Metal-doped graphene monolayers on plastic:
a highly flexible 2D superconducting film

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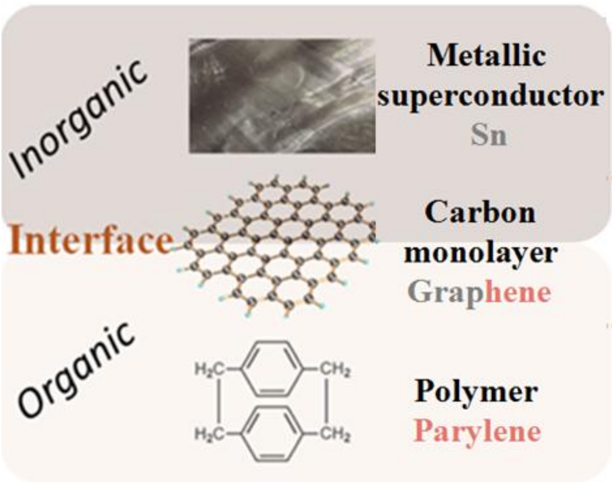
A new macroscopic 2D superconductor flexible film, a mix of 3 original ingredients



if Sn made thin or discontinuous

- no electrical loss
- low thermal conductivity (at low temperature)

flexibility

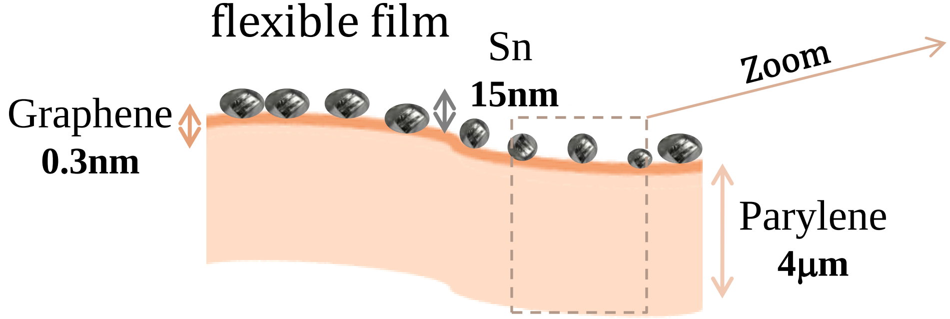
- electrically tunable
- high mechanical resistance

flexibility

- high mechanical resistance
- low thermal conductivity

flexibility

2D superconductor flexible film



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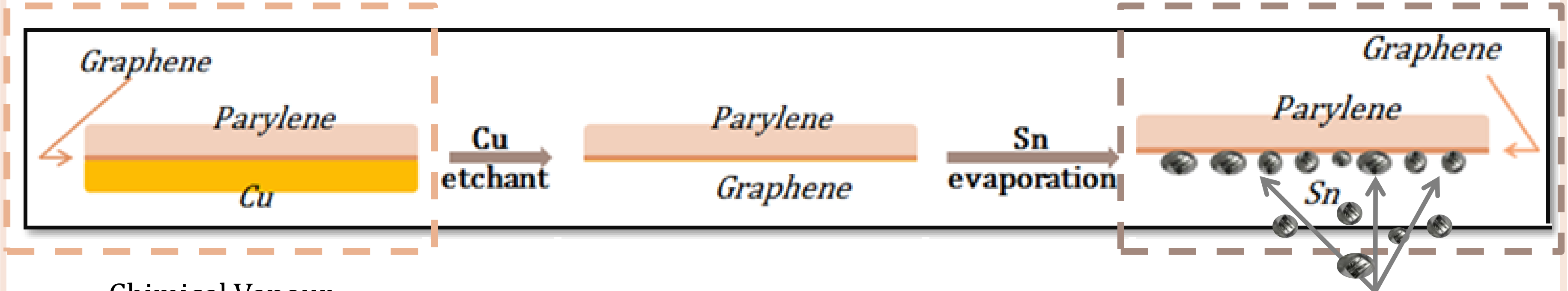
Combining the 3 original ingredients: process overview

