Quantum transport in exfoliated graphene on ultrathin crystalline β-Si_3N_4

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- **Why β-Si_3N_4(0001)/Si(111) substrate**

- **Device Fabrication; Graphene on β–Si_3N_4(0001)/Si(111)**

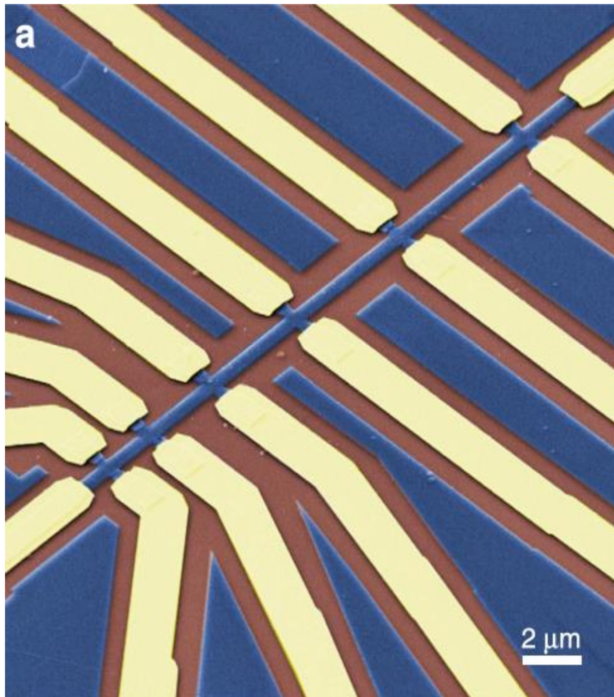
- **STM on graphene/β–Si_3N_4 device**

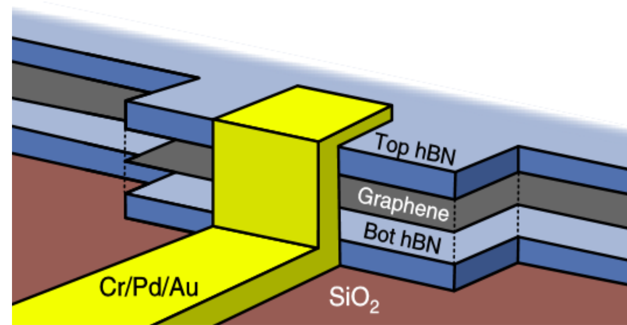
- **Magneto-transport measurements**

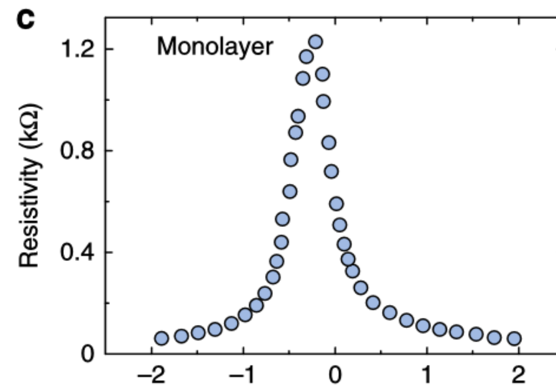
Why high-k Dielectric ?

✓ Preserving the intrinsic mobility

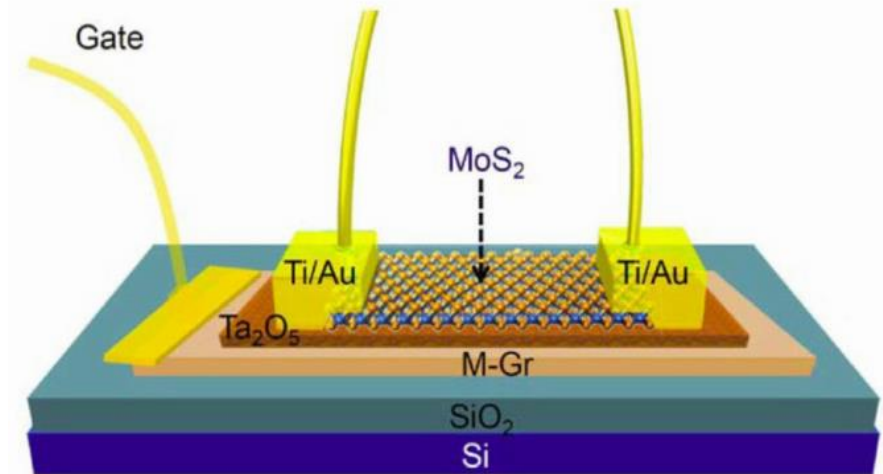
✓ Minimizing operation voltage







F. Pizzocchero etal. Nature Com. (2016)



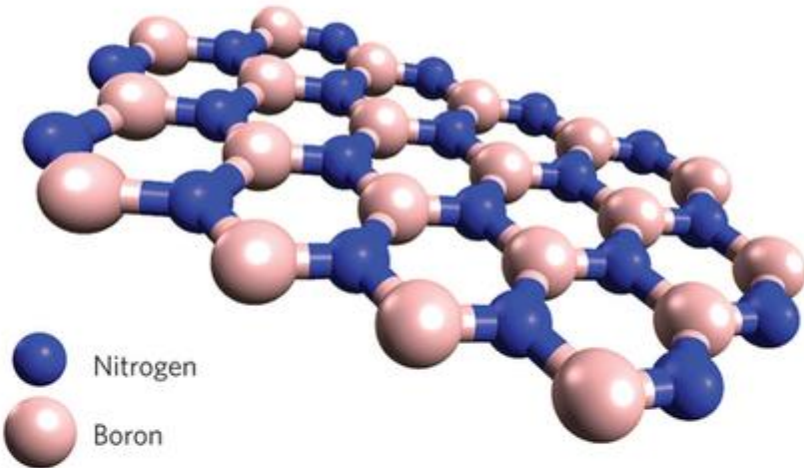
B. Chamlagain etal. 2D Mater. (2017)

Why Si_3N_4 ?

Lattice mismatch (G/hBN)= 1,8 %
Ɛ = 3 - 4
Eg= 6 eV

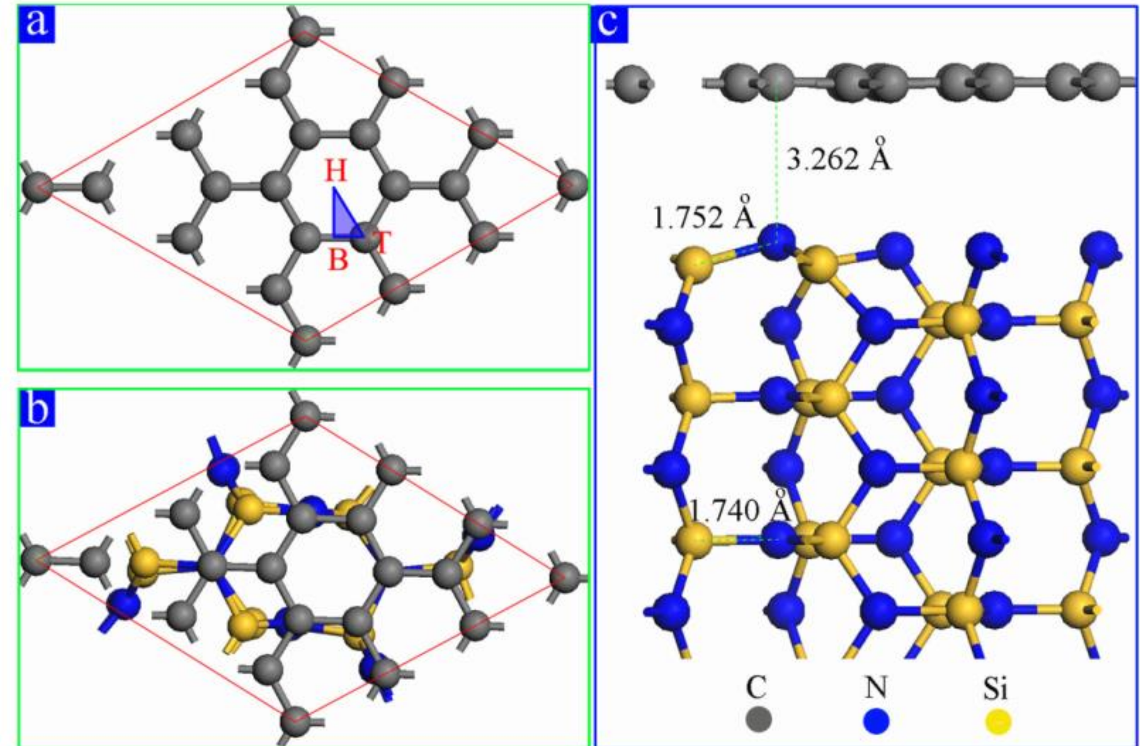
Lattice mismatch (G/Si_3N_4)= 3,66 %
Ɛ = 6 ,6
Eg= 5,3 eV

hBN



Ttrong etal. Nature Nanotech. **(2016)**

Si_3N_4



Yang etal. AIP Advances (2011)

