Nanomechanical properties of graphene in polar and non-polar liquid environments

Benjamin J. Robinson, Oleg Kolosov

Department of Physics, Lancaster University, Lancaster, LA1 4YB, UK

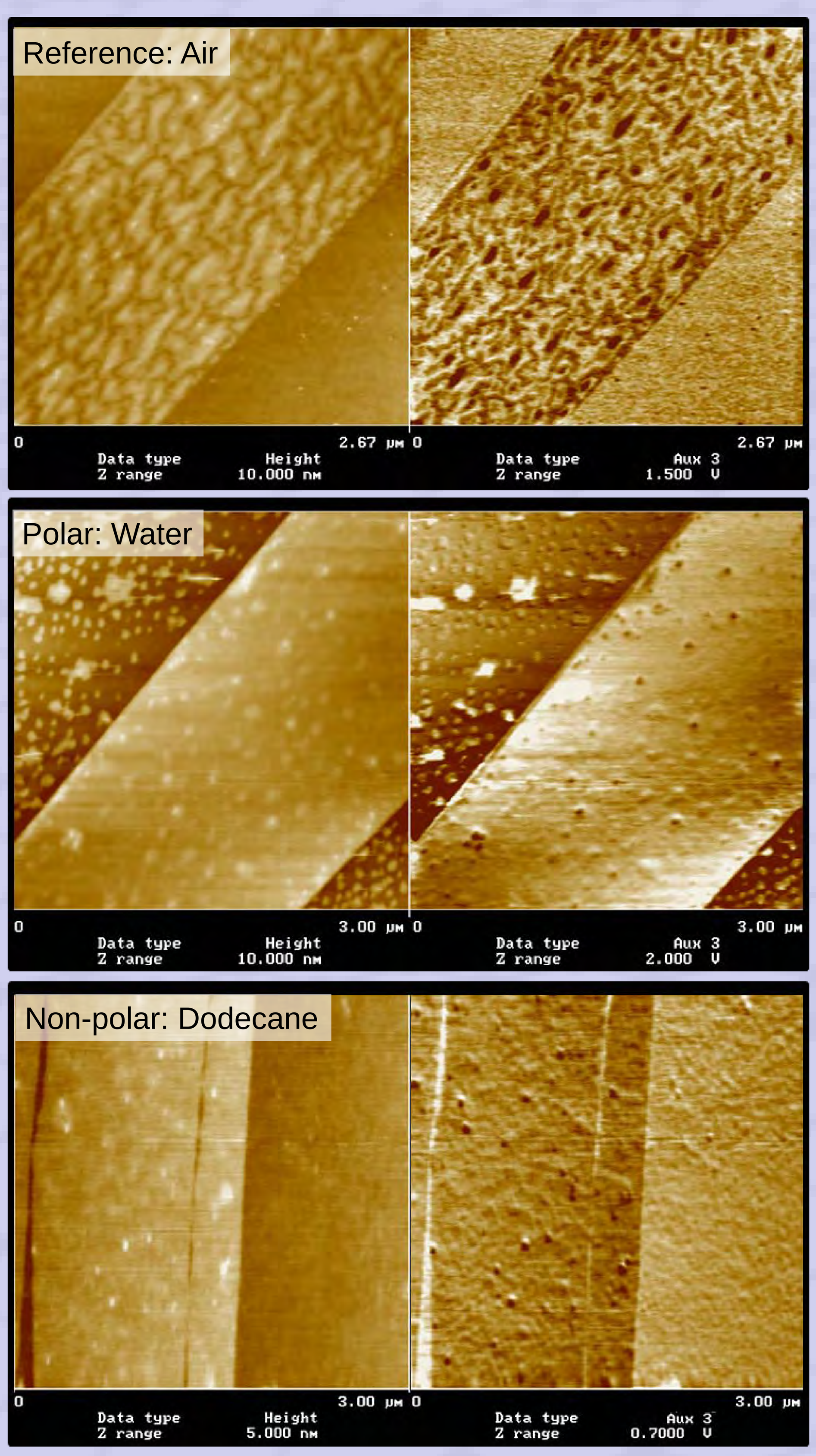
Introduction

Characterisation of graphene and its properties have primarily focused on isolated, suspended single sheets in air or vacuum. Characterisation of graphene interactions with local environment, specifically polar and non-polar liquids is practically unexplored.

