Optimization of Hexagonal Boron Nitride Synthesis

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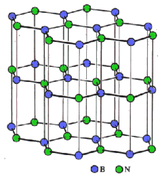
Abstract: Graphene, a two-dimensional (2D) material, has been discussed as the next-generation electronics rather than silicon. Due to graphene's high conductivity, graphene is required to be interfaced with other 2D materials to truly enable 2D nanodevices. Boron nitride (BN), a 2D insulator, has been identified as a promising substrate that improves graphene based devices. Although BN has been successfully synthesized by chemical vapor deposition (CVD), the mechanism of boron nitride synthesis can still be optimized. This study investigates the role of hydrogen in synthesis hexagonal boron nitride (hBN). Scanning electron microscope (SEM) is used to characterize the samples and full coverage of hBN is observed on all samples with different sizes of multilayer hBN.

Background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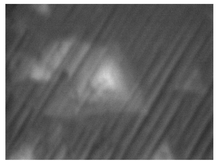
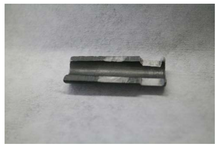
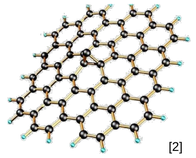
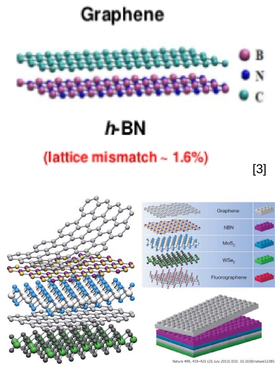





[2]

Boron nitride has many attractive properties:
1: 2D insulator
2: Atomic flatness
3: High electrical resistivity
3: High thermal conductivity
4: Low dielectric constant
5: Large optical bandgap
6: Lack of dangling bonds

Motivation



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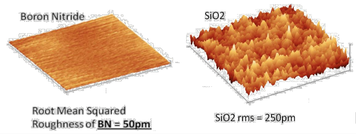
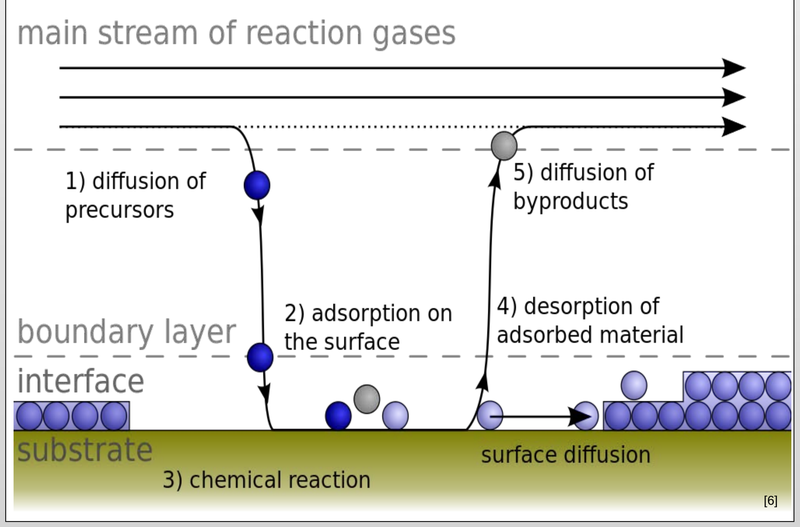
Graphene devices are traditionally built on standard silicon dioxide substrates but the combination sets many limits on the intrinsic properties of graphene. Hexagonal boron nitride (hBN), a two-dimensional insulating material, has been identified as a better alternative that improves graphene-based devices. To have a natural complementary dielectric layer, graphene can be stacked using hBN similar to how silicon has silicon dioxide.



[5]

Chemical Vapor Deposition (CVD)



[6]

