Characterization and fabrication of monolayer graphene on h-BN semiconducting devices

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Since first isolated in 2004, graphene has established itself as a promising material in semi-conducting devices, exhibiting a host of unique properties regarding collective electron behavior.[1] With respect to electronic applications, graphene's massless charge carriers, referred to as Dirac fermions and exhibiting a relativistic-like energy dispersion, offer the potential to push semiconductor technology past the usage of silicon, whose mobility is far exceeded by that of graphene.[2] However, because this high mobility is primarily observed only in isolated settings, one of the objectives for graphene researchers in electronics has been to create and perfect more-practical graphene field effect devices (FEDs). While retaining ultra-fast carrier mobility is difficult, mobility in graphene FEDs still exceeds that in traditional silicon devices.[3] Since traditional FEDs are typically fabricated on silicon/silicon-dioxide wafers, recent discovery of hexagonal boron-nitride (*h*-BN), a material with only a 1.7% lattice mismatch with graphite, has increased hope of reaching isolated graphene level mobility.[4] Motivated by this, we have used a methodology involving monolayer graphene preparation by mechanical exfoliation and transfer to *h*-BN via PMMA. Characteristic data has been taken at low-temperature using liquid He.

[1] K. S. Novoselov, *et al.*, Science **306**, 666 (2004).
[2] K. S. Novoselov, *et al*., Nature **438**, 197 (2005).
[3] M. C. Lemme, *et. al.*, IEEE Electron Device Lett. **28**, 4 (2007).
[4] C. R. Dean, *et. al.*, Nature Nanotech. **5**, 722 (2010).

CHARACTERIZATION AND FABRICATION OF MONOLAYER GRAPHENE ON H-BN SEMICONDUCTING DEVICES

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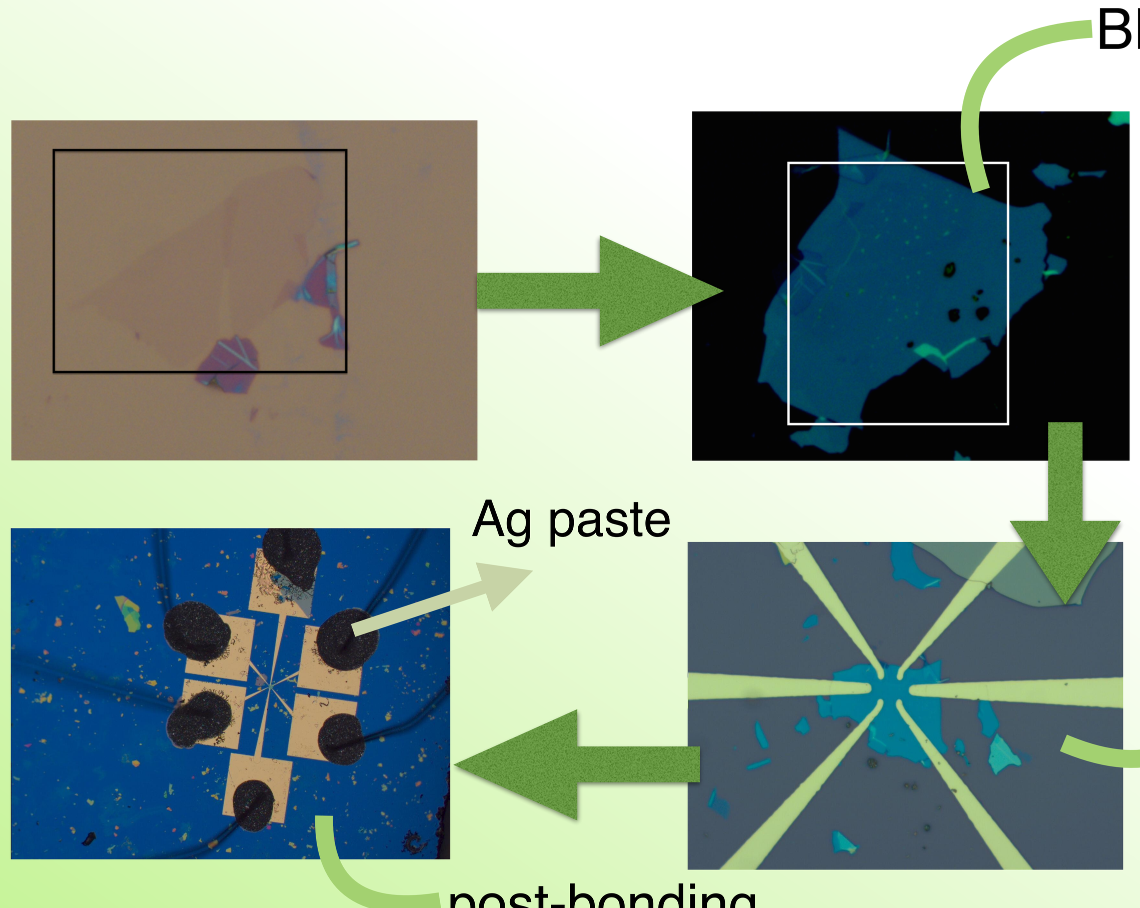
Introduction