An understanding of the changes in graphene properties in different local environments is essential for the future development of applications including rechargeable batteries, super-capacitors and photovoltaics.

We present a methodology and results for its characterisation in different environments.

Graphene under-liquid



An exfoliated graphene flake on a SiO_2 substrate was imaged using both contact AFM and UFM in air (top), water (middle) and dodecane (bottom) environments. Thus topography, friction **and** elastic response can be mapped for the same region.

GRENADA

This is a major new European Commission programme on “GRaphenE for NAnoscaleD Applications” (GRENADA, Framework FP7).

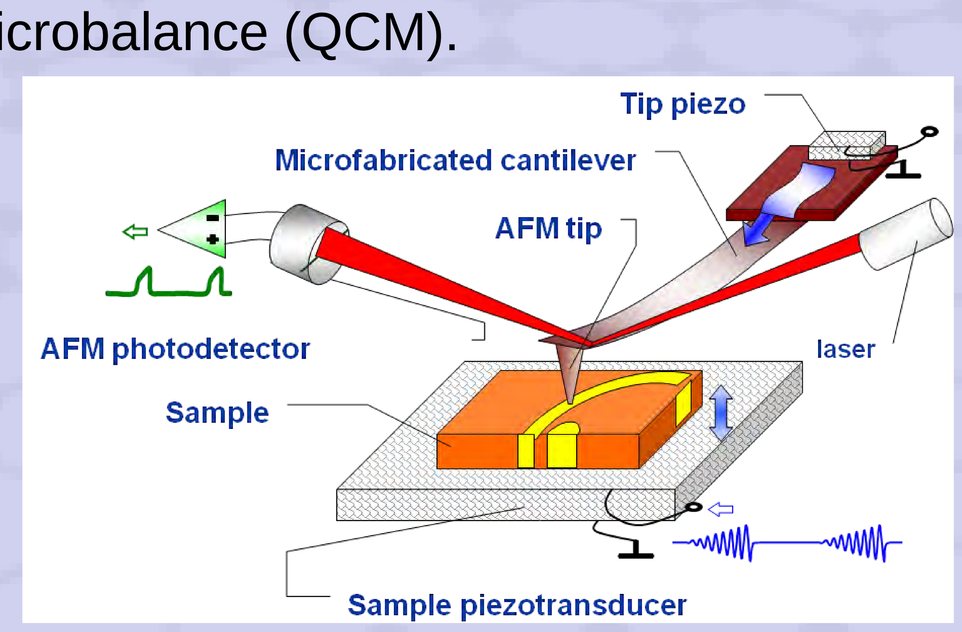
It involves seven leading European academic and industrial research institutions funded to address the theoretical and experimental challenges of using graphene in application relevant environment.

Principle research concerns graphene interacting with polar and non-polar liquids, the role of the substrate, number of graphene layers, defects, chemical modification, etc.

GRENADA will provide theoretical and experimental foundation for large area graphene based devices with tailored electronic, mechanical, thermal and optical properties, specifically a new generation of super-capacitors and rechargeable batteries, optical displays and related applications.