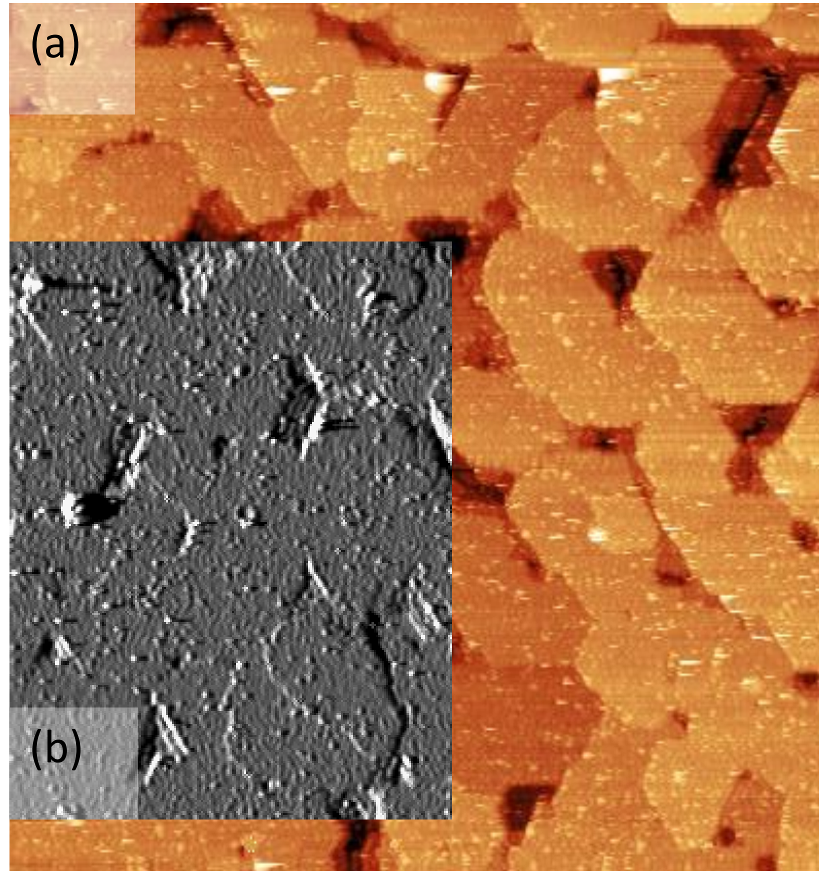
Graphene on β–Si_3N_4(0001)/Si(111)

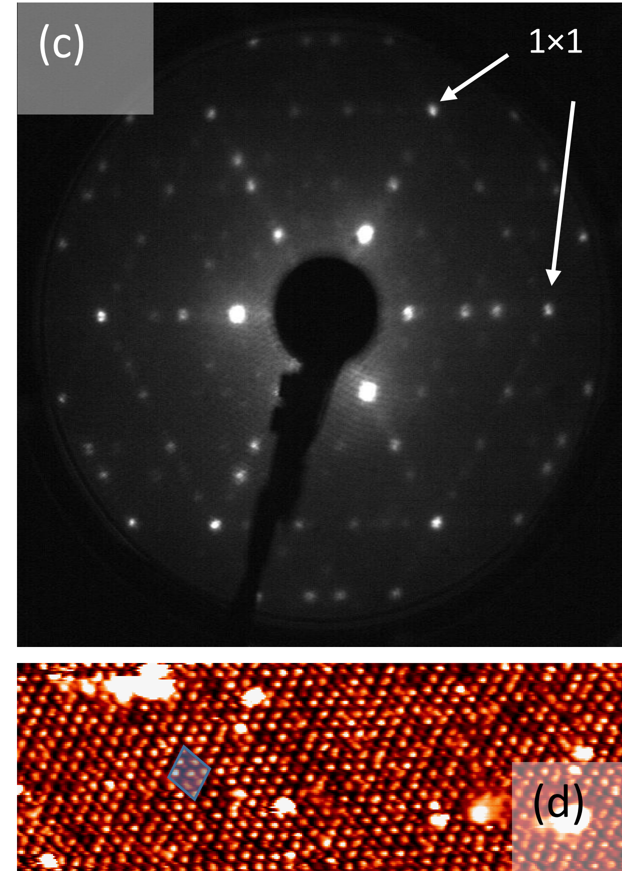
The β-Si_3N_4(0001)/Si(111) substrate; STM, LEED