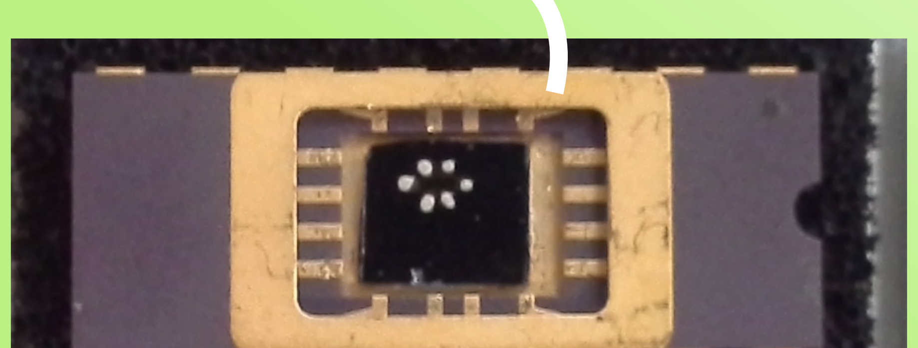
Objective: Characterize a monolayer graphene hexagonal boron-nitride device with high mobility at low-temperature

Method

1. Preparation of graphene by micro-mechanical exfoliation (Si surface), **PVA/PMMA** coating
2. Preparation of BN on SiO_2
3. Transfer via floating PMMA