Results and Analysis

20 scc/m Hydrogen flow

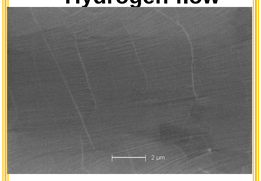


Figure 1: 15 mins of growth

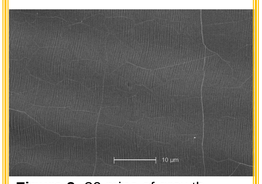


Figure 2: 30 mins of growth

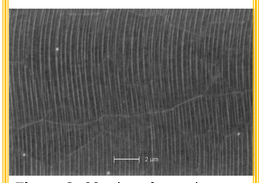


Figure 3: 60 mins of growth

50 scc/m Hydrogen flow

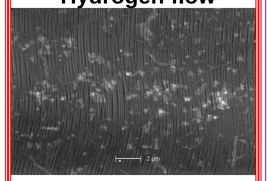


Figure 4: 15 mins of growth

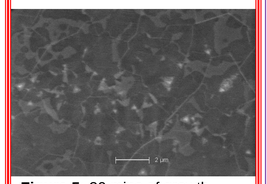


Figure 5: 30 mins of growth

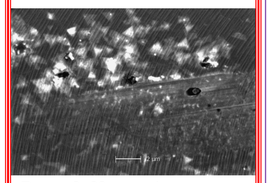


Figure 6: 60 mins of growth

100 scc/m Hydrogen flow

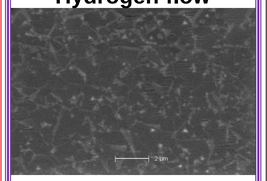


Figure 7: 15 mins of growth

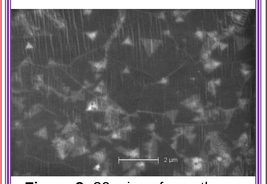


Figure 8: 30 mins of growth

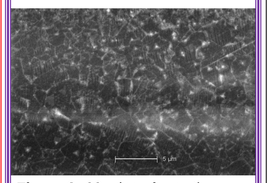


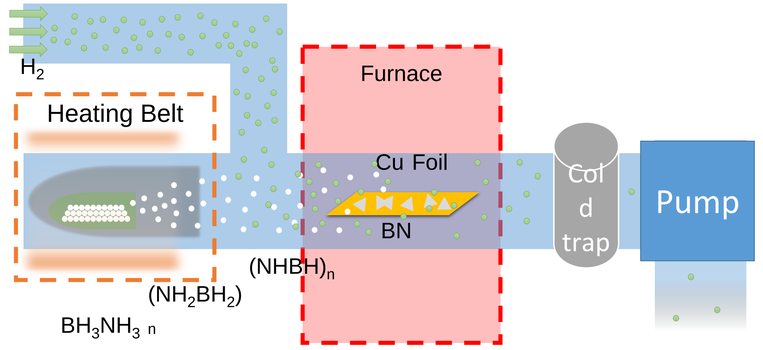
Figure 9: 60 mins of growth

- Full coverage of BN is dominating all the samples.
- Hydrogen etches the edges of BN, which allows the second layer of BN to grow underneath.
- With minimal hydrogen flow (20 scc/m), single layer and full coverage hBN can be observed. With large amounts of hydrogen flow (50 scc/m and 100 scc/m), larger multilayer hBN is formed.

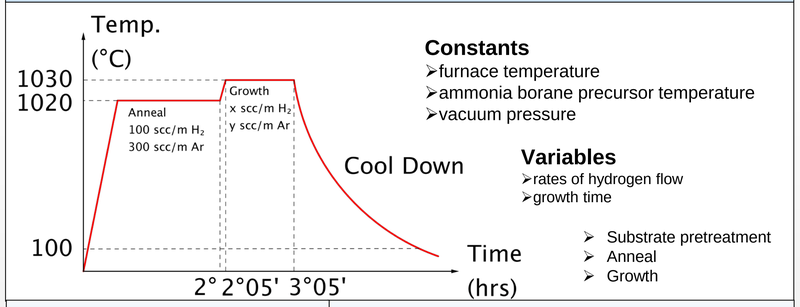
The BN samples above are characterized by scanning electron microscope (SEM) and the sizes of each BN sample are measured

Gas flow ▶ / Time ▼	20 scc/m H_2 80 scc/m Ar	50 scc/m H_2 50 scc/m Ar	100 scc/m H_2 0 scc/m Ar
15 mins	Full Coverage	0.25μm^2	0.29μm^2
30 mins	Full Coverage	0.42μm^2	0.65μm^2
60 mins	Full Coverage	0.53μm^2	0.98μm^2

Method



hBN Growth Temperature Profile



Constants
- furnace temperature
- ammonia borane precursor temperature
- vacuum pressure

Variables
- rates of hydrogen flow
- growth time

- Substrate pretreatment
- Anneal
- Growth

Future Steps

- Investigate the role of cooling rate in synthesis of boron nitride.
- Program precursor temperature controller to prevent itself from overshooting.

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References

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[2] Image courtesy of Internet, http://image.baidu.com/search/redirect?tn=redirect&word=j&juid=23EFD2&sign=cibaacgiwc&url=http%3A%2F%2Ftupian.hudong.com%2Fs%2F%25E7%259F%25B3%25E5%25A2%25A8%25E7%2583%25AF%2Fxgtupian%2F1%2F1&objurl=http%3A%2F%2Fa0.att.hudong.com%2F41%2F58%2F01300001227198134266581940827.jpg
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