500×500 nm²

LEED pattern ➡ (8×8) reconstruction

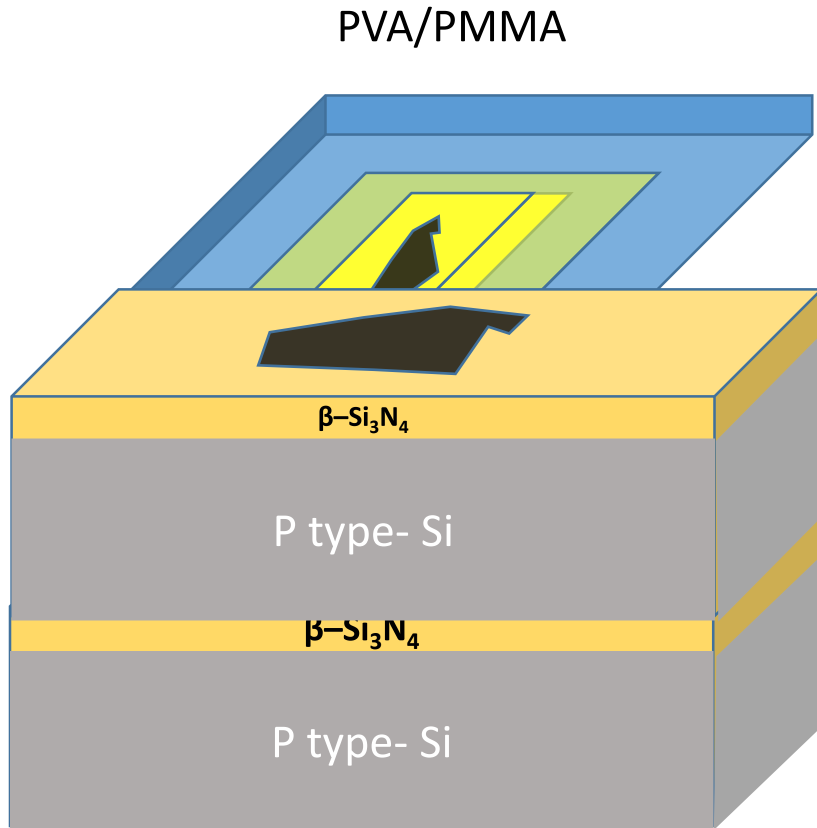
derivative along the x-direction

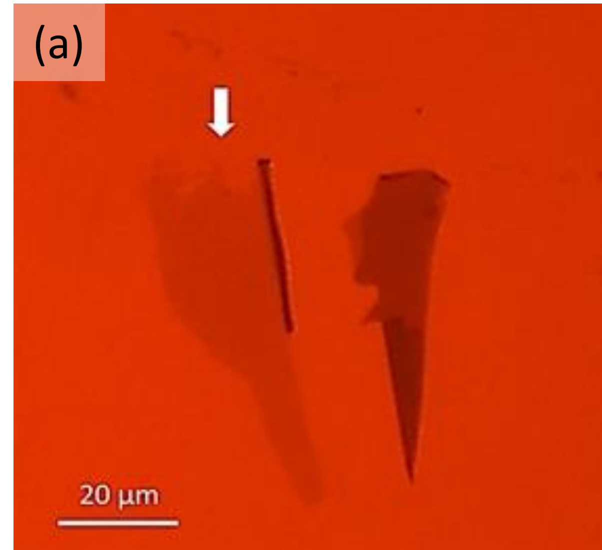


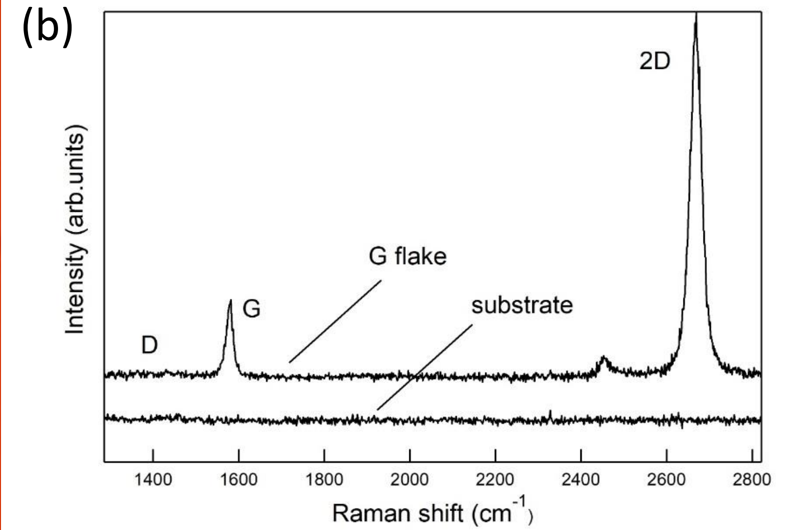


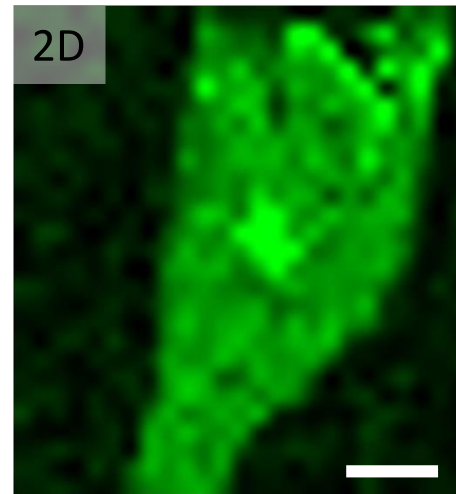
50×16 nm²

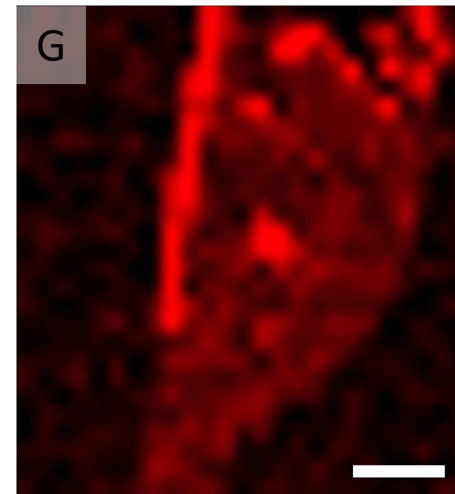
Graphene on β–Si_3N_4(0001)/Si(111); Raman Spectroscopy