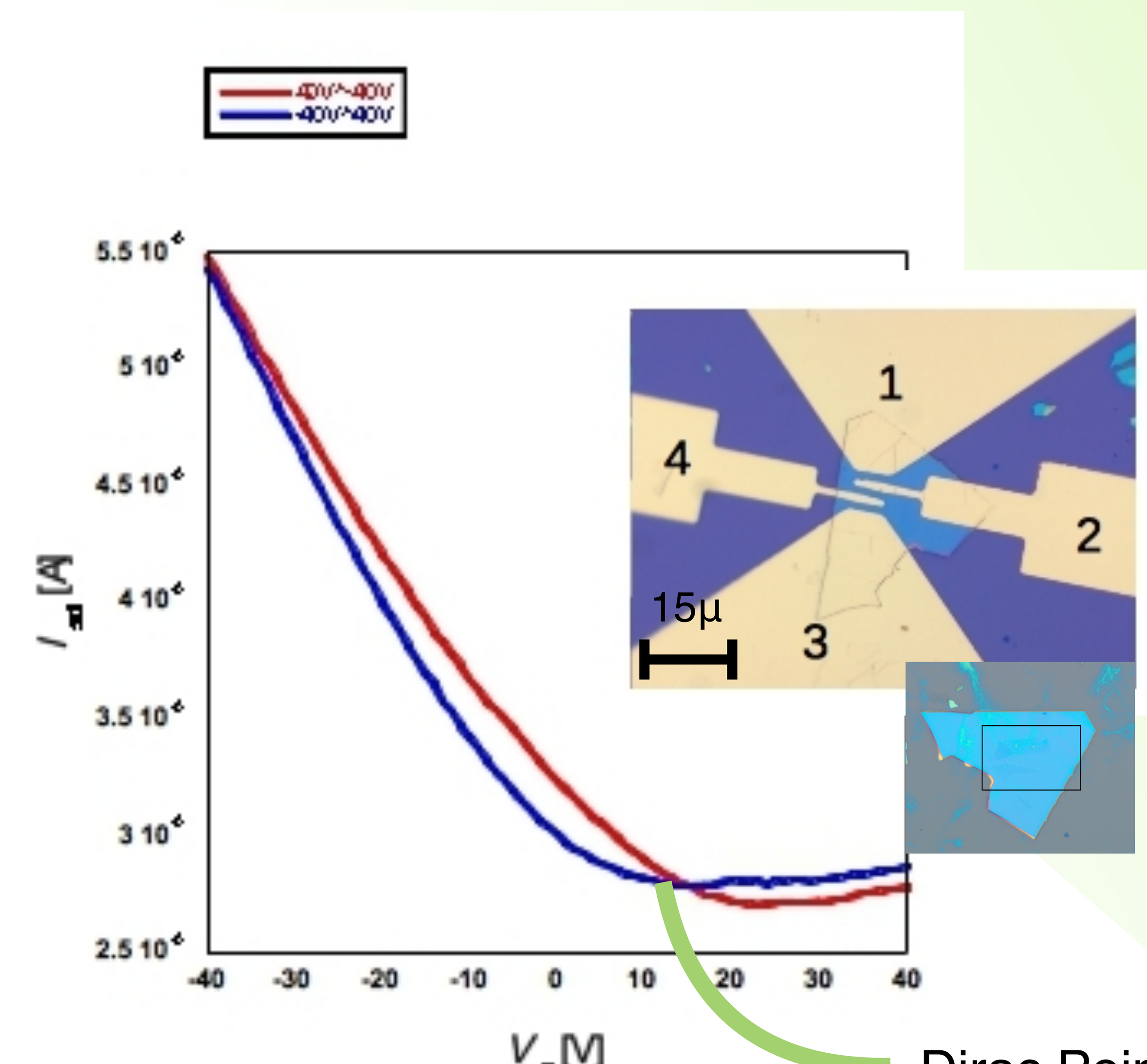


4. Removal of PMMA and addition of photo resist (**LOR, V90**)
5. Photolithography
6. Vapor deposition (Au, Sn) and liftoff (**NMD-3)**
7. Bonding (to chip carrier) and low-temperature preparation



