OPTIMIZED SYNTHESIS BY CHEMICAL VAPOR DEPOSITION OF ATOMIC LAYER HEXAGONAL BORON NITRIDE

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Hexagonal boron nitride (*h*-BN) is a two dimensional material complementary to graphene that can be used to engineer devices with unusual electrical and optical properties such as high mobility electron transistors and far ultraviolet light emitting diodes. Recently, atomic layers of graphene with *h*-BN have been grown using chemical vapor deposition (CVD). CVD also produces high quality *h*-BN films that are thin, uniform, and continuous. Although *h*-BN films of two atomic layers have been demonstrated using CVD, we endeavor to produce monolayer *h*-BN. We optimized CVD synthesis of *h*-BN on copper foil with ammonia borane as the precursor. The *h*-BN was characterized by Raman spectroscopy, atomic force microscopy, and transmission electron microscopy. Scalable synthesis of monolayer *h*-BN films using CVD, which can produce *h*-BN in large quantities at low costs, has the potential to galvanize further research in graphene electronics and the production of optoelectronic devices in industry.

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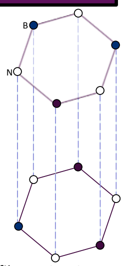
Background — Hexagonal Boron Nitride

What is hexagonal boron nitride (h-BN)?

- Structurally similar to graphite
- Insulator with a large bandgap up to 5.9 eV
- Possesses many attractive properties such as having a low dielectric constant, high temperature stability, and high hardness

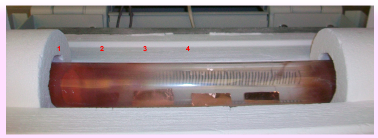


What is chemical vapor deposition (CVD)?

- Process of chemically reacting a volatile compound of desired material, with other gases, to produce a nonvolatile solid that deposits on a substrate
- Produces high quality h-BN in large quantities at low costs

Goal: To optimize the synthesis of h-BN films using CVD, thereby facilitating the paradigm shift from silicon based electronics to next generation graphene electronics

Methods — Growth and Transfer of h-BN

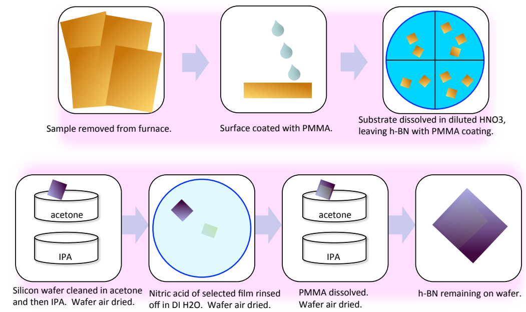


Growth conditions

- boron nitride precursor: ammonia borane (H_3NBH_3)
- Low Pressure: 500 millitorr
- Carrier gas: Argon/Hydrogen
- Growth temperature: 980 °C

Variables

- Growth time, 10 min. – 50 min.
- heating belt temperature, 100 °C – 190 °C
- Cooling: fast or slow
- Substrate: Cu and Ni



Results — Characterization of h-BN

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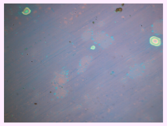
Starting parameters
Heating belt: 150.0 °C
980 °C for 40 min.
Slow cooling



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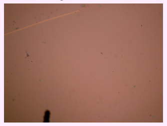
Reproduced Experiment*
Multistep heating: 600 for 20 min.
Heating belt: 120.0 °C
1000 °C for 30 min.
fast cooling



*Shi, Y. M.; Hamsen, C.; Jia, X. T.; Kim, K. K.; Reina, A.;Hofmann, M.; Hsu, A. L.; Zhang, K.; Li, H. N.; Juang, Z. Y.; Dresselhaus, M. S.; Li, L. J.; Kong, J. Synthesis of Few-Layer Hexagonal Boron Nitride Thin Film by Chemical Vapor Deposition. Nano Lett. 2010, 10 (10), 4134–4139

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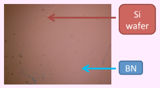
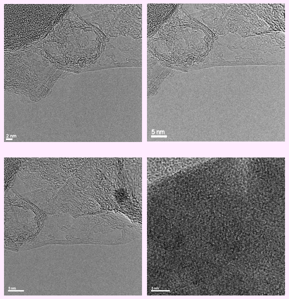


063011I Optical image, 50x

Heating belt: 125.0 °C
980 °C for 40 min.
fast cooling

TEM



Number of layers and lattice structure of sample is visible under transmission electron microscopy.

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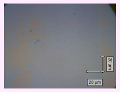
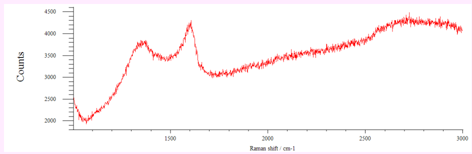
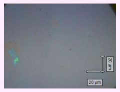
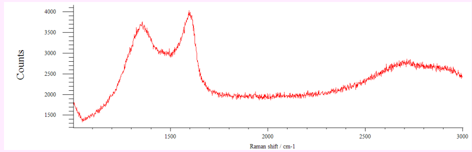
Heating belt: 175.0 °C
980 °C for 40 min.
fast cooling



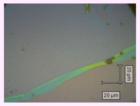






Raman spectroscopy peaks occur at literature value of ~1370 cm^{-1}.

Nickel Foil Substrate



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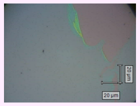

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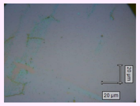

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Conclusion — Analysis and Future Work

Analysis

- Thin and continuous h-BN films were obtained.
- Although monolayer films were not synthesized, two layer h-BN films were grown as shown in the TEM images.
- Repetitions of experiments with the same parameters produced different results.
- Impurities may have arisen during the transfer process.

Future Work

- More experiments need to be conducted in order to grow h-BN films of controllable thickness.
- It has been recently shown by that h-BN is complementary to graphene.* Growth of h-BN on patterned graphene using CVD is ongoing.

*Liu, Z., et al. Direct Growth of Graphene/Hexagonal Boron Nitride Stacked Layers. *Nano Lett.*, 2011, *11* (5), pp 2032–2037

Acknowledgements

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