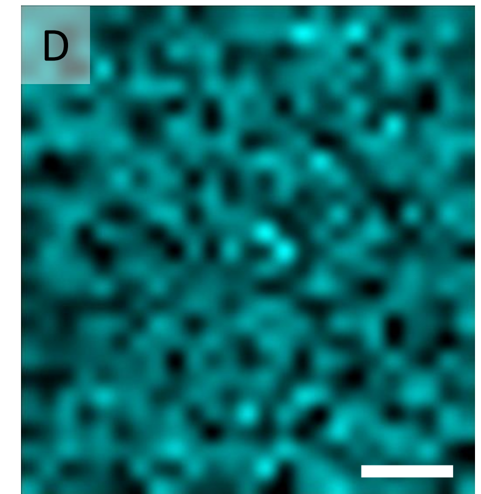




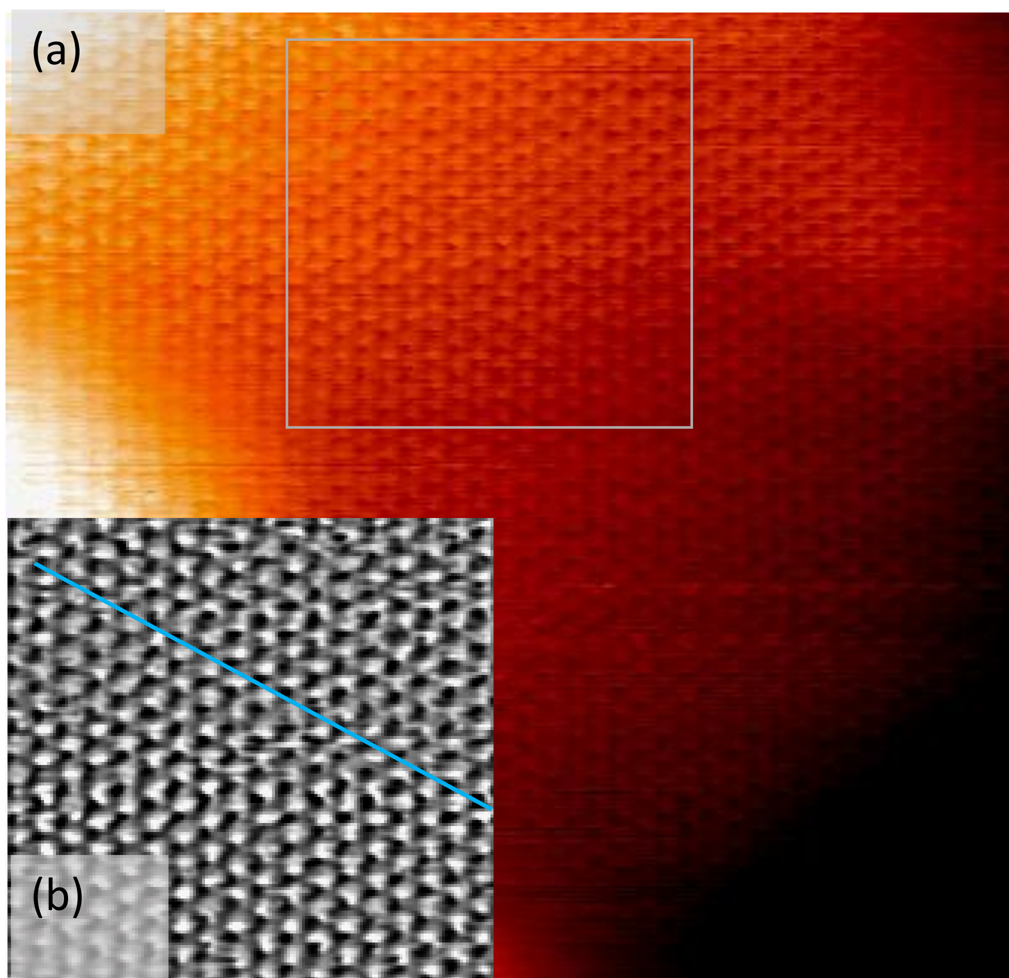


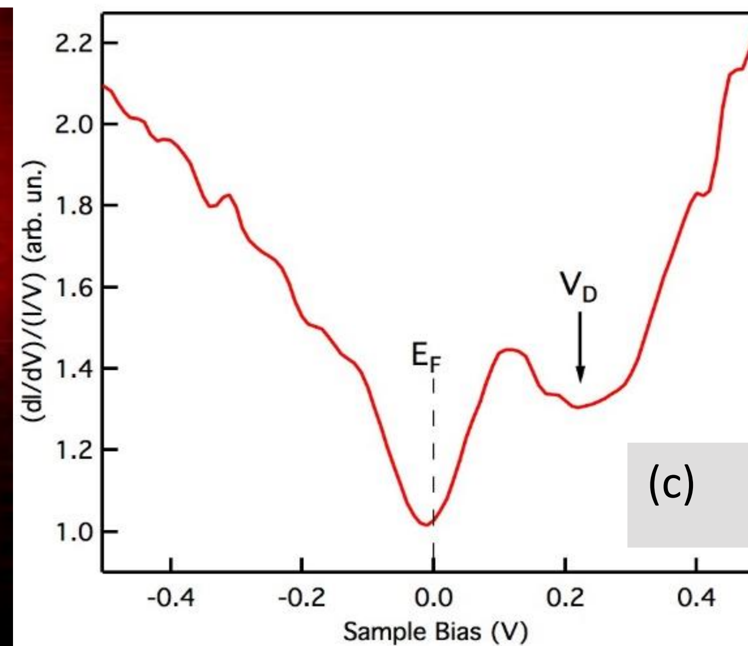


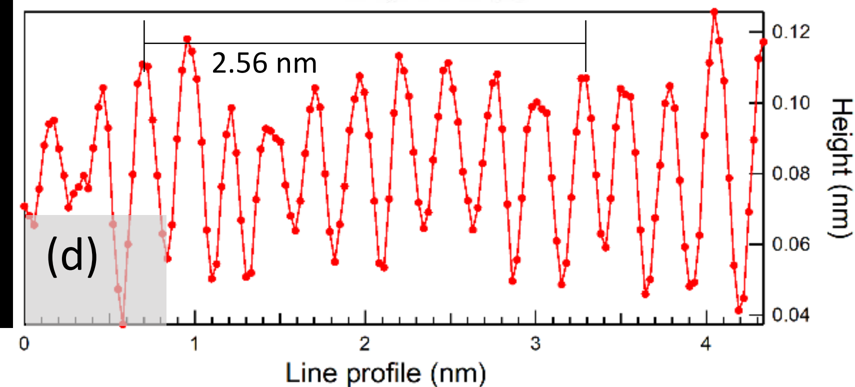




Graphene on β–Si_3N_4(0001)/Si(111): STM, STS

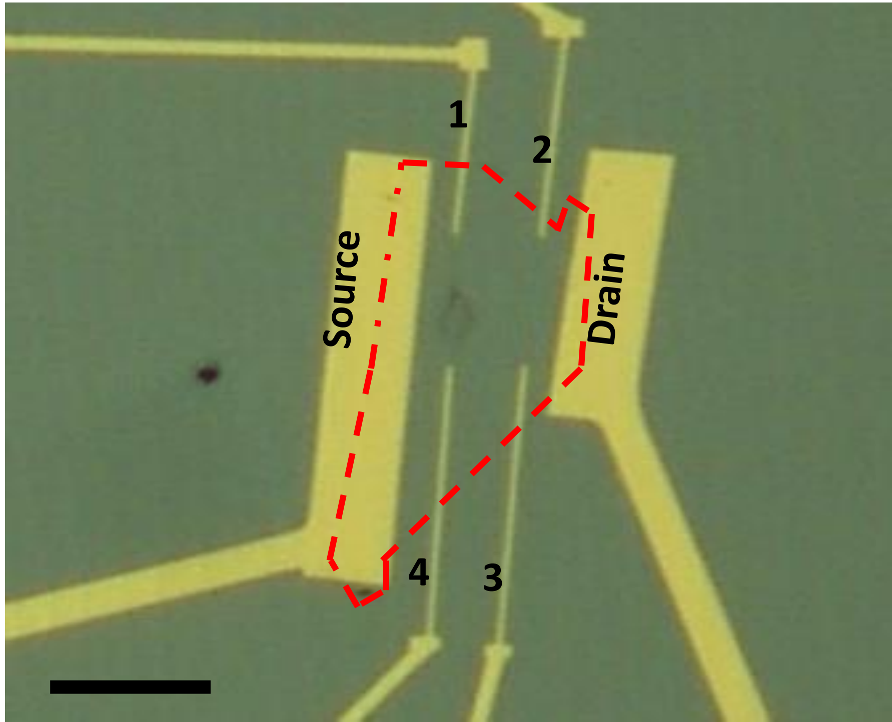




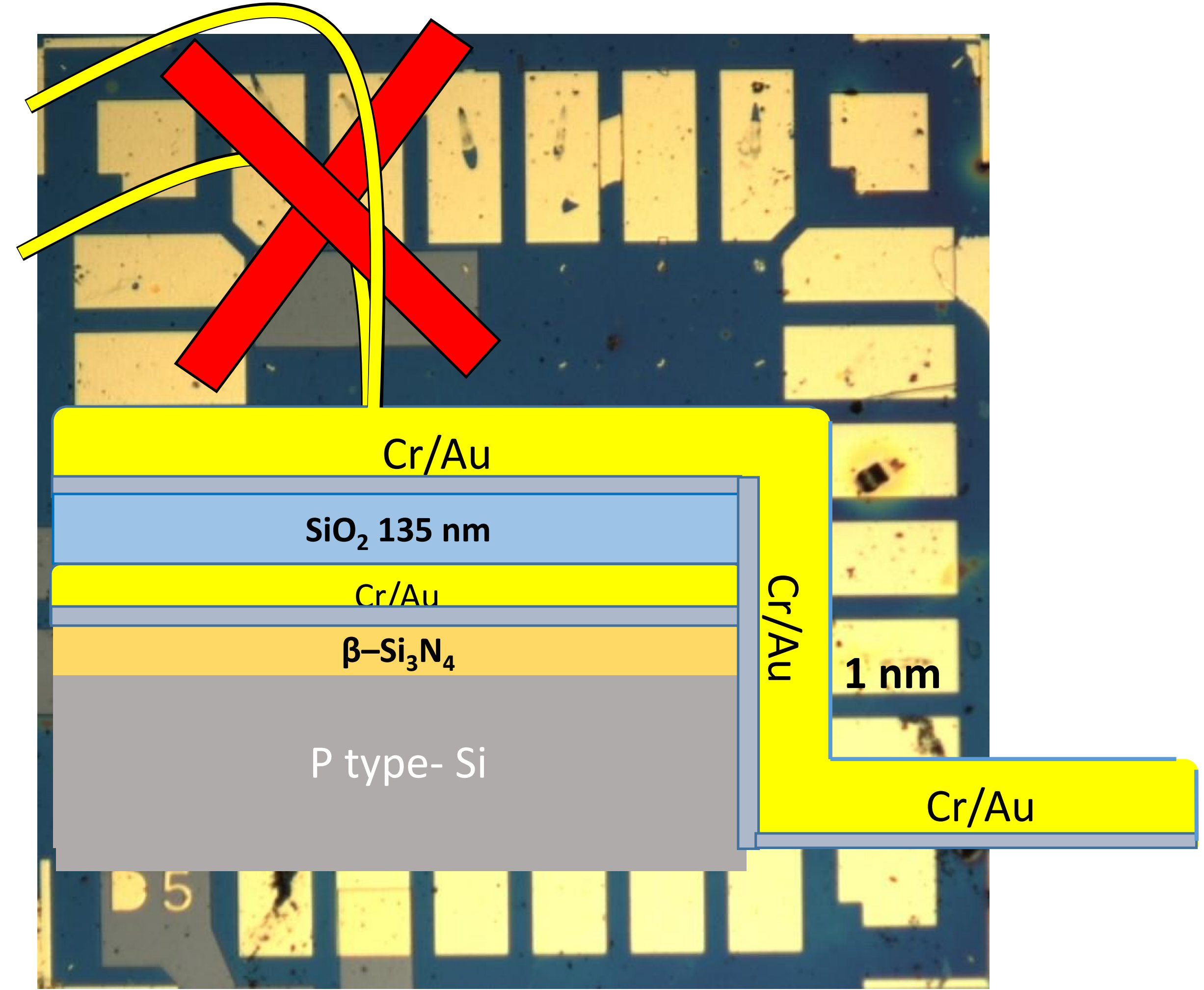


