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Influence of Defects and Charge Transfer from the Substrate on the Surface Potential of Graphene

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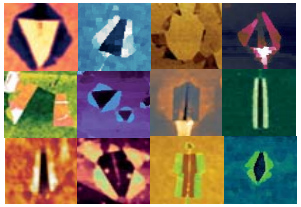
DFG Schwerpunktprogramm 1459 Graphene

SFB 616

nc-AFM 2013 I/14

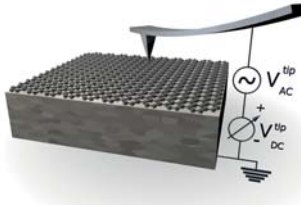
Goals

- Investigation and quantitative characterisation of energy dissipation processes during and after energetic ion irradiation [1]
- Tailoring of morphological and physical properties of 2D materials (e.g. graphene, MoS_2, Mica) [2,3,4]
- In situ study of 2D FETs using AFM techniques, e.g. KPFM, cAFM



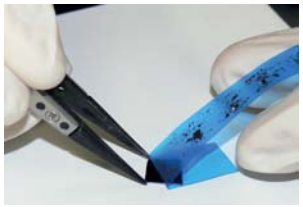
Experiment

- Irradiation experiments at the IRRSUD beamline of the GANIL (Caen, France) and at the M1 branch at the GSI (Darmstadt, Germany)
- Sample characterisation in ambient with tapping mode AFM and Raman spectroscopy
- UHV measurements with non-contact AFM and Kelvin probe force microscopy



Sample Preparation

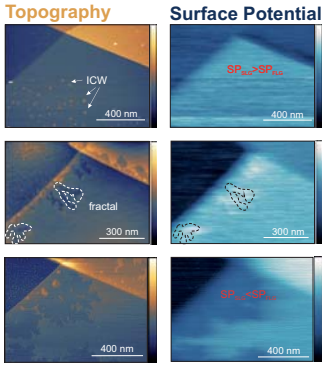
- Samples are prepared using the mechanical exfoliation technique (or Scotch Tape methode). This technique can be applied on any layered material resulting in 2D crystals of the highest quality.
- In situ mechanical exfoliation of graphene on arbitrary, well defined substrates [5]



Tuning the Work Function of Graphene by Defects, Adsorbates & Substrate

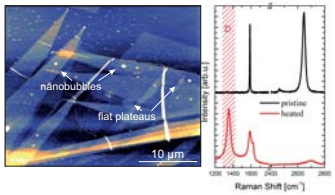
In situ heating of graphene on mica

- Graphene exfoliated in ambient shows intercalated water layers (ICW)
- Surface potential is decreasing with increasing layer thickness
- Annealing in situ (180 °C) removes ICW islands and fractals at the graphene edge are formed
- Fractals exhibits an increased SP - substrate charge transfer is effectively blocked by ICW [6]
- Heating to 600 °C increases the size of the fractals, yet ICW cannot be completely removed
- Surface potential is now decreasing with layer thickness - n-type



Defects in graphene created by nanobubbles

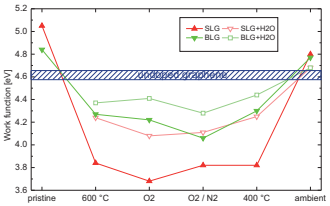
- Origin of the n-type doping is investigated in ambient by tapping mode AFM & Raman spectroscopy
- AFM scans reveal two new structures on graphene:
  - Nanobubbles with a height up to 15 nm
  - Flat plateaus with a constant height of roughly 1 nm



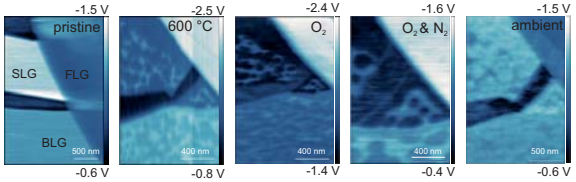
- Raman spectroscopy of SLG shows formation of very prominent disorder induced D-peak by heating
- Raman mapping of D-peak intensity - Intensity generally decreases with increasing layer thickness, yet flat plateaus show a strongly increased defect density.

Tuning of the work function with adsorbates

- Quantitative KPFM for work function (WF) analysis - FLG is used to calibrate the WF of the tip [7]
- Pristine graphene on mica has a WF of 5.09 eV (4.57 eV for undoped SLG) -> p-type doped
- In situ heating to 600 °C decreases the WF to 3.90 eV -> transition to n-type doping

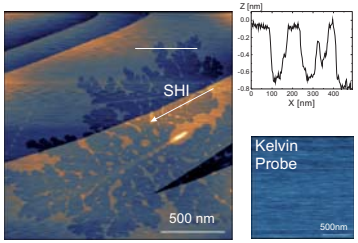


- Exposure of defective graphene to molecular gases - SP of SLG and BLG show different responses
- Ambient exposure leads to a SP contrast inversion again. Thus any values measured by samples exposed to ambient conditions are questionable



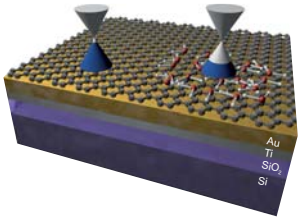
Water intercalated few layer graphene

- Exfoliated FLG often used to calibrate the WF of the AFM tip - influence of ICW is unknown
- Swift heavy ion irradiation under glancing incidence employed to fabricate a channel in which mild heating causes water desorption
- No SP contrast between FLG and FLG+ICW is observed

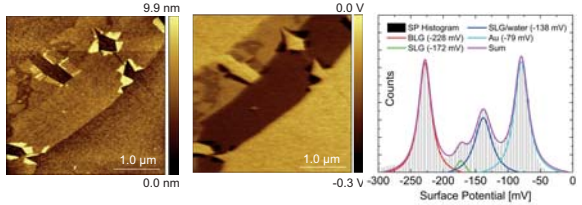


Graphene on thin Au/Ti films

- Physical Vapour Deposition used to grow thin films of Au/ Ti on standard SiO_2/Si substrates
- Goal: Employ Ti diffusion in gold - triggered by sample heating [8] to precisely tune the WF of graphene
- Graphene is exfoliated in ambient and irradiated with swift heavy ions under glancing incidence creating origami like foldings, allowing SLG identification [9]



- In situ non-contact AFM show foldings on SLG and BLG
- Surface potential distribution indicates p-type doping of graphene. However the adsorbate layer is not blocking the charge transfer, which might be due to adsorbates being on top of graphene.



- These findings show the necessity of controlled sample preparation conditions. Using in situ e-beam evaporation and exfoliation, this experiment will be repeated.

References

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