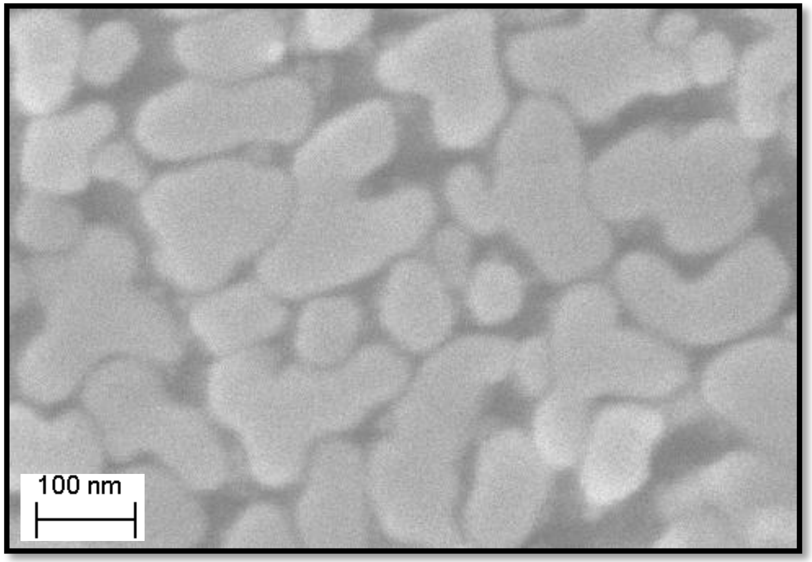


Chimical Vapour
Deposition
(CVD)

Physical Vapour
Deposition
(PVD)

Spontaneous dewetting :

⇒ **Self-organised** network of **non percolating** islands separated by **20nm gaps**.



SEM picture of 15nm-thick Sn islands evaporated on graphene

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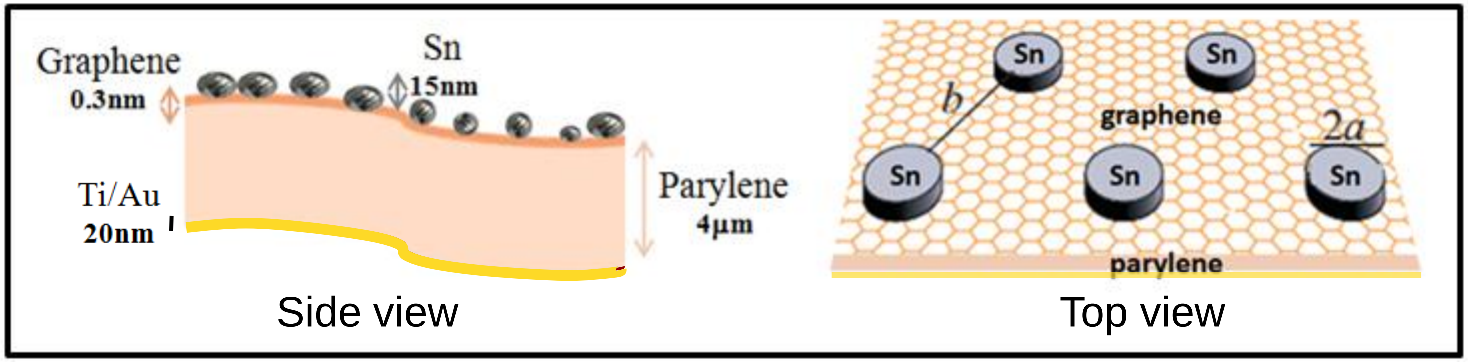
Setup to probe the superconducting transition

Device Under Test (DUT)

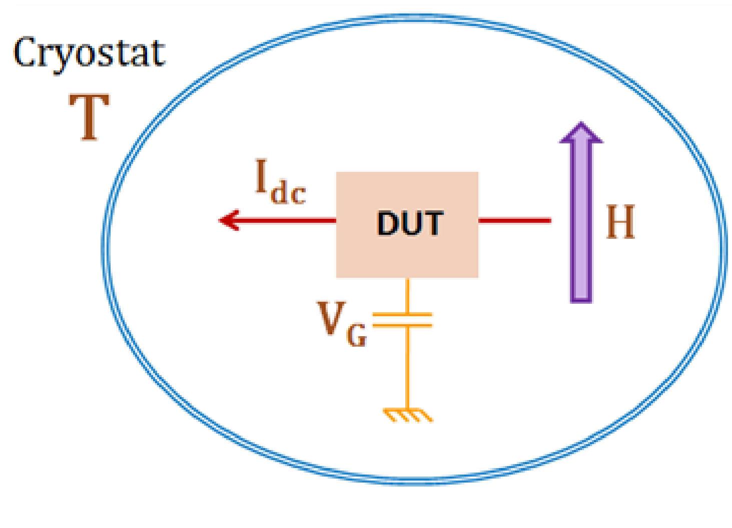


4 parameters to tune
the superconducting transition :

T : Temperature (200mK to 300K)
I_{dc} : DC current bias

High sensitivity

V_G : Gate voltage
H : Transverse magnetic field



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An electrically tunable superconducting material based on graphene