Magnetotransport measurement

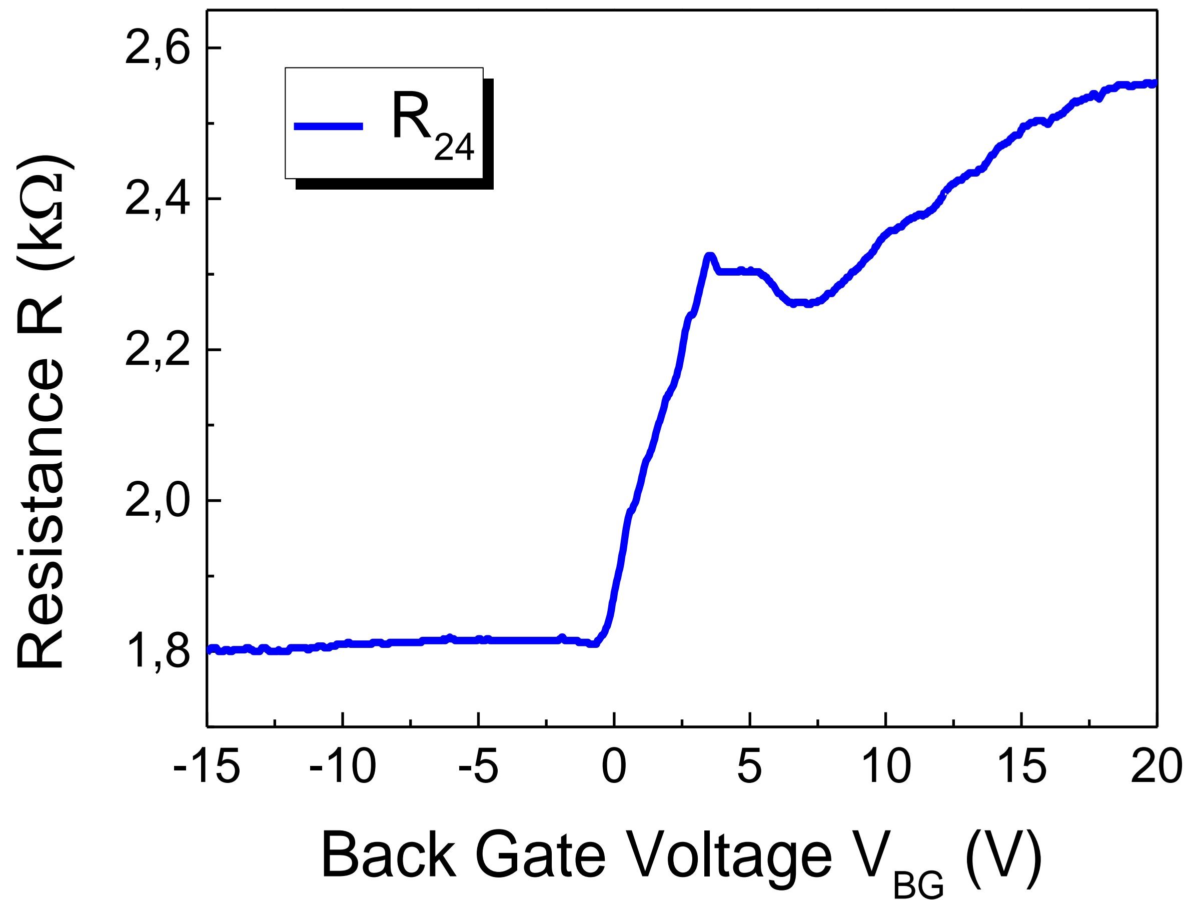
Device fabrication

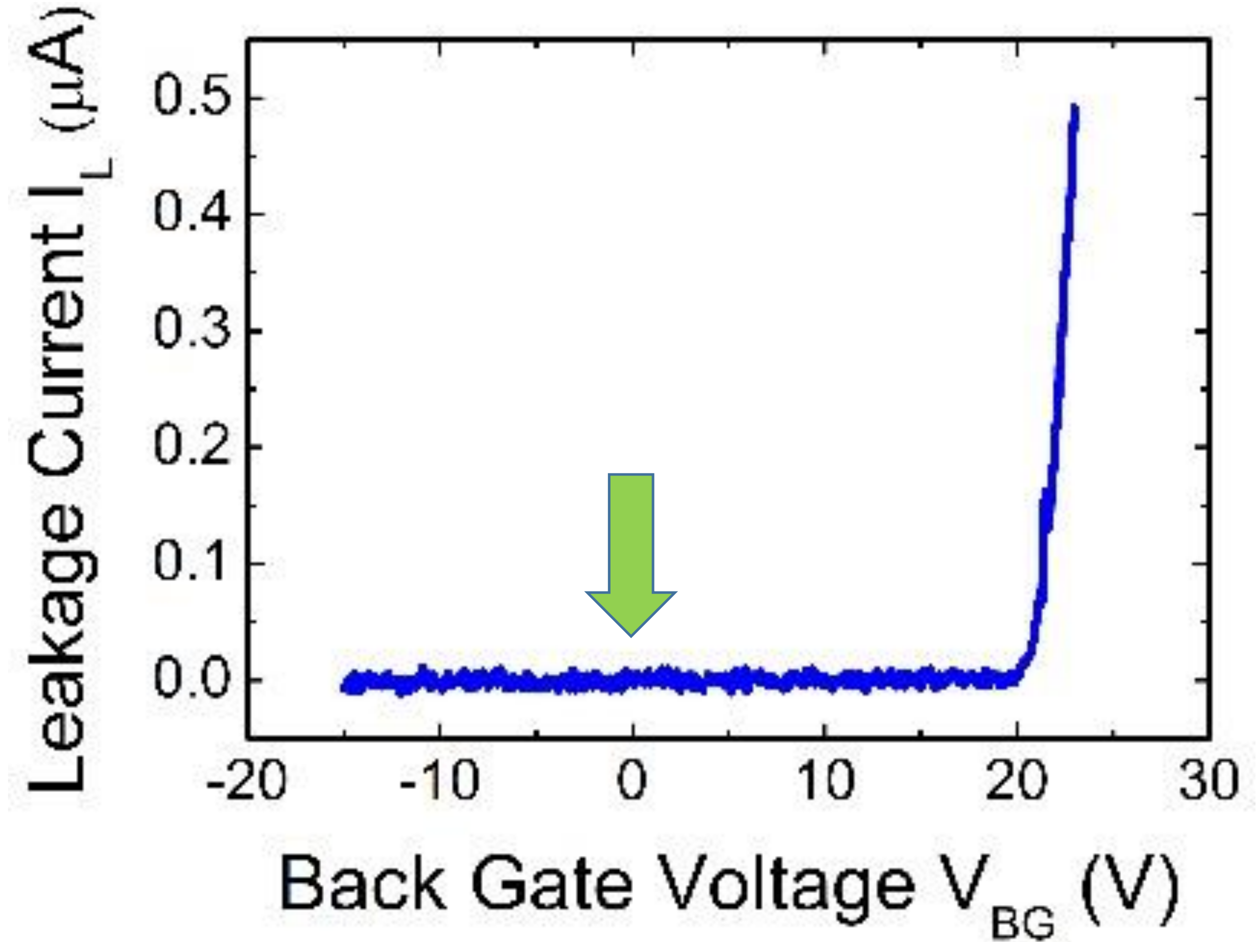


20 μm

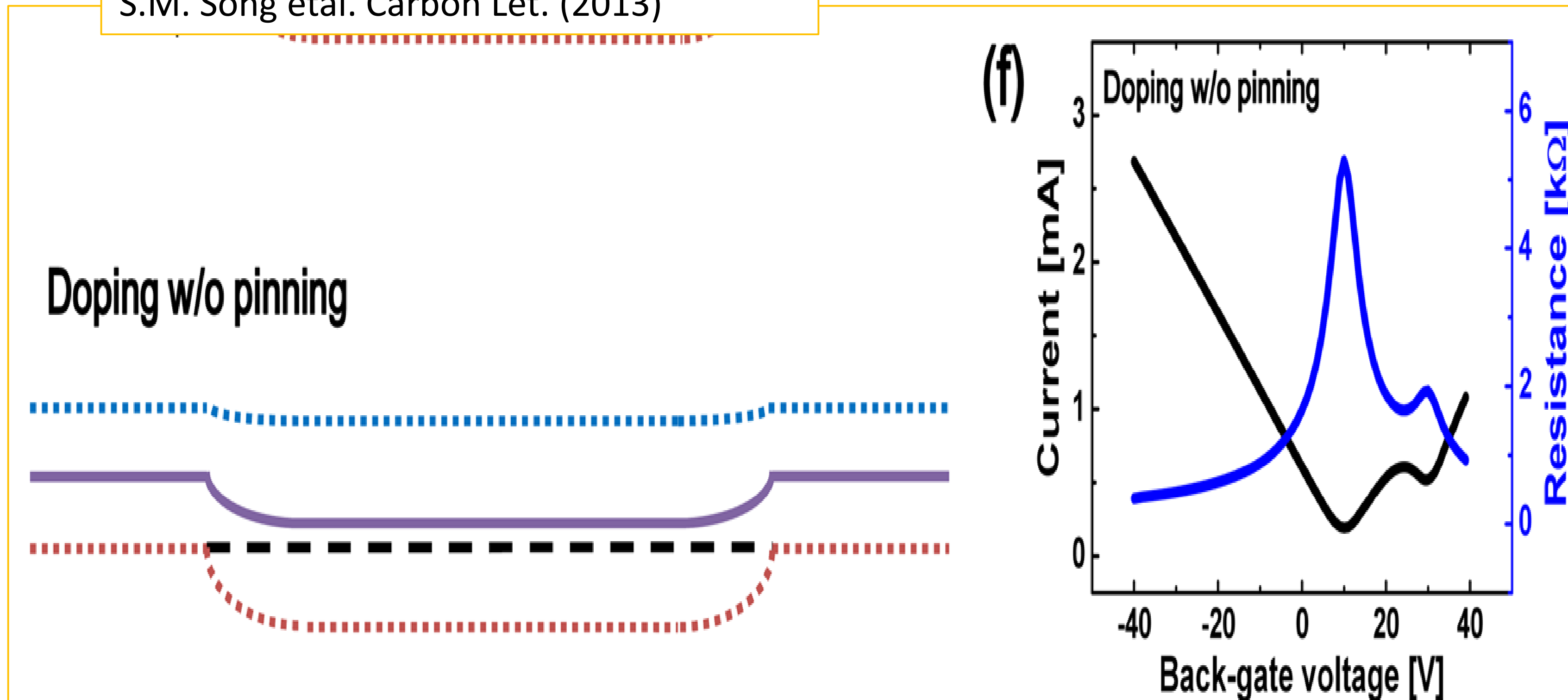


Electrical transport at 4.2 K

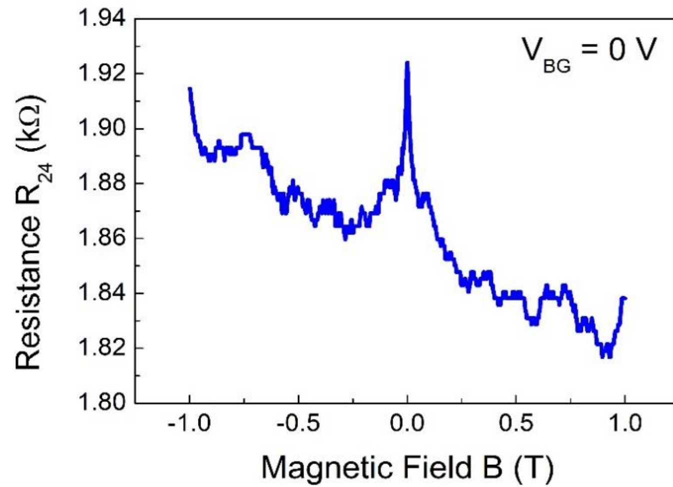




The Origin of second Dirac Point...



