Nanorobotic strategies for graphene handling - microscopic transfer and exfoliation

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I. Motivation

The interest in graphene continuously rises due to its unique electrical and mechanical properties. Although the discovery lies back only a few years, graphene seems to be predened for a wide range of applications, e.g. transparent electrodes, supercapacitors and biological devices.

Despite of the significant progress achieved in recent years, transfer processes of graphene membranes and synthesis of high quality graphene using mechanical cleavage of highly orientated pyrolytic graphite (HOPG) are still based on manual work steps and are therefore inaccurate and not reproducible.

Nanorobotic handling of graphene is a potential candidate to overcome these constraints. It will enable reliable synthesis using nanorobotic assisted exfoliation as well as reliable positioning of individual graphene membranes on any desired substrate with high accuracy.

The strategies presented hereunder can be applied for fabrication of prototype-like graphene based devices as well as for experiments that require high flexibility combined with high accuracy.

II. Nanorobotic strategies

A. Nanorobotic transfer

B. Nanorobotic exfoliation

III. Experimental

Nanorobotic setup inside a dual-beam high-resolution scanning electron microscope with integrated Gas injection system:

- Electron gun
- Secondary electron detector
- Manipulation tool holder
- Fine positioning stage
- Coarse positioning stage
- Ion gun
- Gas injection system
- Samples

IV. Nanorobotic transfer

Few-layer graphene, fabricated by chemical vapor deposition on Ni substrates and transferred on lacy carbon film, can be used for the nanorobotic assisted transfer process.

Adhesive forces are sufficient to keep the membrane attached to the tip. As soon as the membrane touches the substrate, adhesive forces between membrane and substrate exceed those between membrane and tip.

In order to enable exfoliation, adhesive forces between substrate and HOPG must exceed cohesive forces of the HOPG. Usually, thin adhesive films are applied.

V. Nanorobotic exfoliation

The tip can be fixed on the flake using electron beam induced deposition. This bonding was found to be more stable than the weak van der Waals force between the graphene layers.

In order to enable exfoliation, adhesive forces between substrate and graphene must exceed cohesive forces of the HOPG. Usually, thin adhesive films are applied.

Nanorobotic exfoliation enables direct synthesis of high-quality graphene on partially freely suspended substrates and is therefore suitable for prototyping of nano-electromechanical systems (NEMS).

VI. Conclusion and Upcoming work

The presented nanorobotic strategies facilitate handling of graphene on micro-/nanoscale and are therefore well-suited to assist and promote graphene research and technology development.

Upcoming work will focus on:

- Nanorobotic characterization
- Assembly of combined 1D/2D nanostructures
- Graphene device prototyping

References

Sören Zimmermann and Sergej Fatikow, “Nanorobotic handling of few-layer graphene using a combined AFM/SEM/FIB setup”, International Conference on Manipulation, Manufacturing and Measurement on the Nanoscale, Xian, China, August 29 - September 2, 2012, accepted