At T→0K

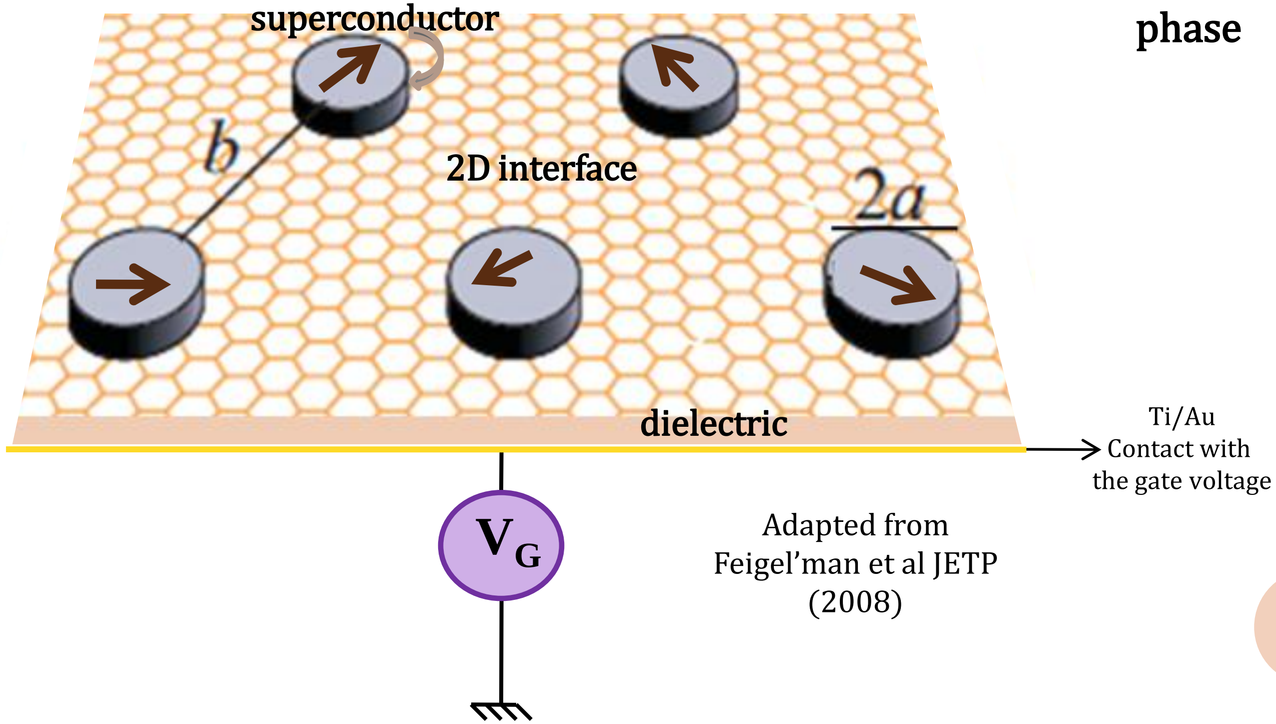
Carriers density (gate V_G)

Sn islands superconductor

Graphene 2D interface

Parylene dielectric

↗ **Superconducting phase**



Adapted from Feigel'man et al JETP (2008)

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An electrically tunable superconducting material based on graphene

At T→0K

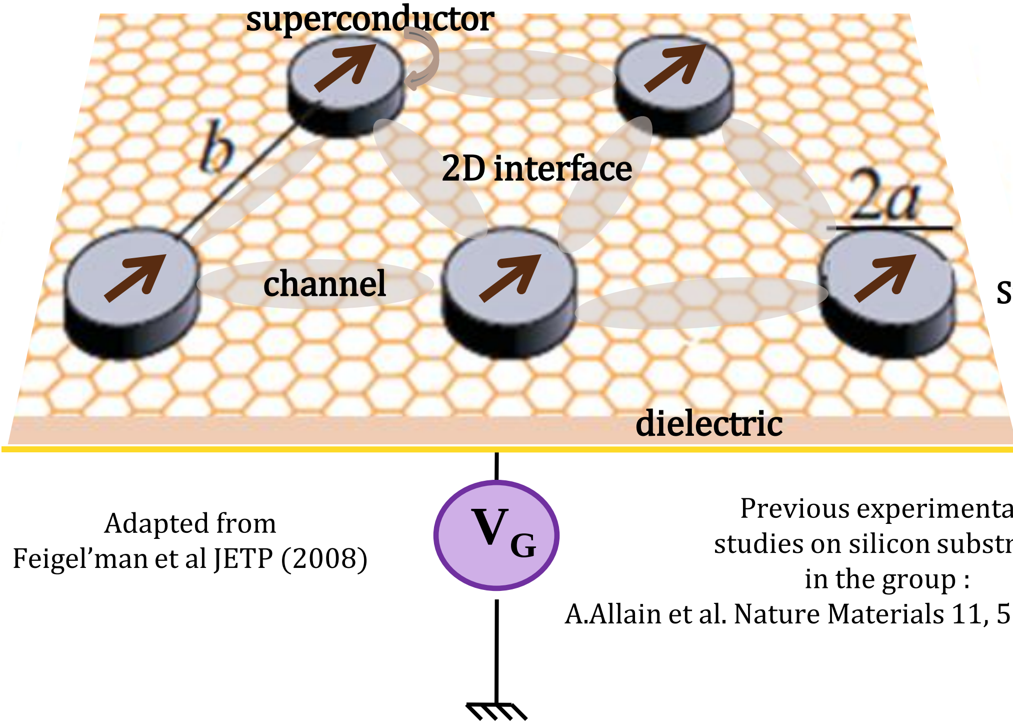
Carriers density (gate V_G)

high

Sn islands superconductor

Graphene 2D interface

Parylene dielectric



Ti/Au
Contact with the gate voltage

Adapted from
Feigel'man et al JETP (2008)