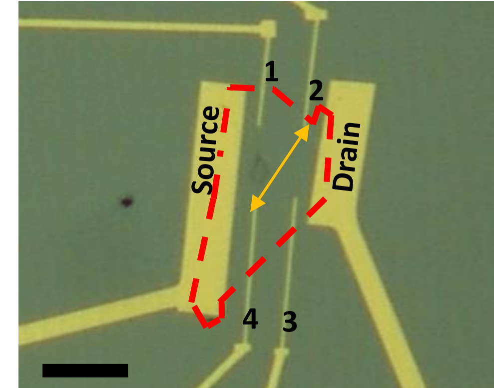
Magnetotransport: Hall Effect at 4.2 K



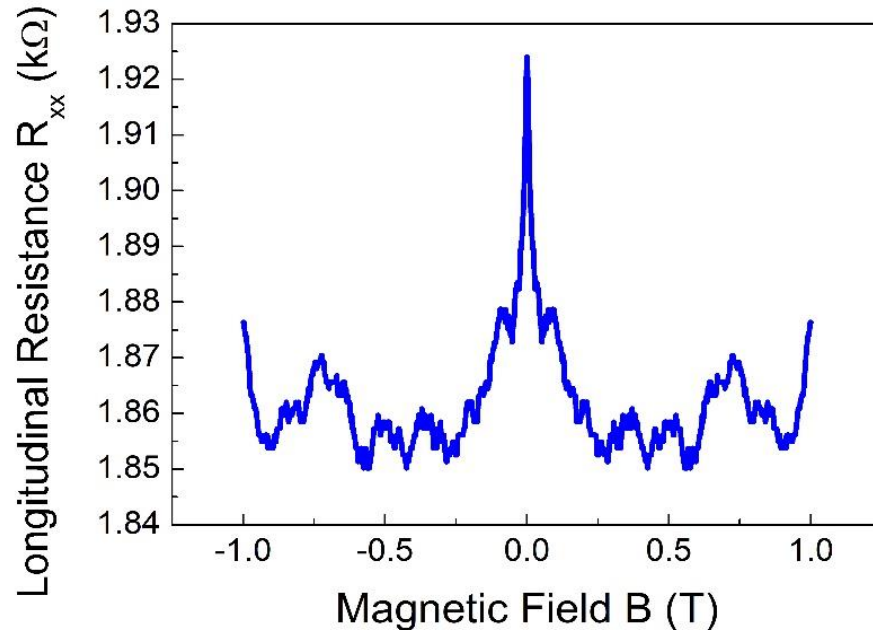
$$R_{24}(B) = R_{xx}(B) + R_{xy}(B)$$

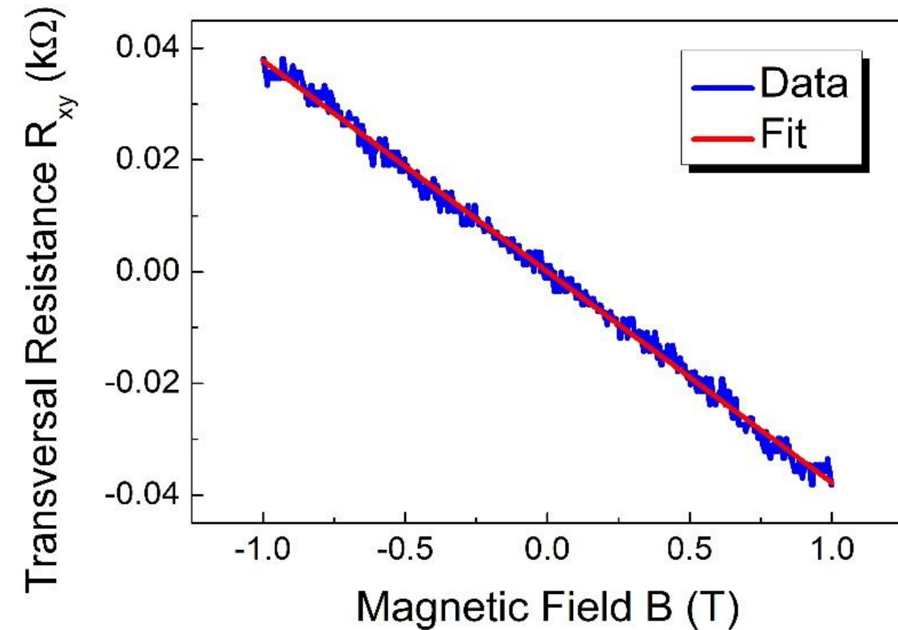
$$R_{xx}(B) = 1/2\,[R_{24}(B) + R_{24}(-B)]$$