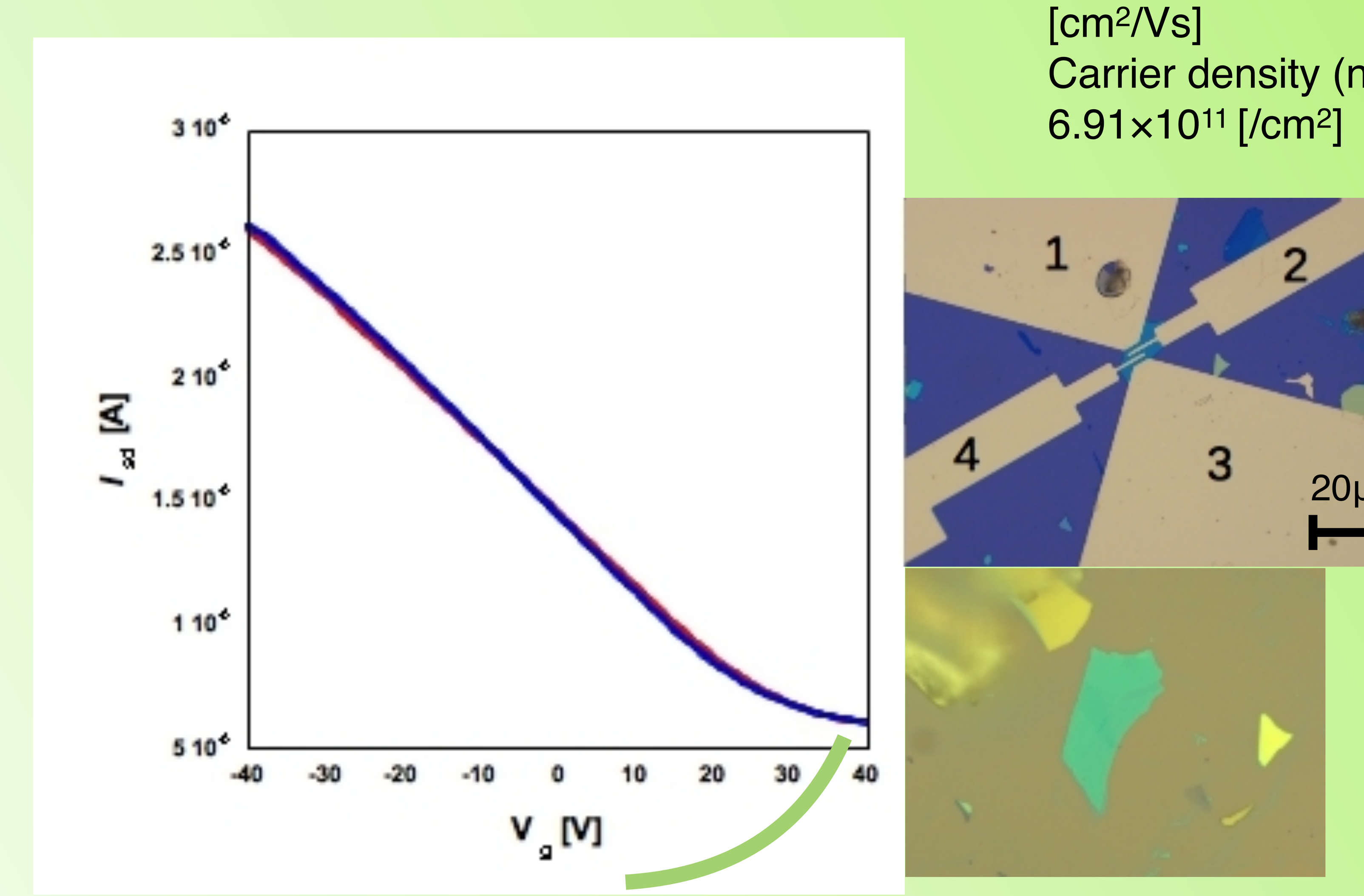
Results & Discussion

Sample Properties



Mobility: 1.56×10^3 [cm^2/Vs]
Carrier density (n_e): 2.25×10^{11} [/cm^2]

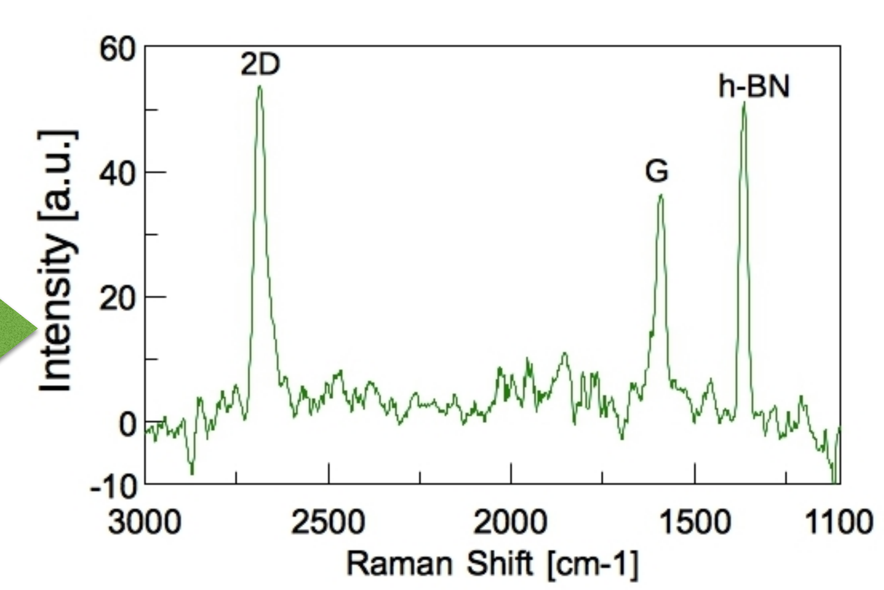
Dirac Point (~10 V), V_g step: 1 V



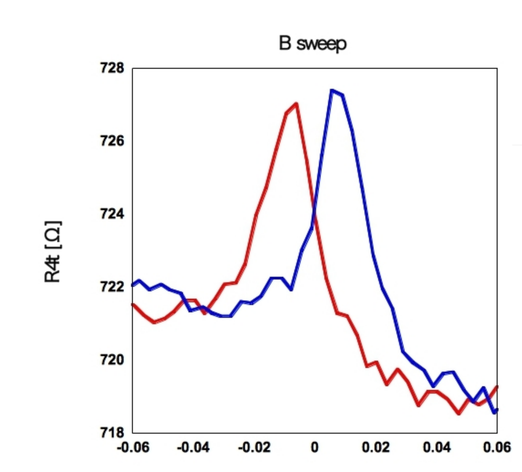
Mobility: 2.22×10^3 [cm^2/Vs]
Carrier density (n_e): 6.91×10^{11} [/cm^2]

