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Patterning Graphene using Nanoimprint Lithography

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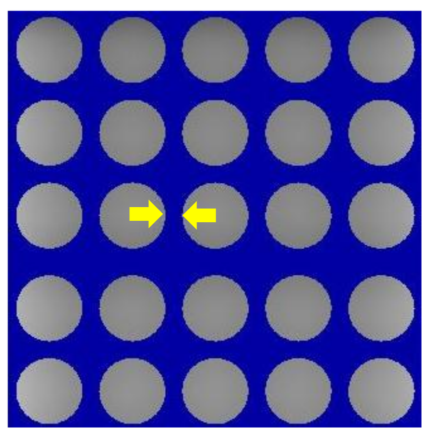
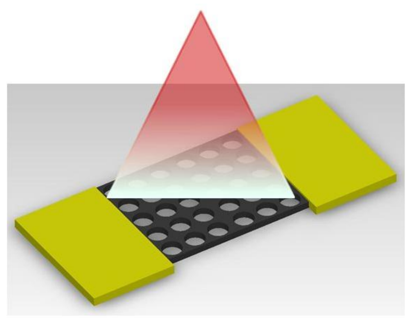
Motivation

Graphene is a 2-D, semimetallic, zero band gap material of hexagonally-arranged carbon atoms with outstanding electronic and optical properties
- •long mean free path > 2mm
- •room temperature mobility potentially greater than 200,000 $cm^2 V^{-1} s^{-1}$
- •absorbs ~2% across a large bandwidth range

Graphene nanoribbons of sub-20 nm width exhibit a band gap allowing incorporation into field effect transistors with large current on/off ratios. Difficulties with repeatability of graphene nanoribbon width hamper large scale application of the material. Recently, graphene nanomeshes using diblock copolymers have been demonstrated where the periodicity of the diblock copolymer provides the template for creating sub-20 nm features.

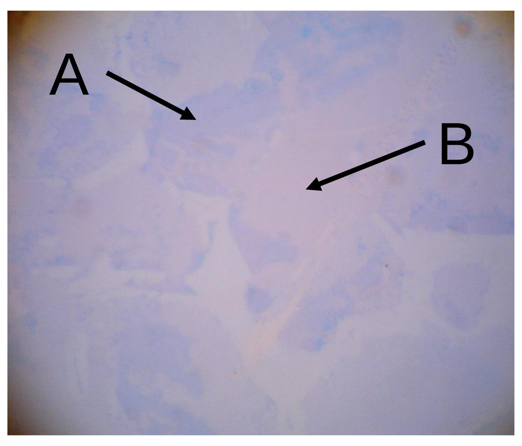


The bandgap scales inversely with the nanoribbon width



Optical transitions in graphene have been shown to be controlled by electrical gating allowing greater than 2% absorption of incident infrared radiation. Demonstrations of ultrafast graphene photodetectors and broad-band optical modulators show the potential of graphene for optical applications.

Transferring graphene to different substrates



Optical image of graphene and few layers of graphene on 300 nm silicon oxide: A) Few layers of graphene stacked on top of one another, indicated by the darker shades; B) single layer of graphene.

Although there are several methods to generate graphene samples, perhaps the most promising for large scale applications is chemical vapor deposition (CVD) of graphene onto nickel or copper substrates. Transferring the graphene to 300 nm silicon oxide allows optical observation of the number of graphene layers.
To transfer graphene, a thin layer of PMMA is spin- or drop cast onto the graphene-on-metal. The metal layer is etched away leaving the graphene and PMMA layers. The PMMA/graphene layer can then be transferred to different substrates for further processing. Once deposited, the PMMA is then dissolved, leaving graphene on the desired substrate.

Future Work

Electrical characterization of graphene nanomeshes for sensor applications. Optoelectronic testing: investigate the photocurrent response of the graphene nanomeshes. Photocurrent mapping in the infrared spectrum provides carrier information for device applications. Optical sensing experiments for bionanophotonic sensing.