Previous experimental studies on silicon substrate in the group :
A.Allain et al. Nature Materials 11, 590–594 (2012)

Superconducting phase

Proximity effect

Superconducting leakage through the graphene

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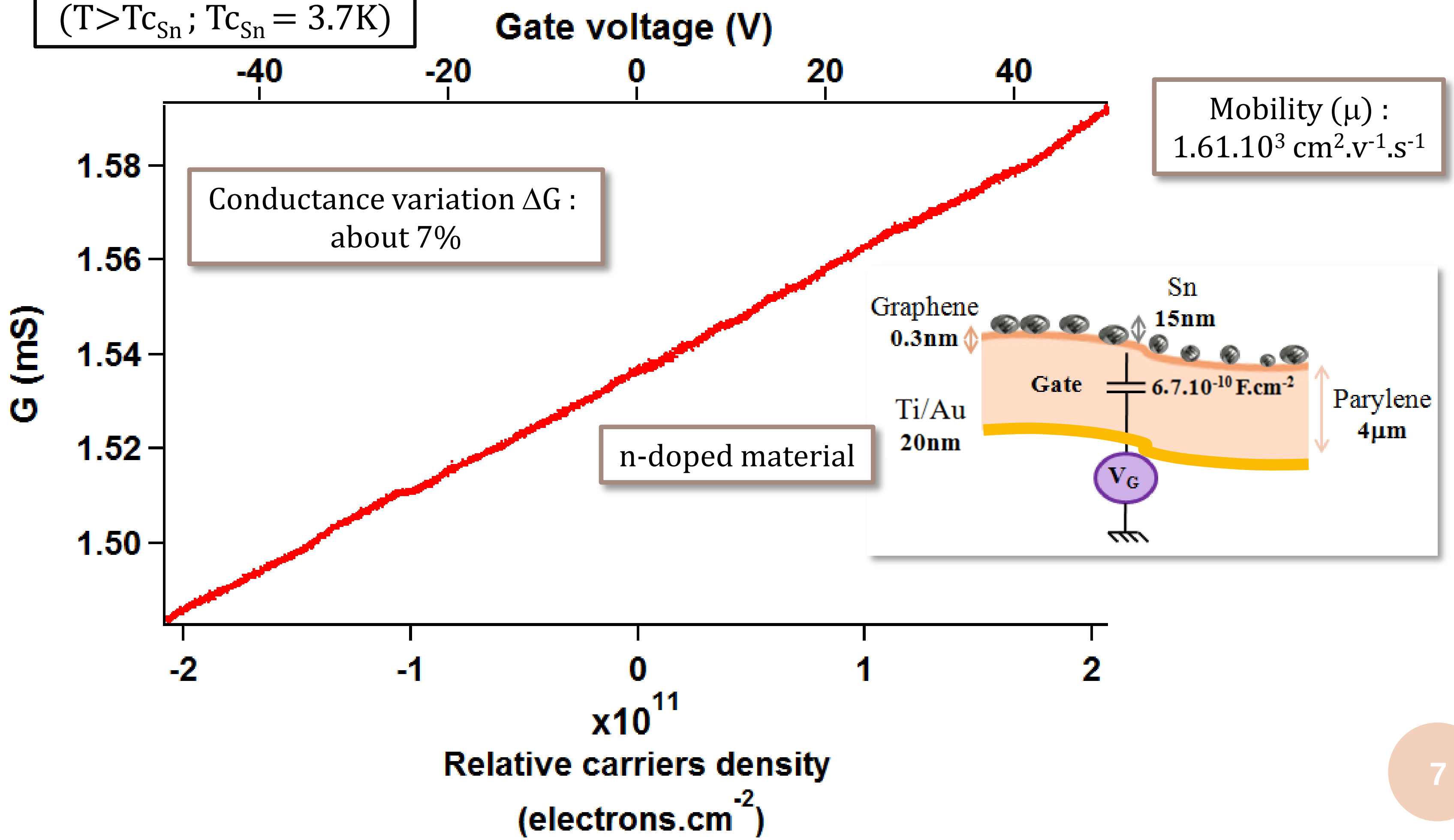
Tuning the normal state conductance by doping with an electrical gate