Methodology

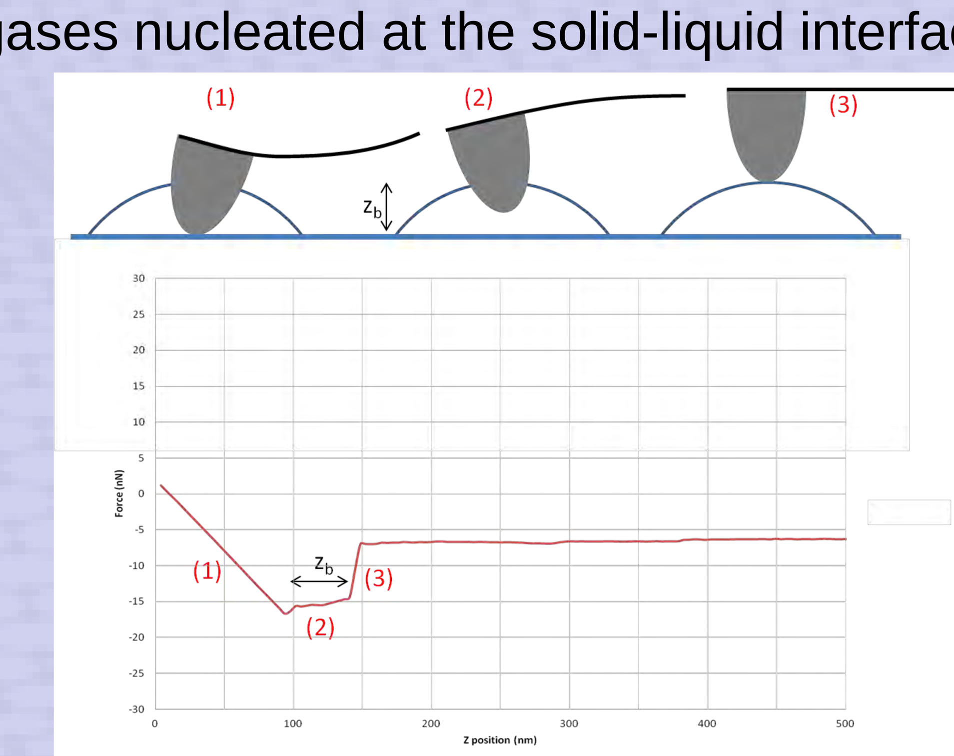
We are developing a set of methodologies for rapid, *in-situ* measurements of graphene nanomaterials including micro-Raman, four-point resistivity measurements in solution and specifically the development of underliquid UFM and liquid-environment quartz crystal microbalance (QCM).



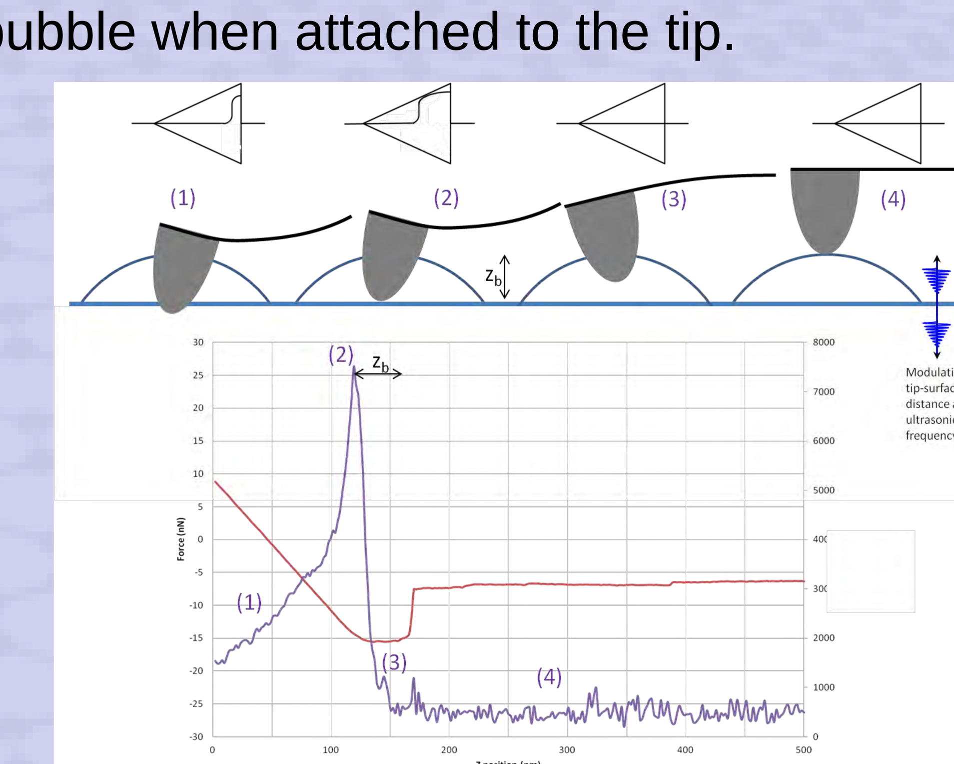
Ultrasonic force microscopy (UFM) combines the nanoscale resolution of the AFM with the elastic sensitivity of acoustic microscopy. High frequency ultrasonic vibrations are applied to the sample forcing it to elastically indent itself against an AFM tip which is very stiff at MHz frequencies.