$$R_{xy}(B) = 1/2\,[R_{24}(B) - R_{24}(-B)]$$

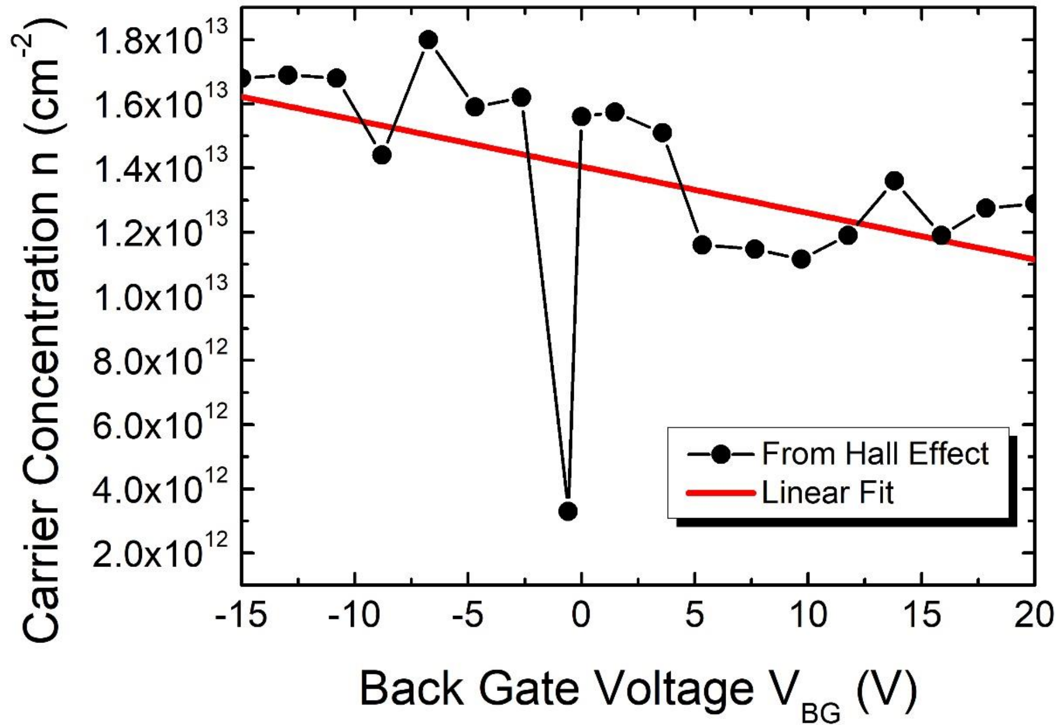


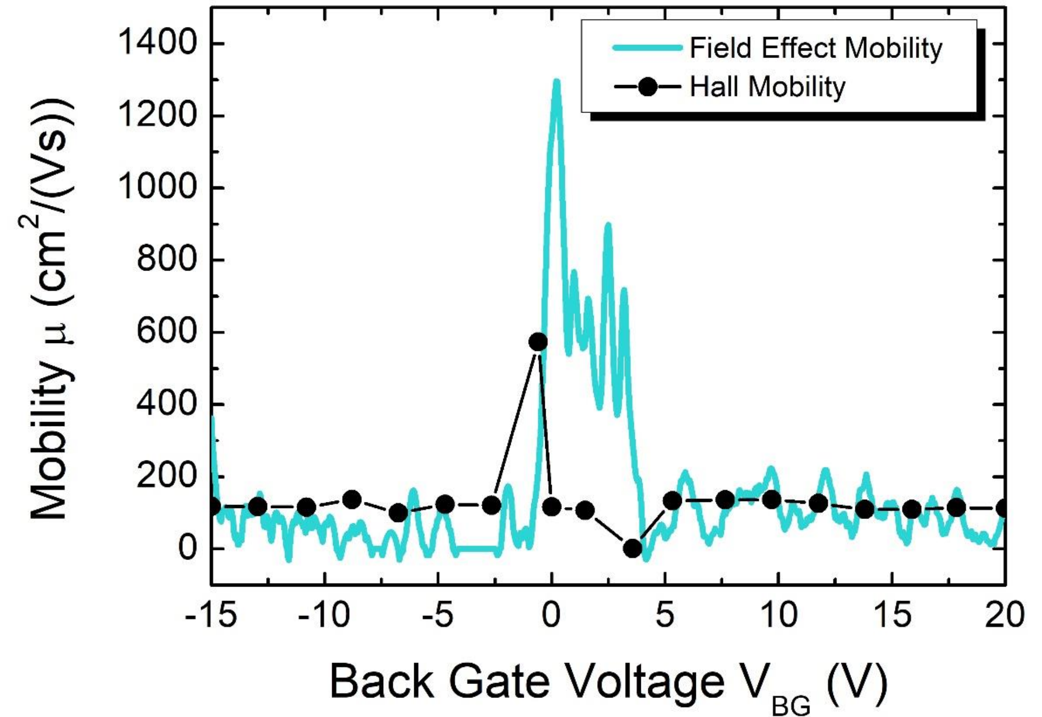
20 µm





Charge carrier concentration n and mobility μ extracted from Hall Effect

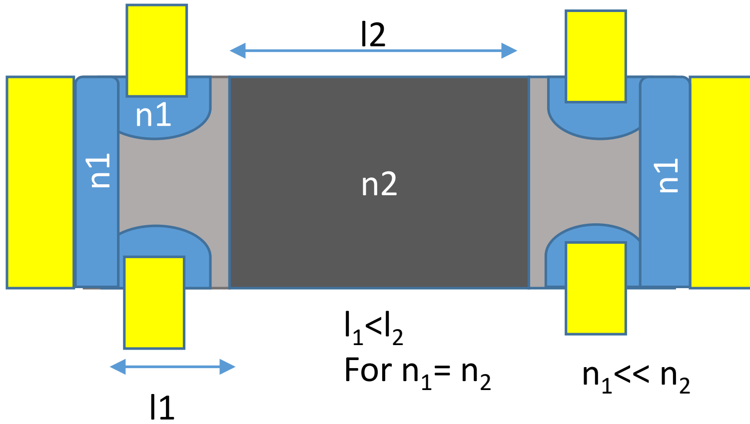


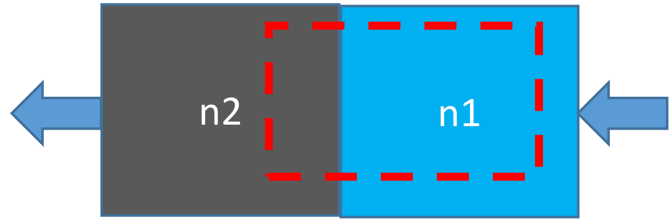


$$n = \frac{1}{e} \cdot \frac{1}{\left({\partial R_{xy}}/{\partial B}\right)}$$

$$\mu = \frac{L}{W\langle R_{xx}\rangle} \frac{1}{ne}$$

The Origin of second Dirac Point...



