

Growth of Boron Nitride for Two-Dimensional Applications

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Abstract:

Boron nitride (BN) is an isoelectronic compound similar to carbon that is sometimes referred to as white graphene. It has several applications due to its excellent chemical properties and thermal stability. BN has weak van der Waals forces between its layers which makes it, like graphene, an excellent self-lubricant. However for certain applications, including but not limited to space applications, it is preferable to graphene. The objective of this project was to grow BN on thin substrates using a horizontal chemical vapor deposition (HCVD) system under high temperatures and pressures. Our precursors were diborane (B_2H_6) and ammonia (NH_3), while our substrates were sapphire ($\alpha-Al_2O_3$) and silicon carbide (SiC). After growth, these samples were characterized using Raman spectroscopy, atomic force microscope (AFM), and the scanning electron microscope (SEM).

Introduction:

Boron nitride (BN) is a compound that is isoelectronic to carbon; instead of carbon atoms, its lattice structure contains an equal number of boron and nitrogen atoms. It can be found in three different forms: nanosheets (BNNS), nanoribbons (BNNR), and nanomeshes (BNNM). There are four different types of BN; amorphous (α -BN), cubic (c-BN), wurtzite (w-BN), and hexagonal (h-BN).

This project mainly focused on h-BN, because it's the most stable form of BN. Its structure is similar to graphene, hence h-BN is sometimes referred to as white graphene. h-BN has strong covalent bonds between the boron and nitrogen atoms with weak van der Waals forces between its layers. This makes it an excellent lubricant with applications in cosmetics and bullet coating, and several space applications.

Using diborane and ammonia as our precursors, we attempted to grow BN on sapphire and silicon carbide substrates. Growing BN is a difficult process, thus several different methods were used to achieve our objectives.

Experimental Procedures:

First, we had to cut the $\alpha-Al_2O_3$ into smaller sizes. We used an available laser with a 1050 nm wavelength. Ideally, to cut through $\alpha-Al_2O_3$, a laser of wave length 1070 nm is require. We were unable to cut through the material, but the laser produced several striations on the back part of the whole sample. This sufficiently weaken the material allowing us to complete the cutting process with diamond tip scribes. The samples were then cleaned using standard RCA cleaning procedures.

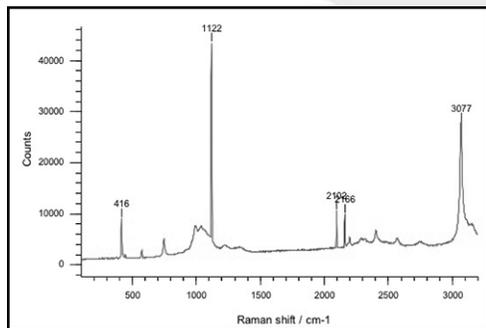


Figure 1: HCVD system. Temperatures can go as high as 1800°C and pressures as high as 400 Torr. (See full color version on page xxxvi.)

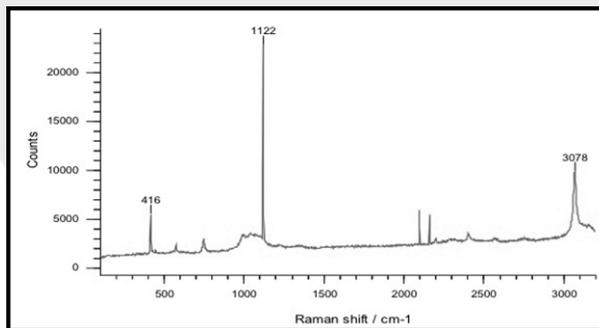
Next was the growth process where we used a horizontal chemical vapor deposition system (HCVD). The HCVD system allowed us to grow several samples on different substrates using different precursors. As you can see in Figure 1, there is a coil-like structure around the furnace that produces electromagnetic fields, which in turn creates a current that allows the device to heat up to temperatures as high as 1800°C. Pressures of about 400 Torr were also observed.

Methods and Results:

Several attempts to grow BN were made without success. We varied many of the parameters (for instance, time, amount of each precursor, and etching time) but were unable to



Graph 1: No-growth sapphire sample.



Graph 2: Sapphire growth in 1050°C.

successfully grow graphene. We used temperatures at 1000°C and 1050°C with a growth time of 15 minutes and 30 minutes. The precursor values differed from 10 sccm to 100 sccm for diborane, and 180 sccm to 200 sccm for ammonia with 9 slm for hydrogen. After each growth period, the samples were observed using Raman spectroscopy. The expected value for BN is about 1300 cm^{-1} and our results showed Raman graphs with 1122 cm^{-1} peaks. With this device, it was very easy to determine if the parameters we used produced expected results. Before using the Raman spectroscopy, we scanned a normal sample and compared it to that of a sample after growth; as you can see in Graphs 1 and 2.

After several attempts and additional research, we determined that having a longer growth period and higher temperatures would probably help us achieve our goal. We also characterized our samples using SEM and AFM systems. In the SEM, we used the energy dispersive spectroscopy (EDS) to determine what was on the samples' surfaces after growth. The sapphire samples showed evidence of aluminum and oxygen and the SiC showed evidence of silicon and oxygen. An AFM was used to compare the surfaces of our samples to that of previous research.

Conclusions and Future Steps:

After several attempts, there was no evidence of BN on any of the substrates. The Raman shift of a clean substrate was exactly the same as that of a substrate upon which growth had been attempted.

The next step towards growing BN on sapphire is to use other precursors instead of diborane, such as triethylboron.

Using this precursor would require using a metalorganic chemical vapor deposition system because triethylboron is a metalorganic substance. We could also continue to extend the growth period and increase the temperature.

Acknowledgments:

I would like to thank Mr. Crawford Taylor, Dr. William Rose, Dr. Gary Harris, Gurpreet Kaur, Mr. James Griffin, the Howard Nanoscale Science and Engineering Facility, and the National Nanotechnology Infrastructure Network Research Experience for Undergraduates (NNIN REU) Program.

References:

- [1] Bresnehan, S. Michael. Prospects of Direct Growth Boron Nitride Films as Substrates for Graphene Electronics. <http://arxiv.org/pdf/1310.1870.pdf>.
- [2] Cubarovs, Mihails. CVD growth of sp²-hybridized boron nitride using aluminum nitride as buffer layer. 2011. <http://iu.diva.portal.org/smash/get/diva2:467821/FULLTEXT01.pdf>.
- [3] Ismach, Ariel. Toward the Controlled Synthesis of Hexagonal Boron Nitride Films. 18 June 2012. <http://pubs.acs.org/doi/abs/10.1021/nn301940k>.
- [4] Paduano, Qing. Self-terminating growth in hexagonal boron nitride by metal organic chemical vapor deposition. 9 June 2014. <http://m.iopscience.iop.org/1882.0786/7/7/071004/article>.
- [5] Senthilingam, Meera. Boron Nitride. 17 December 2013. <http://www.rsc.org/chemistryworld/2013/12/boron-nitride-podcast>.