Nanobubbles on graphene

Characteristic features observed on the graphene flakes, in polar liquid, are believed to be nanobubbles formed due to dissolved gases nucleated at the solid-liquid interface.



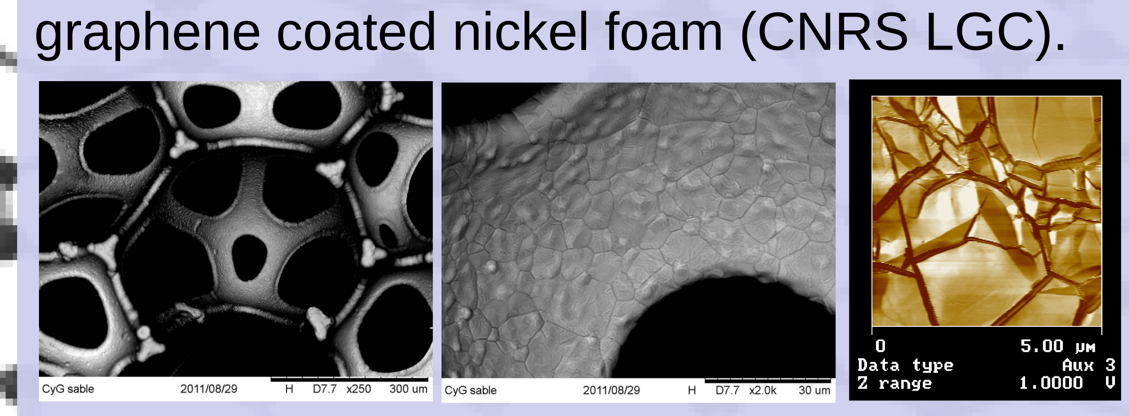
Plateaus observed in the retraction curve correspond to the maximum extension of the bubble when attached to the tip.



UFM response shows a detachment from the solid-solid contact prior to snap out of the tip, suggesting that forces experienced by the tip in the plateau region are not directly due to the graphene flake.

Other graphene structures

UFM analysis of novel graphene structures made by GRENADA partners, such as graphene coated nickel foam (CNRS LGC).



Also, a 6mm diameter Ir(111) single crystal homogeneously covered with single layer graphene of high structural quality.

Future work

The understanding of the physical interactions of graphene with it’s environment will be studied through the development of heterodyne force microscopy (HFM) and *in situ* SPM electrochemistry. We will also develop novel techniques for the investigation of local conductivity of graphene systems in different electrolytic environments.

Conclusions

We have developed a methodology for the characterisation of the nanomechanics of graphene in different polar and non-polar liquid environments. Using these novel techniques we have investigated the topographical, tribological and adhesive properties, we have also identified and studied the formation of nanobubbles on graphene.