SAND2011-5085P

National Institute for Nano Engineering

Nanopatterning of Graphene by Nanoimprint Lithography for Sensor Applications

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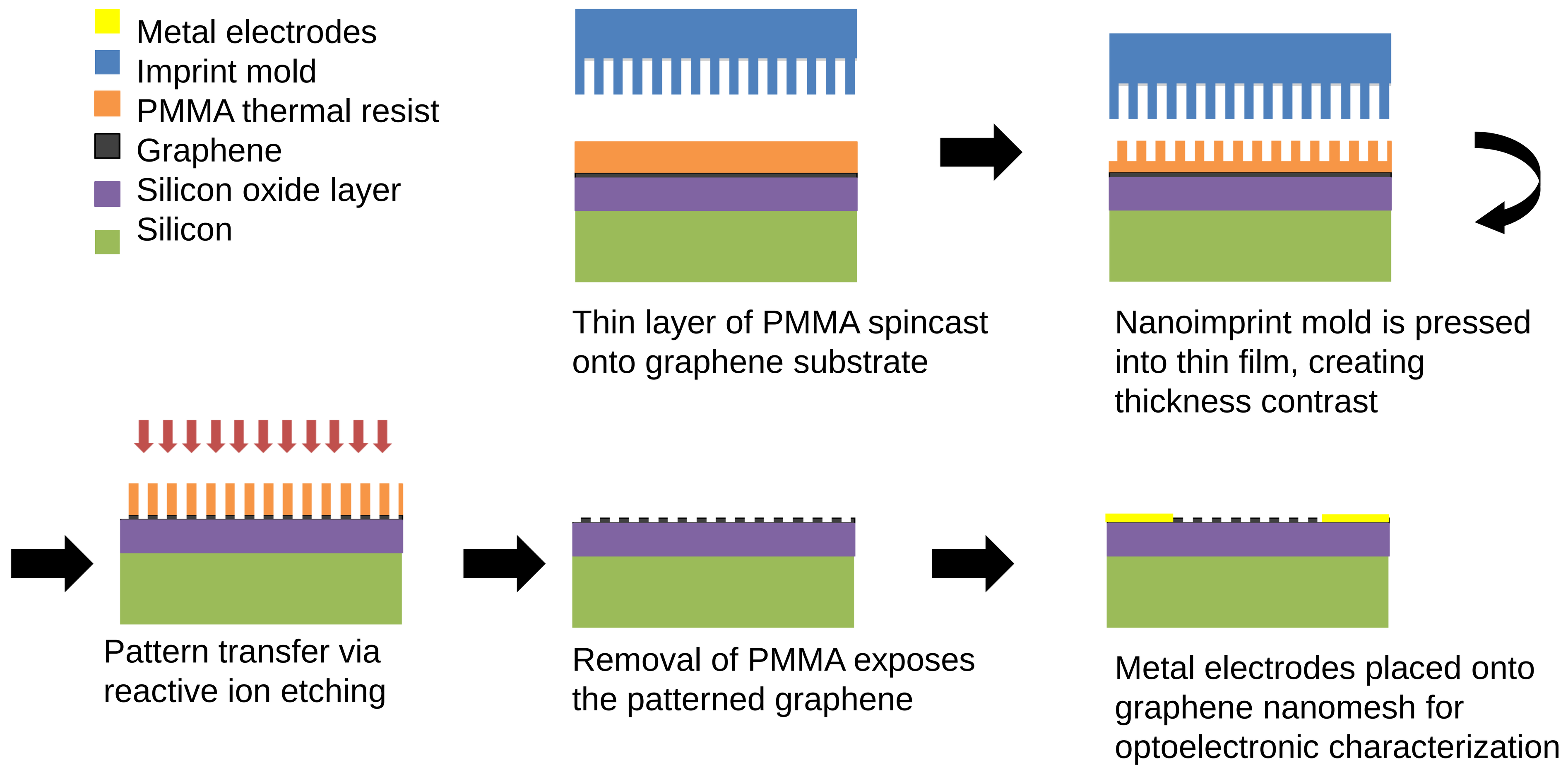
Motivation

Graphene is a 2-D, semimetallic, zero band gap material of hexagonally-arranged carbon atoms with outstanding electronic properties, such as long mean free path > 2mm and room temperature mobility potentially greater than 200,000 $cm^2 V^{-1} s^{-1}$. 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.

Although research emphasis currently focuses on the electronic properties of graphene, the optical properties of graphene are of interest since it absorbs ~2% across a large bandwidth range. 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. Here, we examine the optoelectronic properties of graphene nanomeshes generated from diblock copolymer templates using nanoimprint lithography, allowing for higher current carrying capability and potential large area, high throughput fabrication.

