Fabrication of Graphene and Hexagonal Boron Nitride(h-BN) heterostructures

Narith Chan, Said Ortega, Eric Corona-Oceguera, Kenji Watanabe, Takashi Taniguchi and Claudia Ojeda-Aristizabal

Department of Physics and Astronomy, California State University, Long Beach

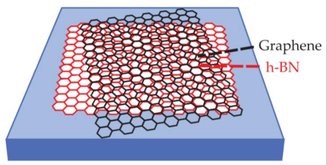
Research Center for Electronic and Optical Materials, National Institute for Materials Science, 1-1 Namiki, Tsukuba 305-0044, Japan

Abstract:

Graphene and hexagonal boron nitride (h-BN) are two-dimensional materials with unique structural and electronic properties. We exfoliated graphene and h-BN monolayers on silicon wafers using a tape transfer method. The wafers were cleaned with compressed air and heated to 180°C to 220°C before exfoliation. We have a tape with thin flakes of graphite, onto which we apply the wafers, after a short while at a high temperature. Due to its thinness, monolayer graphene looks nearly transparent and requires careful inspection of a wafer through the microscope. Once a flake of decent size is found (at least 10 μm), it is further verified through Raman Spectroscopy, which reveals its characteristic graphene peak. This approach enables the successful isolation of monolayer graphene, which is then stacked onto h-BN to create a device that leverages the heterostructure's unique properties, such as high electron mobility.

Introduction:

Graphene is a two-dimensional monolayer of Carbon. It is arranged in a hexagonal honeycomb structure with a carbon atom at each lattice site. Graphene exhibits unique mechanical and electrical properties, ranging from its mechanical strengths to its high electrical conductivity. In 2004, Sir Andre Geim and Sir Kostya Novoselov found a method to isolate a monolayer of graphene from a thick graphite using a simple tape exfoliation method. Hexagonal Boron Nitride (h-BN) is another A two-dimensional material composed of Boron and Nitrogen in a similar honeycomb structure. Unlike Graphene, h-BN is a non-conductor; however, if we place the monolayer graphene on top of h-BN, it will form a unique van der Waals heterostructure. The configuration enhances graphene's electronic and quantum properties by improving the electron Mobility thanks too the flat surface of h-BN and its capability of isolating charges from the SiO2 substrate.



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Methods:

This project focuses on exfoliating graphene and h-BN on a silicon dioxide wafer.

- Using Nitto blue tape (Nitto SPV224 PVC Surface Protective Film) to isolate thick bulk graphite and spread it around by folding and peeling multiple times (Mother tape).
- We cut another piece of tape and stick it on the mother tape, peel it slowly, and we get the baby tape.
- We cut the wafer into a square with a length of 1cm using a diamond-tipped scriber by drawing lines and applying pressure on the wafer to break it.
- Then, we clean the silicon wafer with Acetone, Methanol, and Isopropanol for 30 seconds each and evaporate the residue with compressed Nitrogen air.
- Start heating the silicon wafer from 180°C to 220°C for around 120 seconds.
- At this point, lift it from the heating plate and apply the wafer on the baby tape, then start exfoliating the monolayer of graphene by peeling the tape slowly for around 3-5 minutes.
- Similarly, we follow the same process for h-BN, but we heat it at a temperature of approximately 150 °C for around 120 seconds.

Results:

The silicon wafer containing countless thick crystals is placed on the glass slide, and we observe the thin layer of graphene through an optical microscope. A graphene monolayer is transparent and difficult to detect. The magnification should be 50x or 100x to ensure better visibility of the sample. The figures below show different pictures of each layer of graphene and h-BN at 50x and 100x. Notice that the color of the graphene changes depending on the thickness of the crystal. We are observing a huge monolayer or bilayer with a length of more than 15 μm to ensure that we can insert electrodes along its length. Each electrode has a length of 2 μm, and the separation between each electrode must be around 1 μm. Therefore, high-quality graphene can be transferred on top of h-BN to create a nanoelectronics device for advanced applications.

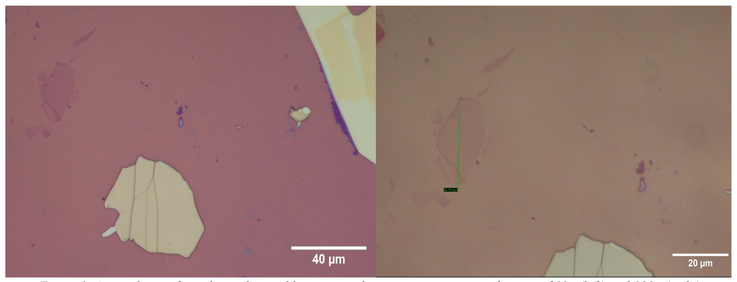


Figure 1. A monolayer of graphene observed by an optical microscope at a magnification of 50x (left) and 100x (right)

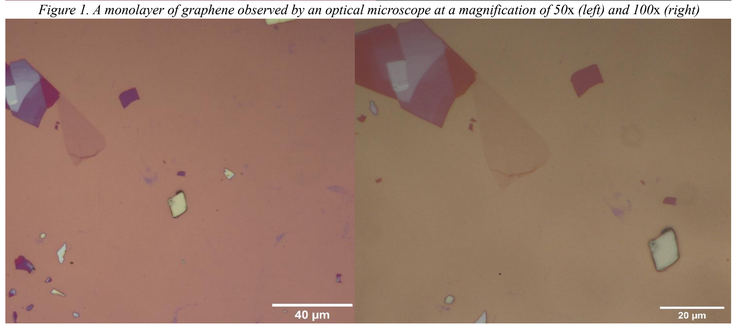


Figure 2. ABilayer of graphene observed by an optical microscope at a magnification of 50x (left) and 100x (right)

