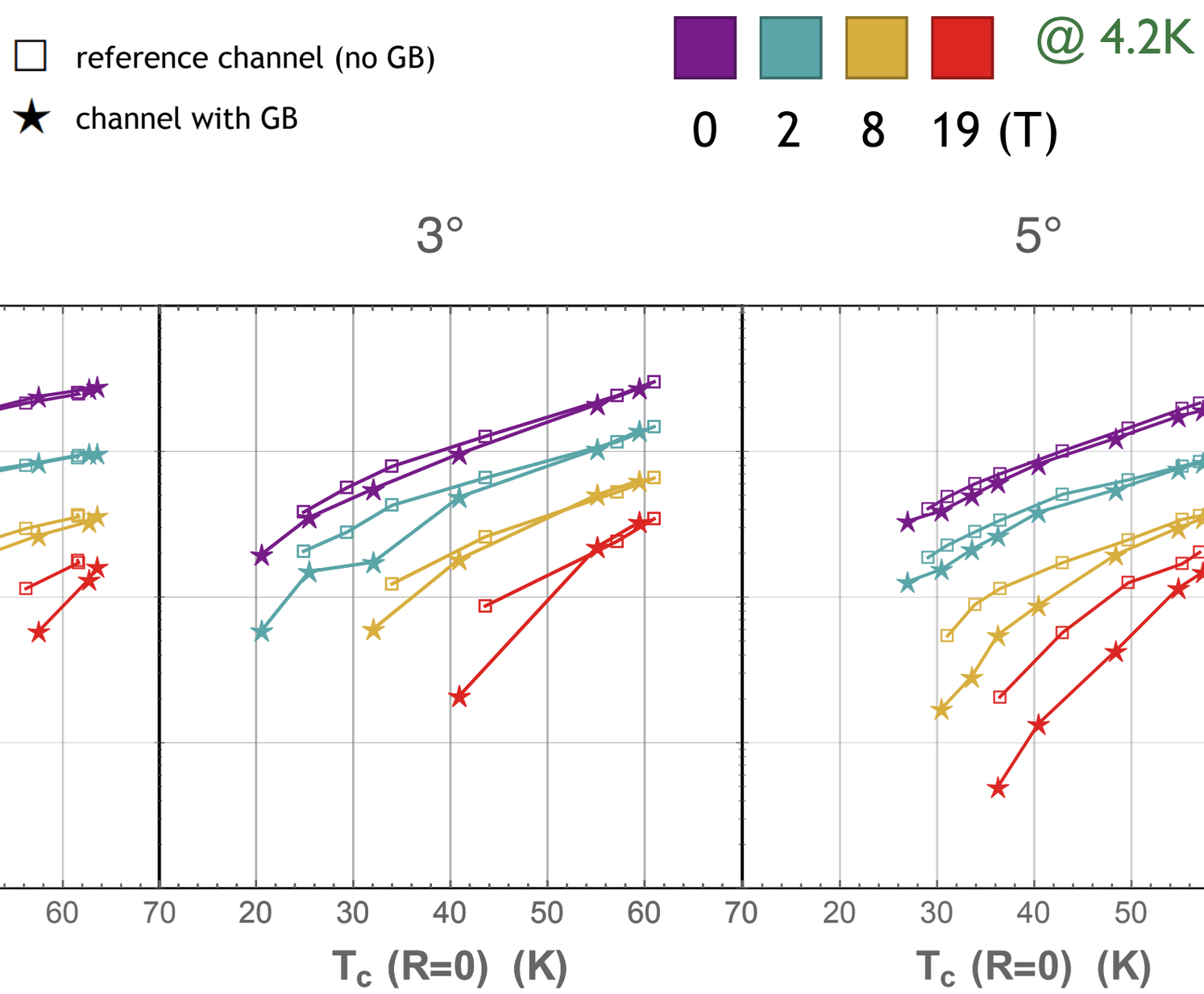
Taking into account this yields a relatively good fit



Refinements of this model shall include a dependence of the barrier height with electric field effect and the evolution of the coherence length across the phase diagram