At T = 4K
(T>Tc_{Sn} ; Tc_{Sn} = 3.7K)

Mobility (μ) :
$1.61.10^3$ $cm^2.v^{-1}.s^{-1}$

Conductance variation ΔG :
about 7%

n-doped material



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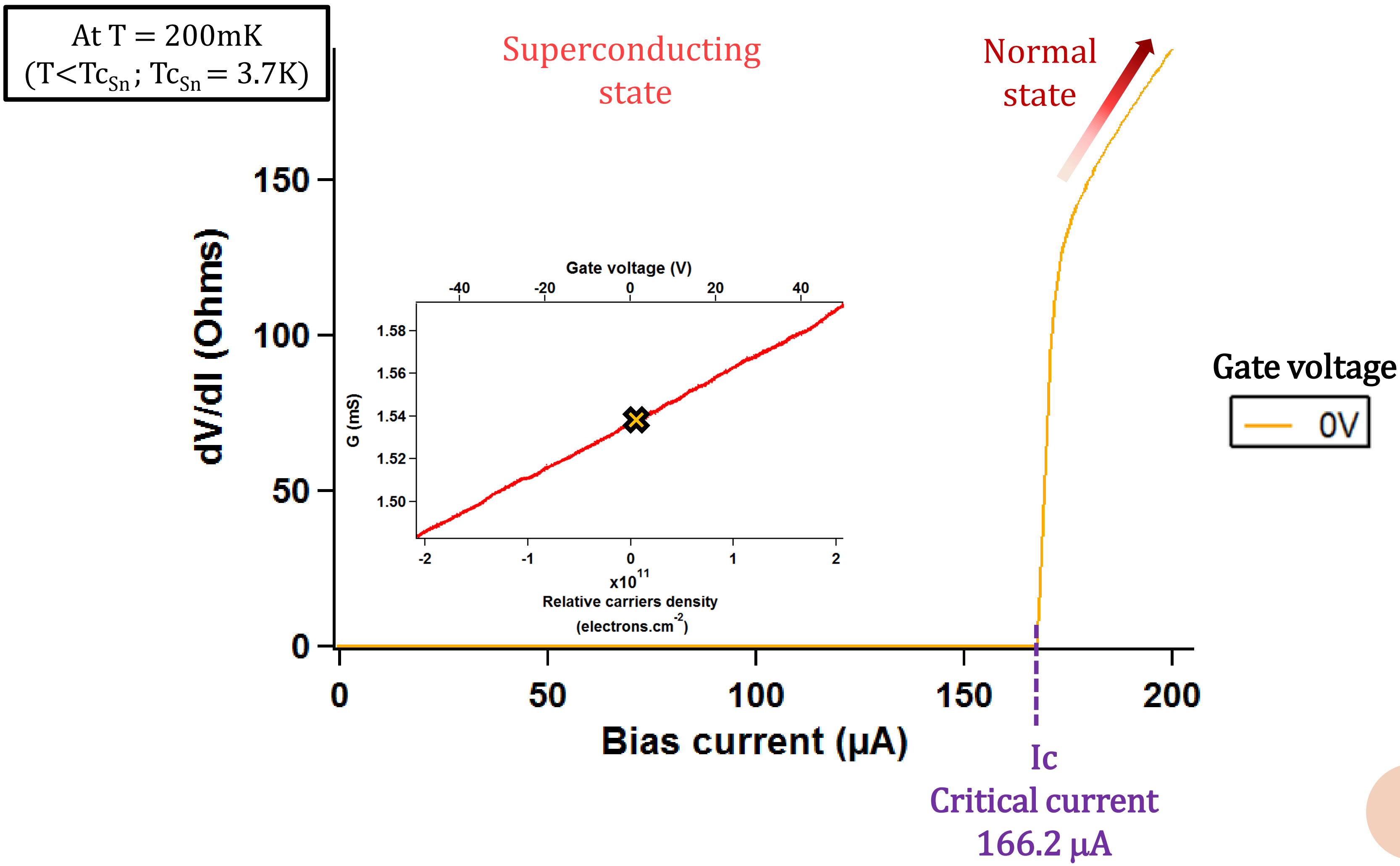
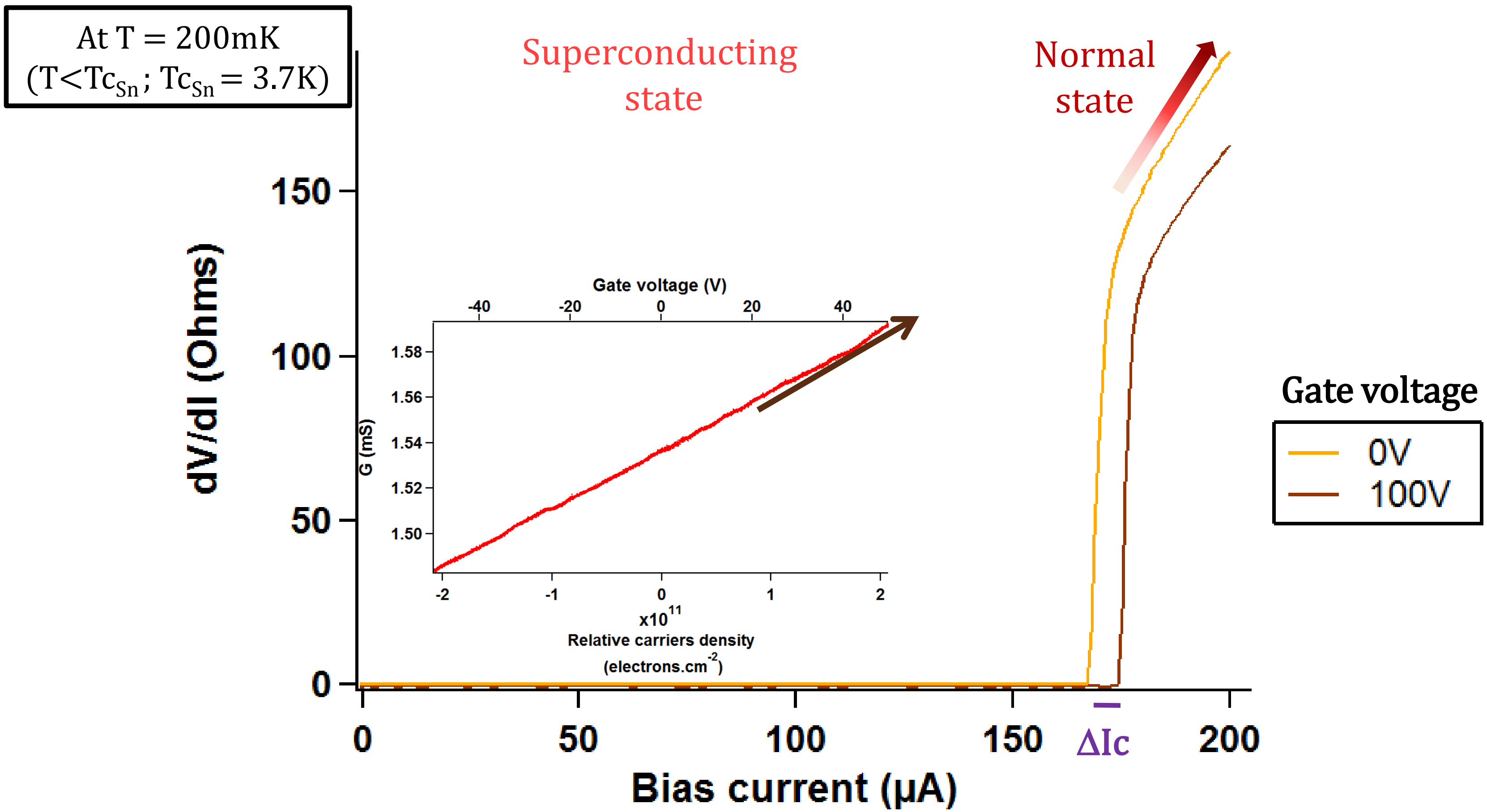
Tuning the superconducting transition with an electrical gate

