Optimization of Hexagonal Boron Nitride for 2D Electronics

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Abstract

The 2D insulator hexagonal boron nitride (hBN) has been highly researched for its exceptional thermal conductivity, high tensile strength, and isostructural characteristics with graphene. However, the optimal parameters for its synthesis by chemical vapor deposition (CVD) have never been fully understood. This study investigated the relationship between precursor temperature and the growth of hBN for further synthesis. Raman spectroscopy and scanning electronic microscopy (SEM) were used to quantify the size, percent coverage, and number of layers of hBN. This research represents significant progress to optimize the precursor temperature for high-quality, large-scale hexagonal boron nitride for potential 2D nanoelectronics and other 2D nanodevices.

Introduction

- hBN has profound and distinct properties:
  1. One-atom thickness
  2. Exceptional thermal conductivity
  3. High in-plane mechanical strength
  4. High chemical stability
  5. High tensile strength (Young's modulus equivalent to diamond)
  6. Low dielectric constant (2-4)
  7. Strong electrical insulation (band gap - 5.97eV)

- Applications:
  1. Prospective transparent and flexible electronics
  2. Nanotransistors (heterostructures with graphene)

- These create a need for production of large-scale, high-quality hBN films

- Promising method: Chemical vapor deposition (CVD)

- The optimal parameters and fundamental growth mechanisms have not been extensively studied

- Here, we report the effects of controlling precursor temperature in CVD to study its impact on the growth of hBN

<table>
<thead>
<tr>
<th>Sample</th>
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<th>BNCu47</th>
<th>BNCu46</th>
<th>BNCu44</th>
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<tbody>
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<td>Tₒ (°C)</td>
<td>75</td>
<td>80</td>
<td>85</td>
<td>90</td>
</tr>
<tr>
<td>Percent coverage</td>
<td>10-20</td>
<td>60-80</td>
<td>100 (monolayer) (bilayer)</td>
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Figure 1 Table of precursor temperature vs. percent coverage of hBN

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Figure 2 SEM image of hBN domains with Tₒ at 75°C

Figure 3 SEM image of hBN domains with Tₒ at 80°C

Figure 4 SEM image of hBN domains with Tₒ at 85°C

Figure 5 SEM image of hBN domains with Tₒ at 90°C

Figure 5 Raman spectrum of bilayer BN with peak at ~1366 cm⁻¹

Figure 6 Raman spectrum of bilayer BN with peak at ~1366 cm⁻¹

Results

Methods

1. Pretreatment
   - Copper foil
   - Ammonia borane (H₃BNH₃)
2. Anneal
   - High-temperature furnace
   - Low pressure chemical vapor deposition (CVD)
3. Growth
   - Parameters

Conclusions

- Trend observed from the graphs and data collected:
  - Increasing Tₒ can effectively increase:
    - the nucleation density
    - the percent coverage on Cu
    - the number of layers of hBN grown

References


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Image

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