Mechanical cleaning of graphene

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Influence of substrate on graphene properties

\[ \mu = \frac{1}{n \rho_{xx}} \sim 28,000 \text{ cm}^2 \text{ V}^{-1} \text{ s}^{-1} \]

\[ n = 2 \times 10^{11} \text{ cm}^{-2} \]

\[ \mu = 230,000 \text{ cm}^2 \text{ V}^{-1} \text{ s}^{-1} \]
Boron nitride and graphene

- Band gap: 5.97eV (SiO₂ : 8.9eV)
- Dielectric const ε: 3-4 (SiO₂ ε: 3.9)
- Lattice mismatch with graphene: 1.7%
- Inplane covalent bonds → less dangling bonds
Graphene transfer on hBN

- Exfoliation of hBN onto SiO2 wafer
- Exfoliation of graphene onto a PMMA-watersoluble layer on SiO2
- Lifting PMMA layer off the SiO2 layer in H2O
- Transfering graphene onto hBN flake on SiO2
- Lift off of PMMA in acetone

Mechanical cleaning of graphene sheets

- Cleaning in annealing oven: 400°C in Ar/H₂
- Cr/Au contacts fabricated with e-beam
- Again annealing in oven: 300-440°C
- Contact mode AFM
- Roughness
  - before processing: 0.2nm
  - after processing: 1nm
  - after CM AFM: 0.2nm
Back gate dependence

\[ \mu = \left( \frac{t_{SiO_2}}{\epsilon_0 \epsilon_r, SiO_2} + \frac{t_{hBN}}{\epsilon_0 \epsilon_r, hBN} \right) \frac{d\sigma}{dV} \]

- Before CM AFM:
  - \( V_{pn} = 4V \rightarrow 20V \)
  - \( \mu = 2.6 \cdot 10^2 - 3.4 \cdot 10^3 \text{cm}^2/(\text{Vs}) \)
- After CM AFM:
  - \( V_{pn} = -7V - 1V \)
  - \( \mu = 9.2 \cdot 10^2 - 8.9 \cdot 10^3 \text{cm}^2/(\text{Vs}) \)
Top gated bilayer graphene device

\[ \mu = 36000 \text{cm}^2/(\text{V} \cdot \text{S}) \]
SLG in H2-plasma

- Graphene deposition
- Annealing at 300°C, 1hr and 400°C, 1hr
- Patterning holes with e-beam
- AFM: PMMA residues
- 5min H₂ plasma
  - 50Watt
  - 0.03mbar
  - 500°C
- AFM: less residues than before

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Influence of H$_2$ plasma on graphene

G peak

2D peak

Raman of graphene

G peak

D peak

2D peak

D+$D^*$ peak

Raman of DHVIII_8678

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M.S. Dresselhaus, Raman spectroscopy of carbon nanotubes
Hydrogenation of graphene: graphane

Science, 323, 610 (2009)

Science, 323, 589 (2009)
Conclusion

• Boron/nitride less disordered than SiO$_2$
• CM AFM using low forces clean graphene surfaces
• moderate mobilities for bilayer graphene
• Plasma etching could also be used as a cleaning method