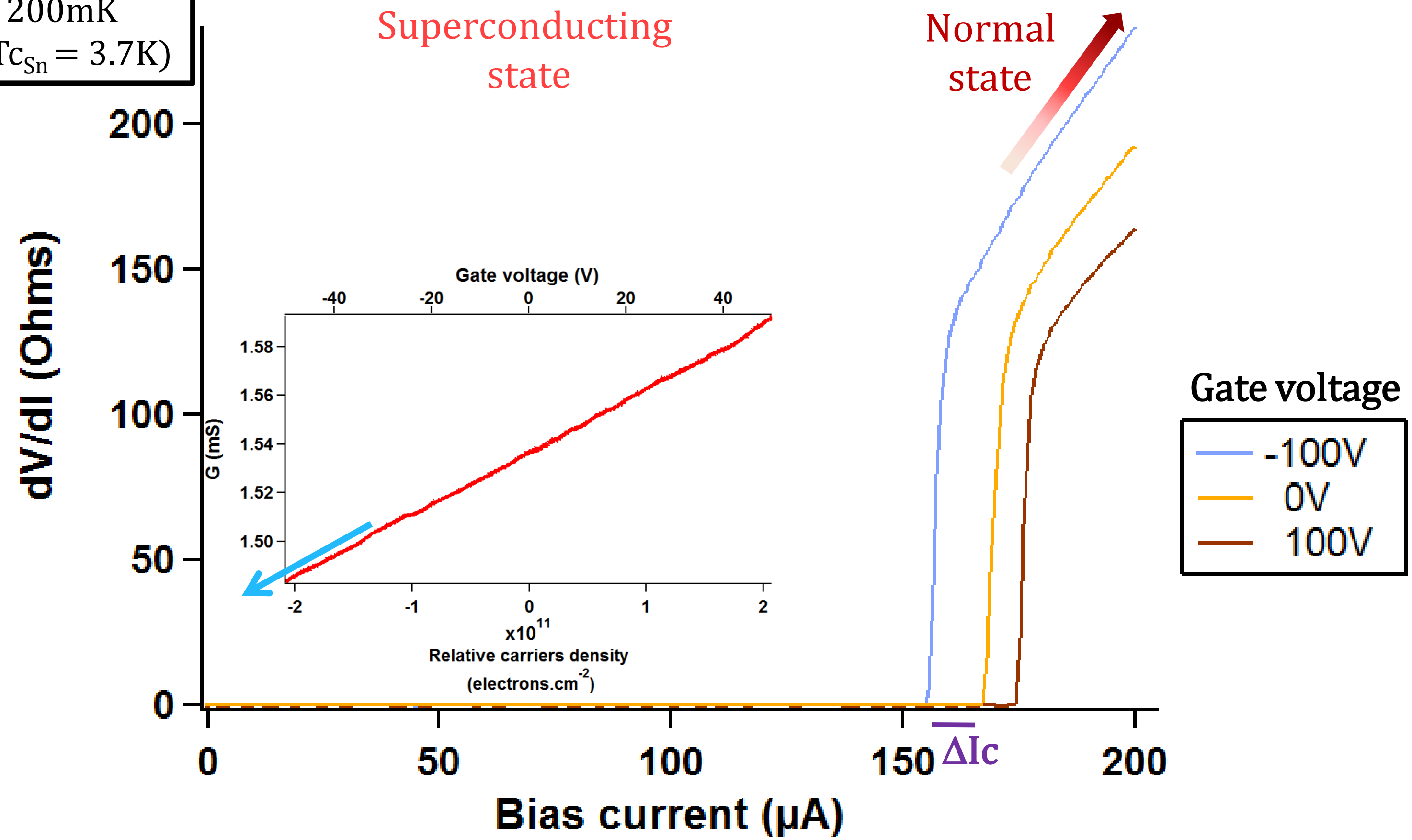


Tuning the superconducting transition with an electrical gate



Tuning the superconducting transition with an electrical gate

At T = 200mK
($T<Tc_{Sn}$; Tc_{Sn} = 3.7K)



The critical current (Ic) is tuned by the gate voltage

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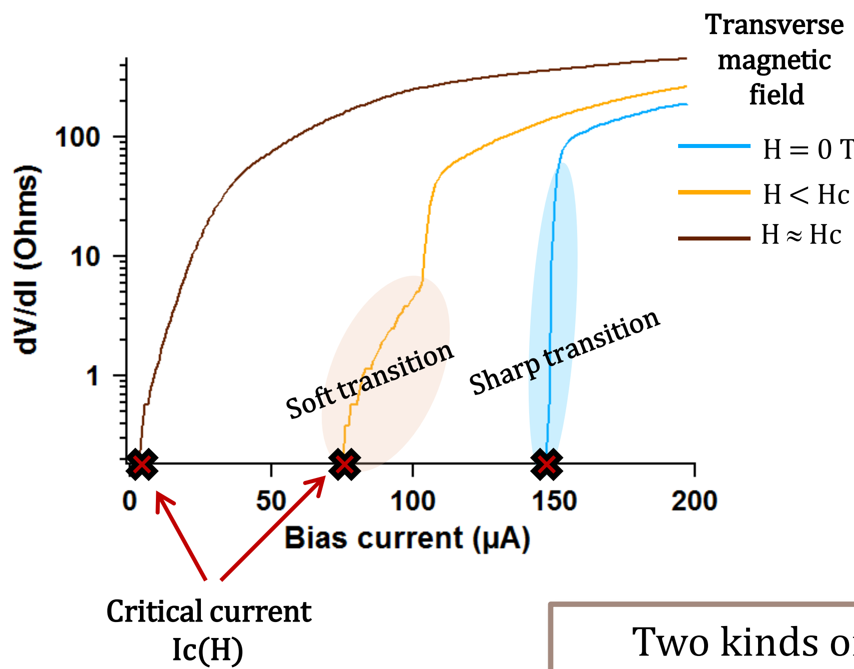
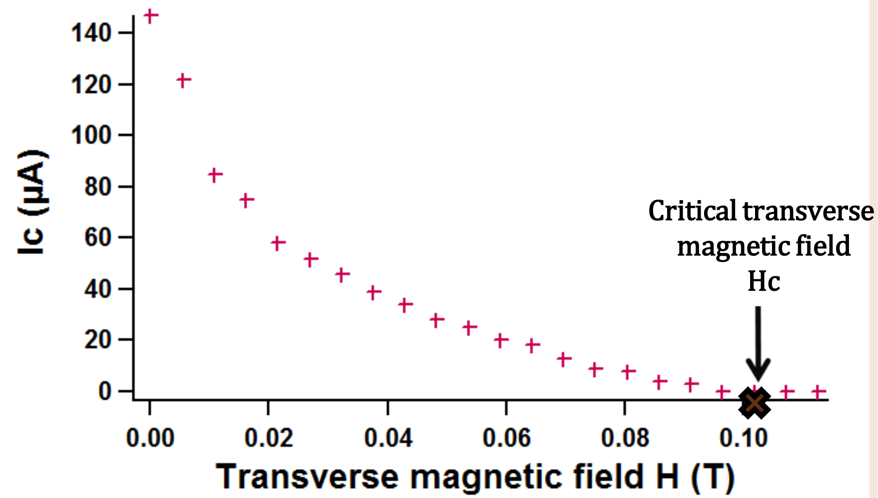
Tuning the superconducting transition with a transverse magnetic field