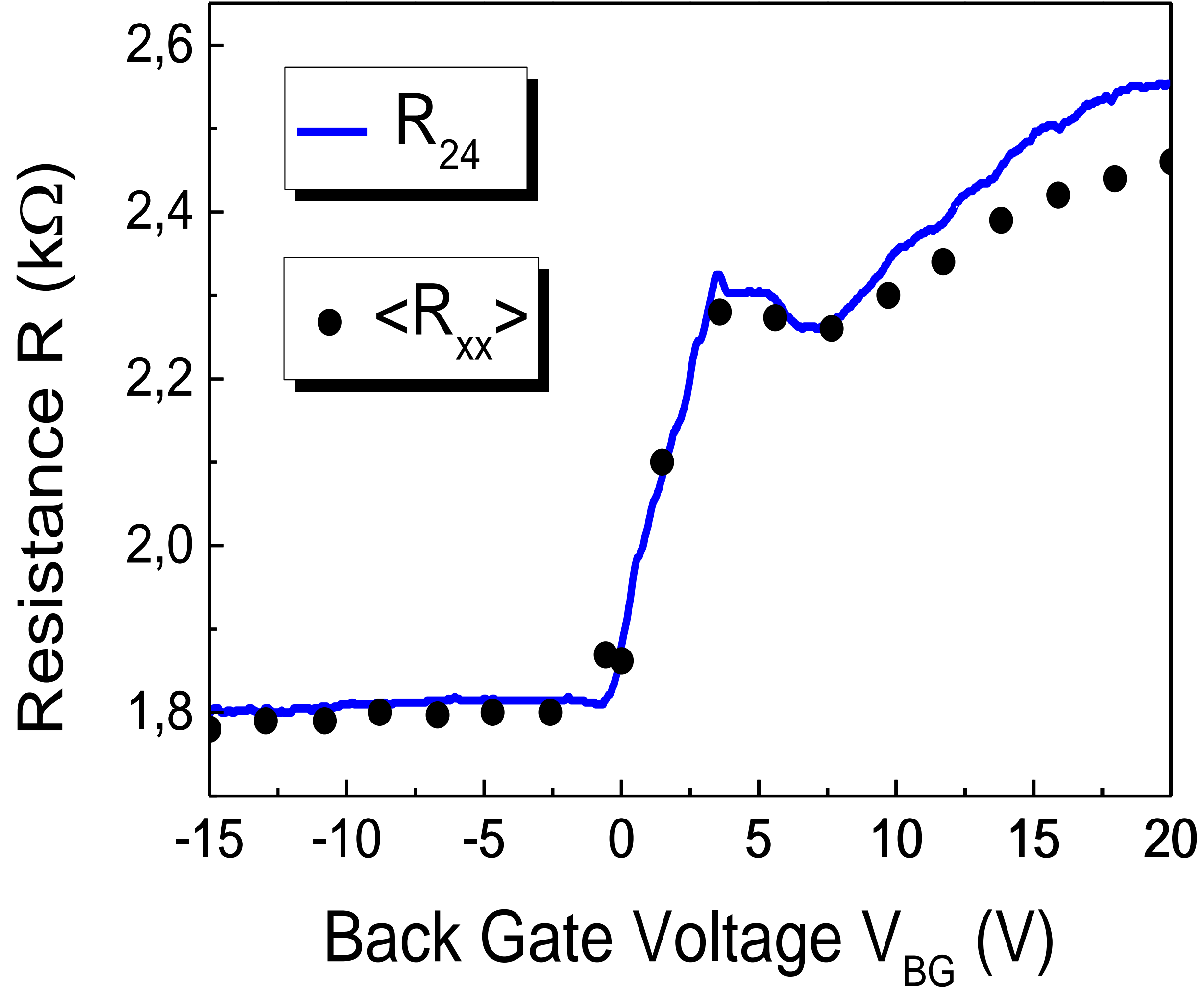


$Rxx=R_2+R_1$

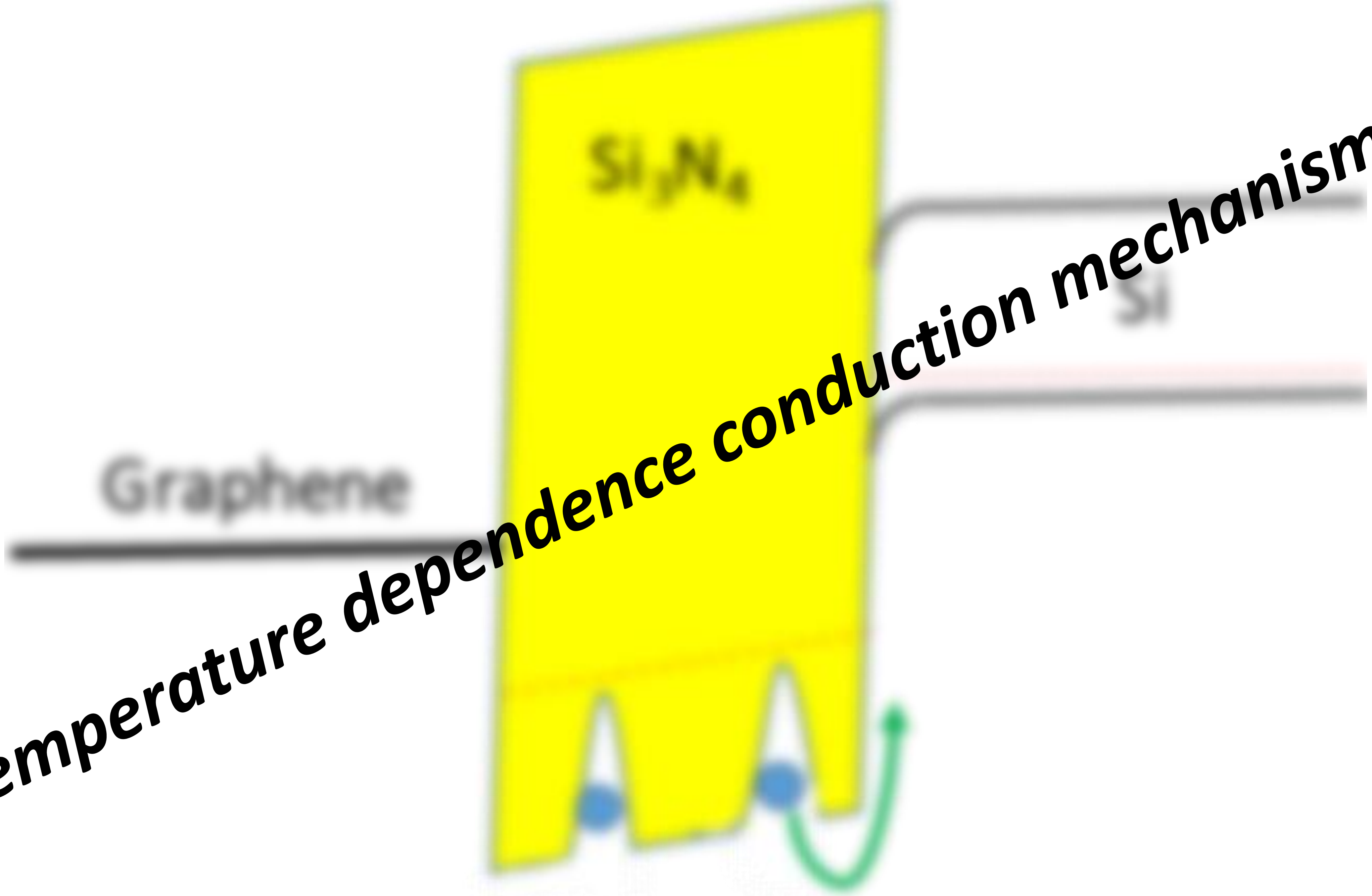
$=\rho l_2+ \rho\ l_1$

$=(1/en) \times (l_2/n_2+l_1/n_1)$

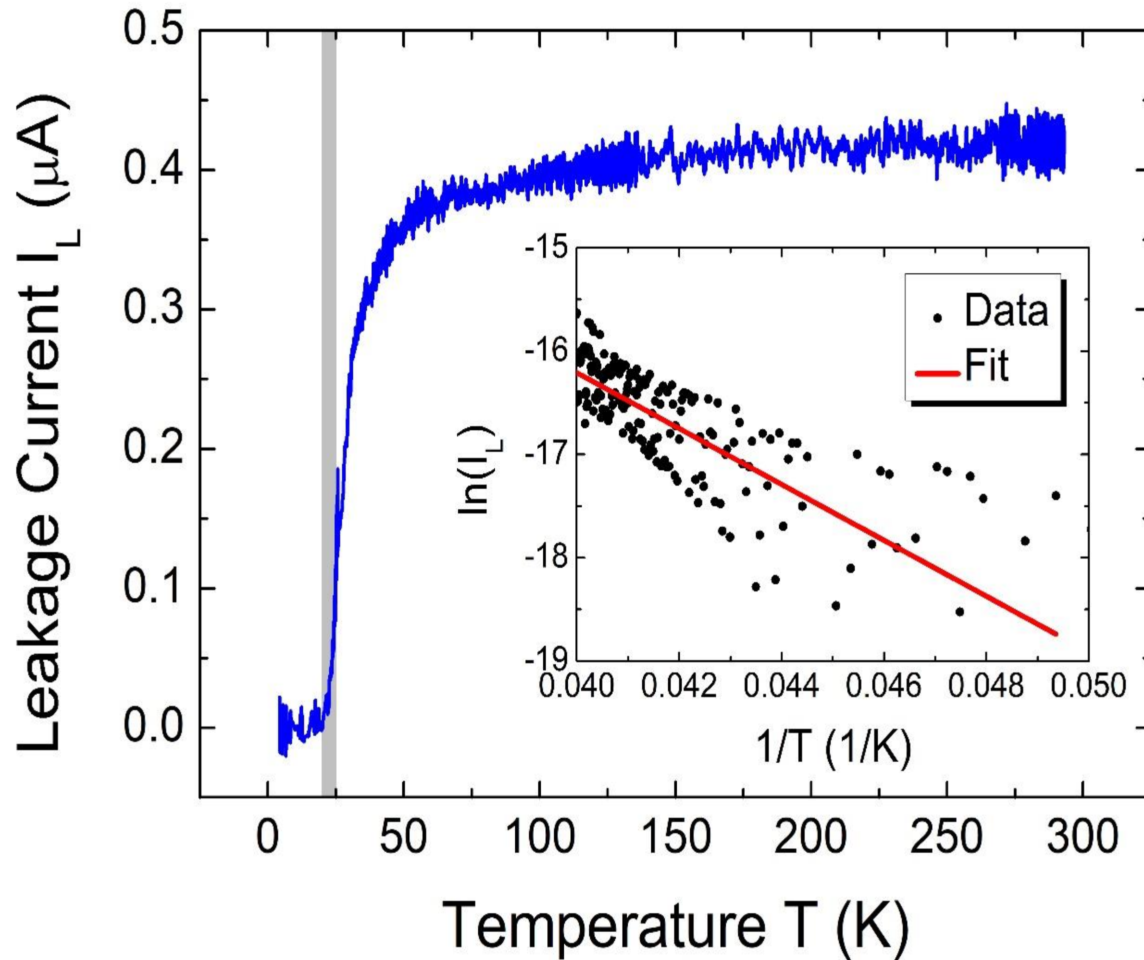
In case $n_1<< n_2$
$Rxx \sim l_1/n_1$



Temperature dependence conduction mechanisms



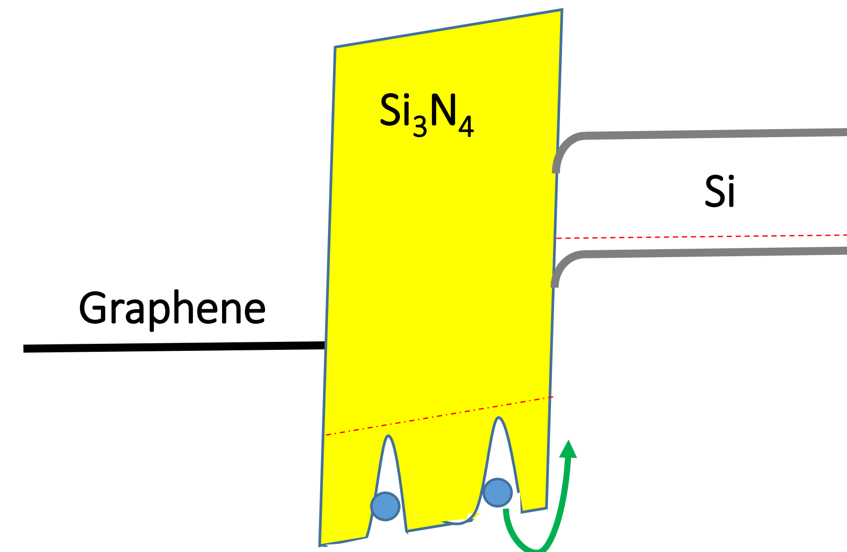
Temperature dependence conduction mechanisms



✓ **Pool-Frenckle**

$$J = q\mu N_C E \exp\left[\frac{-q\left(\Phi_T - \sqrt{\frac{qE}{\pi\varepsilon_i\varepsilon_0}}\right)}{k_B T}\right],$$

$\Phi_T = 0.96$ eV



In a nutshell

- ***Large*** area grown ***Crystaline*** β-Si_3N_4(0001)
- Observation of ***charge carrier modulation***
- ***Very low leakage current at 4.2 K*** in this ultrathin high-k Dielectric
- ***Pool-Frenckle*** conduction mechanism for leakage current

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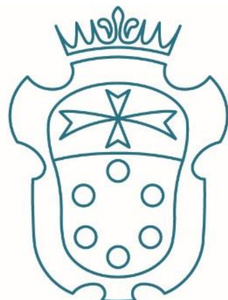

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Thanks for your attention