Dirac Point (~40 V), V_g step: 1 V

Raman Spectroscopy

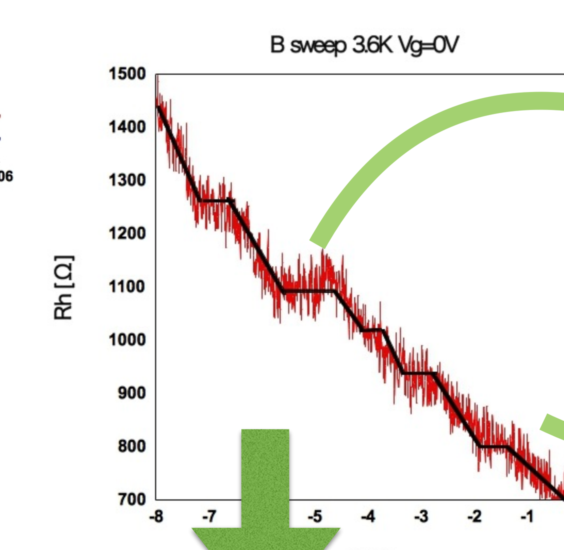


Low-Temperature



Magnetic Resistance

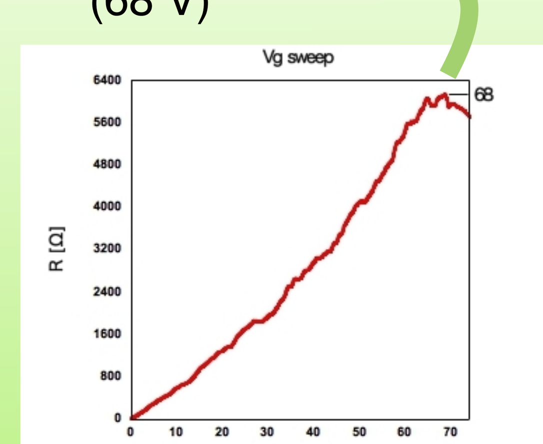
According to Raman, the sample is monolayer.

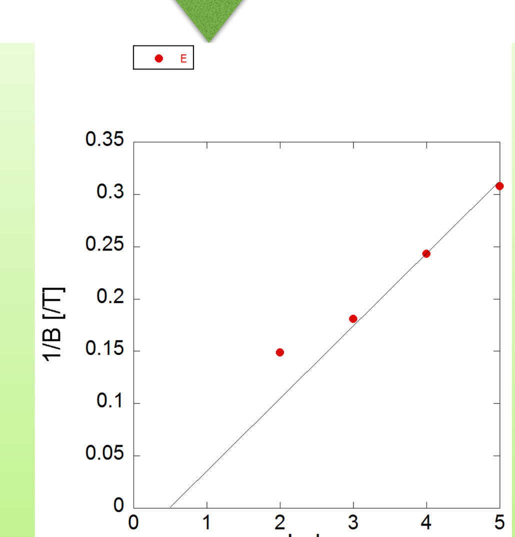


Plateau due to the quantum Hall effect

R_{xy}

Dirac Point (68 V)





Characteristics

$n_e = 1/e(dR_{xy}/dB)$
$\mu = (L/W)(en_eR_{xx})^{-1}$
$B_c S_\phi = h/e$
<u>Low-Temperature Properties</u>
$B_c = 0.017$ [T]
$L_\phi = 493$, L = 9 [µm], W = 6 [µm]
$n_e = 2.96 \times 10^{12}$ [/cm^2]
$\mu = 4.36 \times 10^3$ [cm^2/Vs]

Summary

This was the lab's first experiment involving graphene on BN as opposed to just SiO_2. We hope that the usage of BN, a flat, hydrophobic surface (no dangling bonds) high band gap insulator, will lead to devices with higher mobility than the traditional graphene-SiO_2 device.

RICE NSF NanoJapan International Research Experience for Undergraduates

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