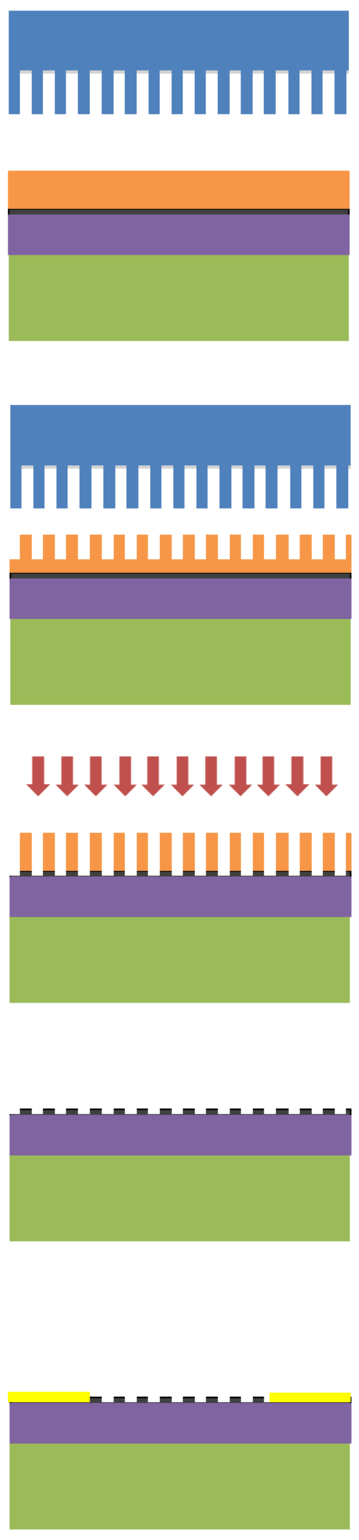
Nanoimprint Lithography

High throughput, low cost nanofabrication

Sub-100 nm structures can be generated by the two-step NIL process: imprint and pattern transfer.

The mold is first pressed into a thin spin cast layer of resist film at temperatures above the PMMA glass transition temperature, creating topological features of different heights. The features are then transferred into the desired substrate using anisotropic etching.

- Metal electrodes
- Imprint mold
- PMMA thermal resist
- Graphene
- Silicon oxide layer
- Silicon



Thin layer of PMMA spincast onto graphene substrate

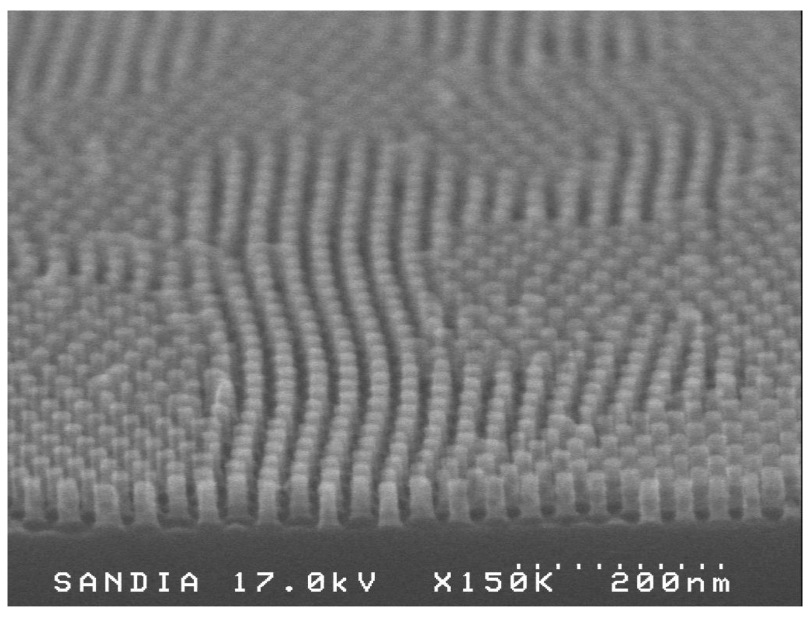
Nanoimprint mold is pressed into thin film, creating thickness contrast

Pattern transfer via reactive ion etching

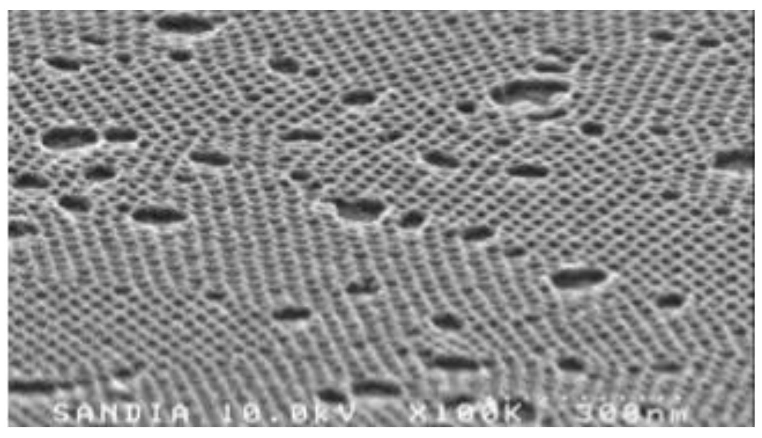
Removal of PMMA exposes the patterned graphene

Metal electrodes placed onto graphene nanomesh for electrical and optoelectronic characterization

Diblock Copolymer Mold and Imprint



SEM image of diblock copolymer nanoimprint mold. The graphene nanomesh width is determined by the distance between each cylinder. The nanoimprint lithography tool, Nanonex NX-2000, uses the thermal imprint resist, MR-1 PMMA, for this process.



SEM image of nanoimprinted PMMA on oxide substrate.

Acknowledgments

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