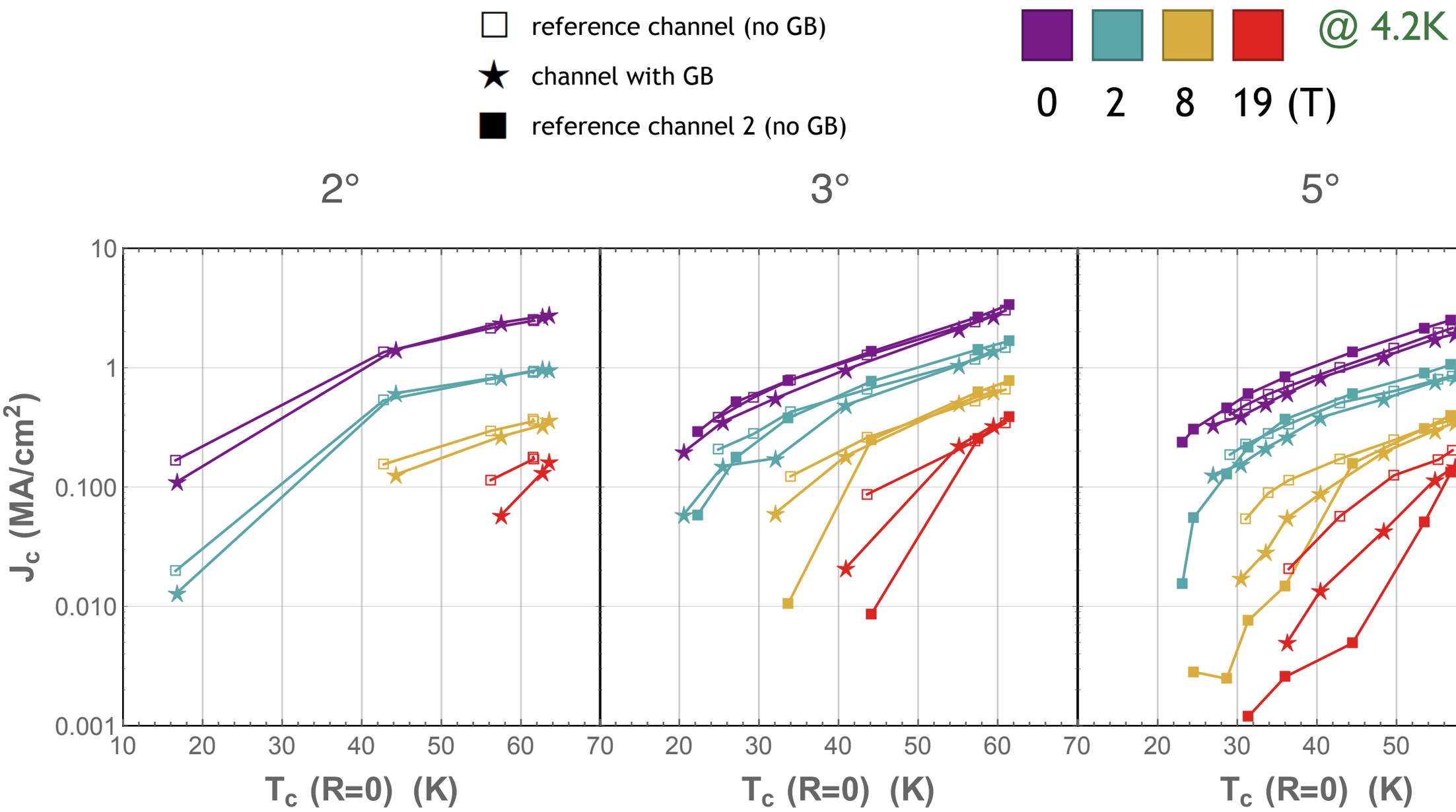
Other angles

Given the vicinity of the transition from JJ (weak-link) to strong link behavior we explored lower GB angles, namely :



Other angles

Checking against a second reference channel on the same device makes it much more complicated to be conclusive



Conclusions and Perspectives

Facts :

1) A strong tuning of the transport across an 8° grain boundary was achieved.

2) For lower angles the transparency of the grain boundaries is such, that the tuning, if present, is hidden by data scattering

Perspectives :

The vicinity of the strong link regime for films grown on 8° bicrystals and the difficulty to observe any difference between inter- and intra-grain transport for films on 2° to 5° bicrystals provide the following research orientation :

1) Find 7° bi-crystals and repeat
2) Work with thicker films (able to sustain higher initial doping) hoping that the limited penetration depth of the electric field won’t be detrimental

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- Thank you for your attention -

Alexandre Fête