T = 200mK
($T<Tc_{Sn}$; $Tc_{Sn} = 3.7K$)

Gate voltage Vg = 50V





Two kinds of transitions

1) H = 0T → Sharp transition

2) H >0T → Soft transition :
hallmark of the 2D superconductivity

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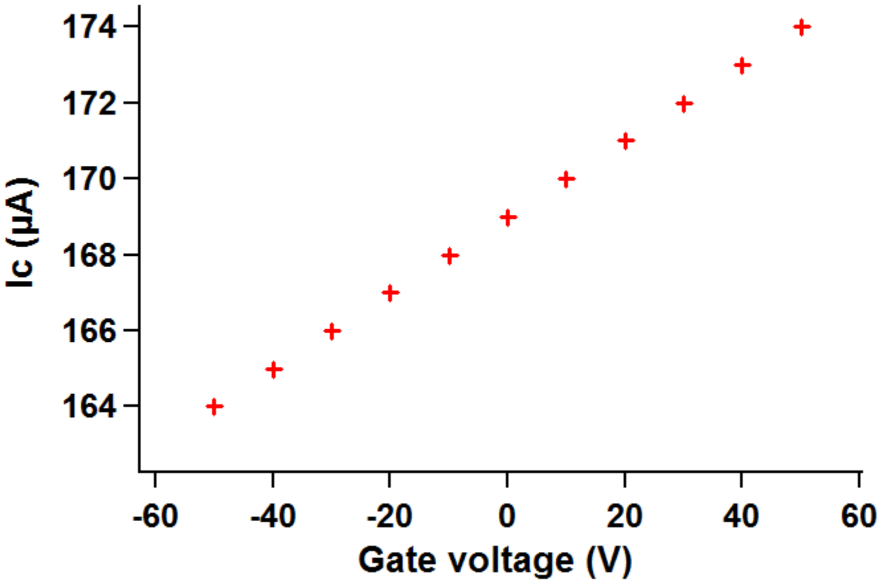
Conclusion :
2D superconducting flexible plastic film electrically tunable

Critical current density (H= 0T):
0.1 A.m^{-1}

Critical temperature :
2.4 K



Critical current (Ic) variation with a gate voltage:
0.1 µA.V^{-1}

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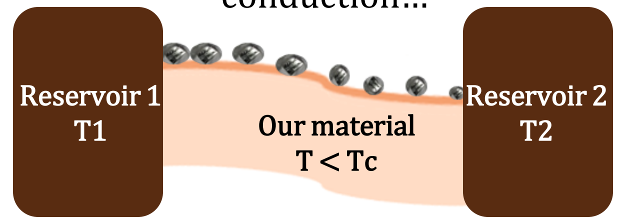
Applications :

Superconducting

Very good electrical conductor

Low thermal conductor

Electrical signal conduction…



…without electrical loss
…without bringing heat

Flexible

High mechanical resistance

Flexible electronics applications

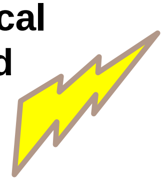
High sensitivity
to the environment

very sensitive detector

Particle

Transverse magnetic field

Electrical field



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Perspectives :

$\Rightarrow$Does our material fit with Berezinsky-Kosterlitz-Thouless model for 2D superconductors ?

$\Rightarrow$ Is it flexible at low temperature and how much is it possible to bend it?

$\Rightarrow$ Do its properties change with bending and stress ?

$\Rightarrow$ In what extent could we improve its electrical tunability if we make it thinner?

Thank you for your attention

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