On Surface Synthesis and Dry-Transfer of Graphene Nanoribbons

Safi Mohammed[1], Zafer Mutlu[2], and Jeffrey Bokor[2]

[1]Foothill College, [2]University of California, Berkeley, Berkeley, CA

2019 Transfer-to-Excellence Research Experiences for Undergraduates Program (TTE REU Program)

Abstract

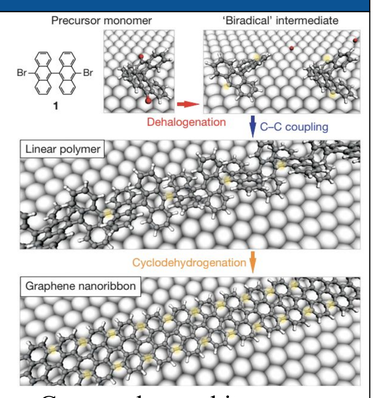
1. On-surface synthesized atomically precise graphene nanoribbons (GNRs) possess unique structural and electrical properties that make them critical for the development of high-performance field-effect transistors (FETs).
2. Currently, the fabrication of GNR-based transistors is conducted by synthesizing GNRs on metallic substrates (Au (111), etc.) and transferring them onto non-metallic substrates (SiO_2, etc.) through a wet-transfer method. This causes degradation of intrinsic GNR properties.
3. We present a dry-transfer method which involves picking up on-surface synthesized 7-atom wide armchair-edge GNRs (7-aGNRs) from a gold substrate using a polymer film and stamping them onto a SiO_2 substrate for FET device fabrication.

Background

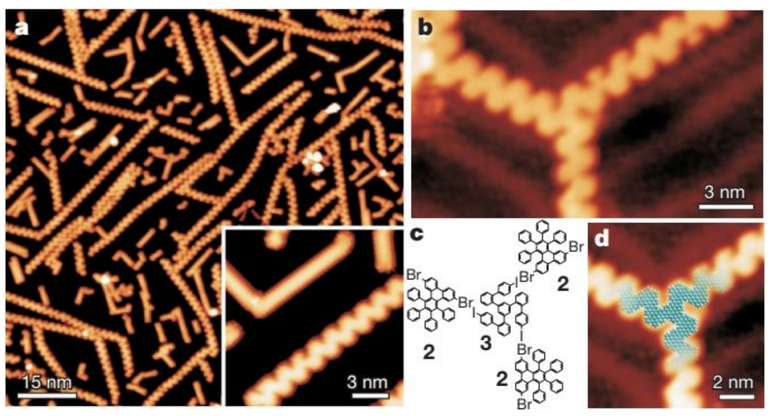
In 2004, Andre Geim and Konstantin Novoselov discovered a surprisingly simple method for isolating the two dimensional material graphene. Their discovery helped launch a new branch of research dedicated to investigating the nature of two-dimensional materials. Today, there have been vast improvements in the isolation of graphene, enabling a more thorough characterization of its properties. Graphene is promising for the development of superior transistor devices.

Synthesis of GNRs

- **Au(111) is deposited on SiO_2 /Si chip using Chemical Vapor Deposition (CVD)**
- **GNRs are synthesized in an ultra-high vacuum (UHV) system named "Triton"**
- **10,10'-dibromo-9,9'-bianthryl precursor monomers are thermally sublimed on surface and polymerized**
- **Annealing polymers on the surface results in a sequence of cyclization and dehydrogenation which leads GNRs that are 7 carbon atoms across and have armchair edges.**



Grey, carbon; white, hydrogen; red, halogens; underlying surface atoms shown by large spheres.[2]



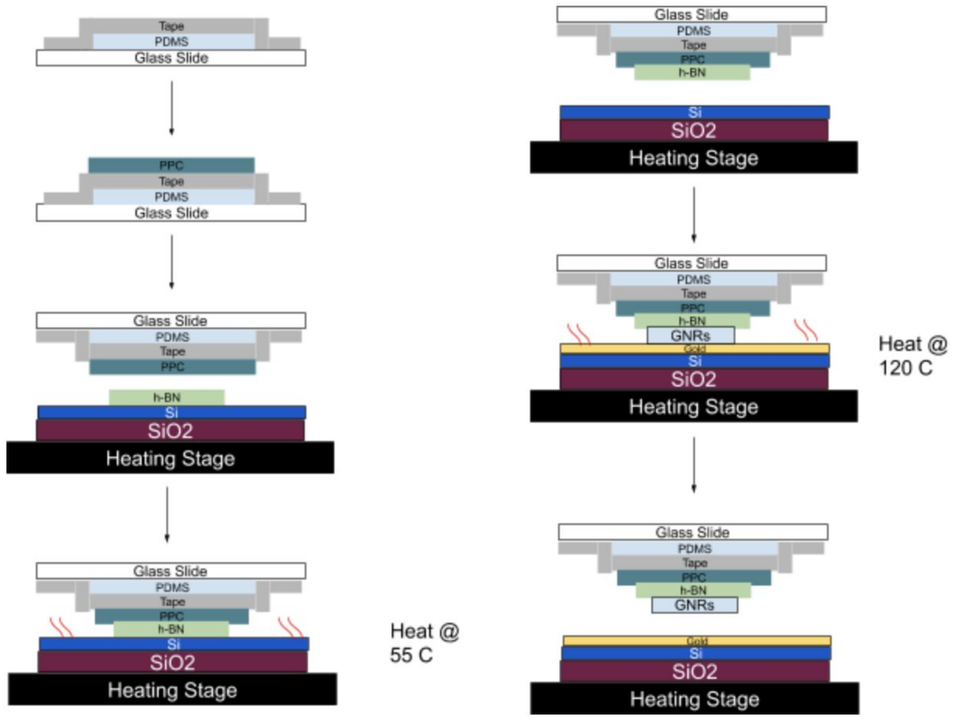
a, STM image of 7-GNR
b, Threefold GNR junction obtained from 1,3,5-tris(4''-iodo-2'-biphenyl) benzene monomer
c, Schematic model of junction fabrication
d, Model (blue, carbon; white, hydrogen) forming junction[2]