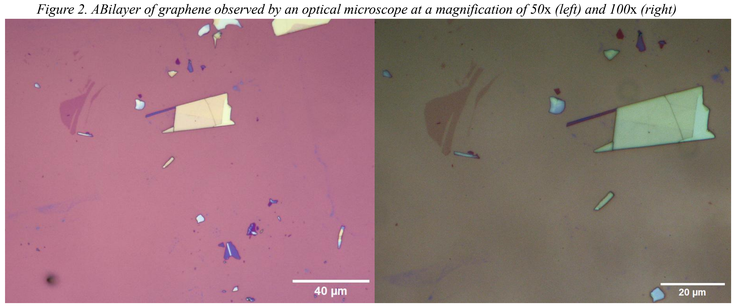


Figure 3. A Tri-layer of graphene observed by an optical microscope at a magnification of 50x (left) and 100x (right)

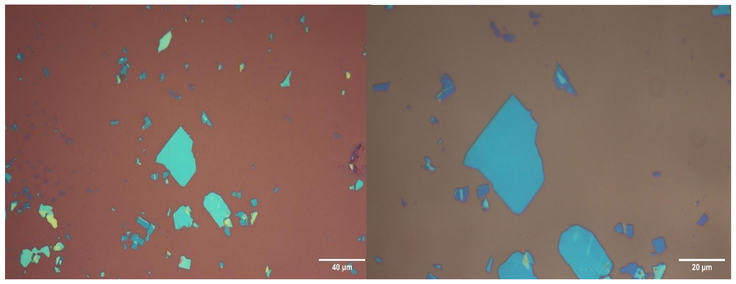


Figure 4. A thick layer of h-BN observed by an optical microscope at a magnification of 50x (left) and 100x (right)

How do we determine the layer of each crystal that we observed? We can't determine the layer of graphene accurately based on looking at its transparency. In this project, we focus on checking its layer and properties by using a method called Raman Spectroscopy, in which each layer of graphene has different characteristics and properties. We can determine the number of graphene layers by comparing the G peak at k = 1600 cm-1 and the 2D peak at k = 2700 cm-1. A software called "WiTec project 6.1" will be used to perform the Raman Spectroscopy. For graphene, we use a laser with a 532 nm wavelength and a laser power of 3 mW. The grating for graphene is 600g/mm, BLZ 500.00nm. Also, the wave number of the laser is 799.8/cm. We can perform a single spectrum, a line scan, or an area scan on a sample. The figures below show the Raman spectra of monolayer, bilayer, and trilayer of graphene. It is shown that for a monolayer, the G peak is peaks are equal, and the G peak is higher than the 2D peak for a trilayer of graphene. Similarly, the Raman spectra of h-BN show an E_2g peak at k=1350/cm. Using this method, we can distinguish different layers of graphene accurately.

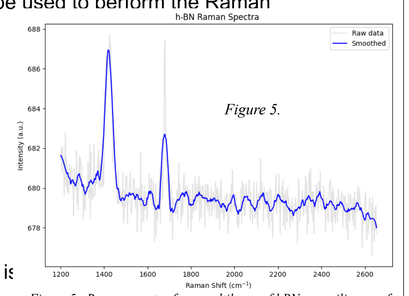


Figure 5. Raman spectra for a multilayer of hBN on a silicon wafer.

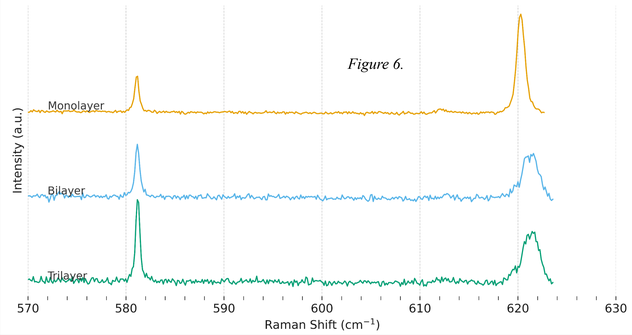


Figure 6. Comparison of Raman spectra for monolayer, bilayer, and tri-layer graphene layers

Conclusions:

The electronic properties of a graphene and h-BN structure are useful for advanced applications. After fabricating high-quality graphene and h-BN, we stack the graphene on top of h-BN to produce a high-mobility device. We were able to successfully exfoliate different layers of graphene and h-BN using the tape method, and we confirmed their thickness through RAMAN Spectroscopy. The h-BN provides a stable and uniform platform to isolate the graphene. The electronic properties of graphene improve once stacked onto h-BN, which reduces scattering and preserves the high electronic mobility. This project helps further the data on graphene conductivity and viability in superconductive applications. In future work on this project, we will create electrode patterns on the sample using the QCADs design and the technique called Electron Beam Lithography. Using our samples, we will explore the effects of phthaloayanine molecules on the coherent electronic transport of monolayer graphene.

Acknowledgements:

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