Nanoimprint Lithography

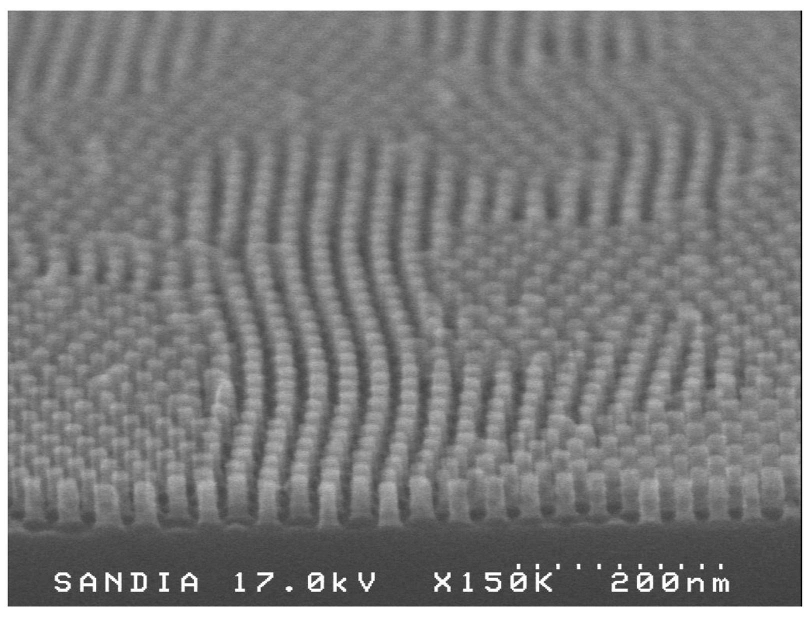
Nanoimprint lithography is a high throughput, low cost method for generating sub-100 nm structures using two steps - imprint and pattern transfer. The mold is first pressed into a thin spin cast layer of resist film, creating features of different heights. The features are then transferred into the desired substrate using anisotropic etching.



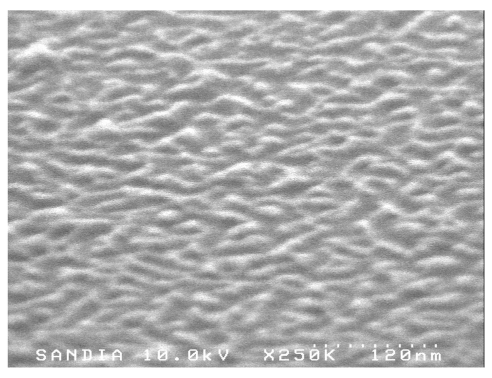
Next Steps

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.

Diblock Copolymer Imprint Template



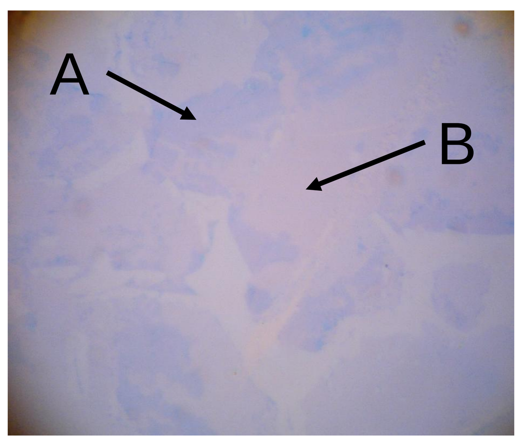
SEM image of diblock copolymer nanoimprint mold. The graphene nanomesh width is determined by the distance between each cylinder. The nanoimprint lithography tool, Nanonex NX-2000, uses the thermal imprint resist, MR-1 PMMA, for this process.



SEM image of initial nanoimprint and etching on graphene substrate. Although the cylinder pattern did not transfer directly, the formation of a continuous mesh may still yield new information about nanopatterning of graphene. Further characterization of the nanoimprinting process onto graphene is ongoing.

Transferring graphene to different substrates

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.



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.

Acknowledgments

Chip Steinhaus, David Heredia, Aaron Katzenmeyer, Jean Fakhoury, Jiyoung Chang, Qin Zhou, Bryan Loyola, Elaine Yang, Peter Yang

Sandia National Laboratories is a multi-program laboratory managed and operated by Sandia Corporation, a wholly owned subsidiary of Lockheed Martin Corporation, for the U.S. Department of Energy's National Nuclear Security Administration under contract DE-AC04-94AL85000