Transfer Procedure

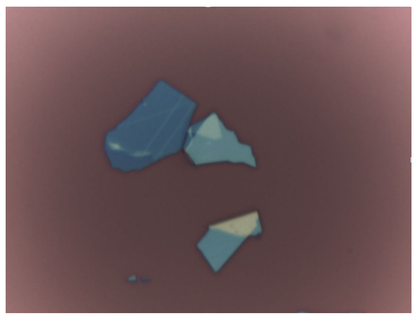
Create a PPC-PDMS -Clear Tape stack

Transfer h-BN on stack

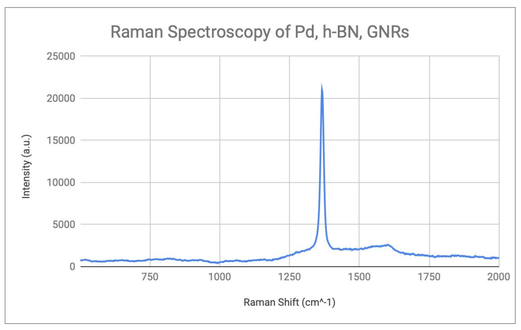
Use temperature controls and Van der Waals forces to pick up GNRs

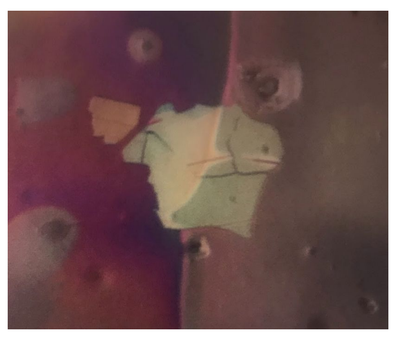


Results

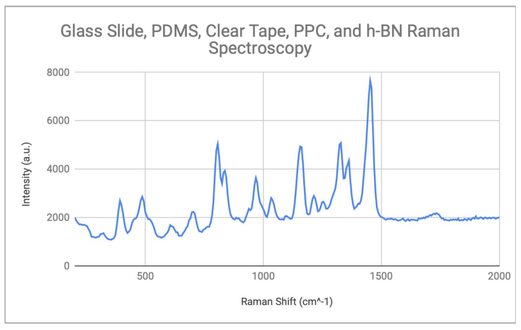


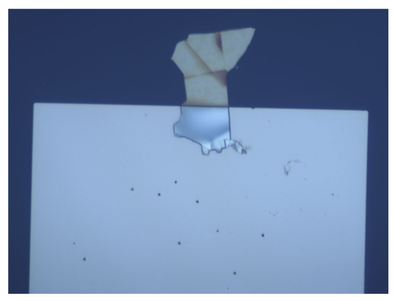
Optical image of hexagonal boron nitride flake



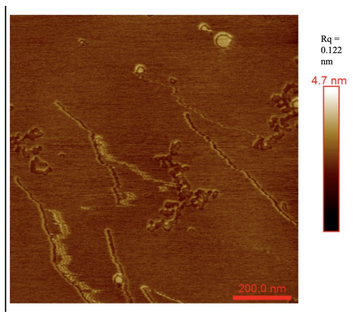


Optical image of h-BN during pickup process

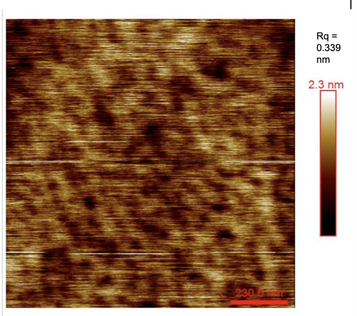




Optical image of h-BN on Pd material after transfer process



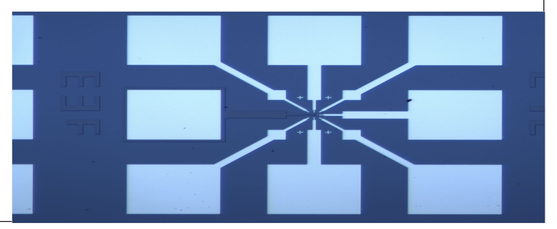
AFM of h-BN flake (front)



AFM of h-BN flake (back)

Future Work

- Characterize the density, uniformity, yield, and producibility of the dry-transfer procedure on the hexagonal boron nitride surface
- Measure the electronic responses of the of the dry-transferred GNRs through transport and optical spectroscopy



References

[1] Bennet, P. et al. Bottom-up graphene nanoribbon field-effect transistors. Applied Physics Letters (2013).
[2] Cai, J. et al. Atomically precise bottom-up fabrication of graphene nanoribbons. Nature 466, 470–473 (2010).
[3] Llinas, J. et al. Short-channel field-effect transistors with 9-atom and 13-atom wide graphene nanoribbons Nature Communications (2017).

Acknowledgements

I would like to thank Zafer Mutlu for his excellent mentorship; Nicole and Kimmy for their exceptional stewardship of the program; Professor Jeff Bokor; Center for Energy Efficient Electronics; and the Transfer-to-Excellence REU program for providing this formative experience.

Contact Information
Safi Mohammed
Email: safiii.m7@gmail.com
Cell: 510-449-6885

Support Information
This work was funded by
National Science Foundation
Award #1757690