Reversible Hydrogenation and Bandgap Opening of Graphene and Graphite surfacea Probed by Scanning Tunneling Spectroscopy

Castellanos-Gomez et al.

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Influences of different plasma on graphene

RF = 13.56 MHz
Gas mixture: Ar (85%), H₂ (15%)
Gas flow = 200 sccm
Pressure = 0.05 mbar
Power = 3 W
Influence of insulation of sample from plasma

- Ar plasma with insulated sample: strong graphene etching
- Ar/H2 plasma with insulated sample: hydrogenation of graphene
- Ar plasma with non-insulated sample: much less etching of graphene
Influences of different plasma on graphene

RF = 13.56 MHz
Gas mixture: Ar (85%), H$_2$ (15%)
Gas flow = 200 sccm
Pressure = 0.05 mbar
Power = 3 W

RF = 13.56 MHz
Gas mixture: H$_2$
Gas flow = 20 sccm
Pressure = 0.4 mbar
Power = 25 W
Concerns about Ar/H2 plasmas

- Both Ar and H₂ ions present in the plasma
  - $E_{\text{Ar}} = 15.76$ eV
  - $E_{\text{H₂}} = 15.42$ eV

- Hydrogen ions are needed to hydrogenize the surface of almost defect free graphite [PRB 66 245416 (2002)]

- Therefore the applied dc voltage should not be too high

- Probably they need Ar gas to generate plasma at such low power (3 W)
  - Impact of Ar ions on graphene surface?
Characterisation of graphene flakes
STM measurements before and after plasma exposure
STS measurements: looking for a gap

HOPG

(a) Freshly cleaved HOPG
(b) 40 min. Ar/H₂ plasma
(c) 10 min. 280°C
(d) 40 min. Ar/H₂ plasma
(e) 10 min. 280°C

CVD graphene

(f) As received CVD graphene
(g) 40 min. Ar/H₂ plasma
(h) 10 min. 280°C
(i) 40 min. Ar/H₂ plasma
(j) 10 min. 280°C
STS measurements: looking for a gap

HOPG

CVD graphene

02.08.2012
A. Castellanos-Gomez et al., small 8, 10, 1607 (2012)
Histograms of counts at zero differential conductance
Conclusion

• Ar/H₂ plasma used to hydrogenate CVD graphene and HOPG samples.

• No evidence for the etching of the samples by the plasma could be found

• Hydrogenation induces a energy gap in both, graphene and graphite samples

• Hydrogenation is reversible. Heating the samples leads to desorption of H atoms
Ar plasma treatment only

HOPG

Counts

0
3000

CVD graphene

Differential conductance (nS)

V_{tip} (Volts)

Differential conductance (nS)

V_{tip} (Volts)

Differential conductance (nS)

V_{tip} (Volts)

Differential conductance (nS)

V_{tip} (Volts)