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Optimization of Vapor Phase Epitaxy for Thick Boron Nitride Films

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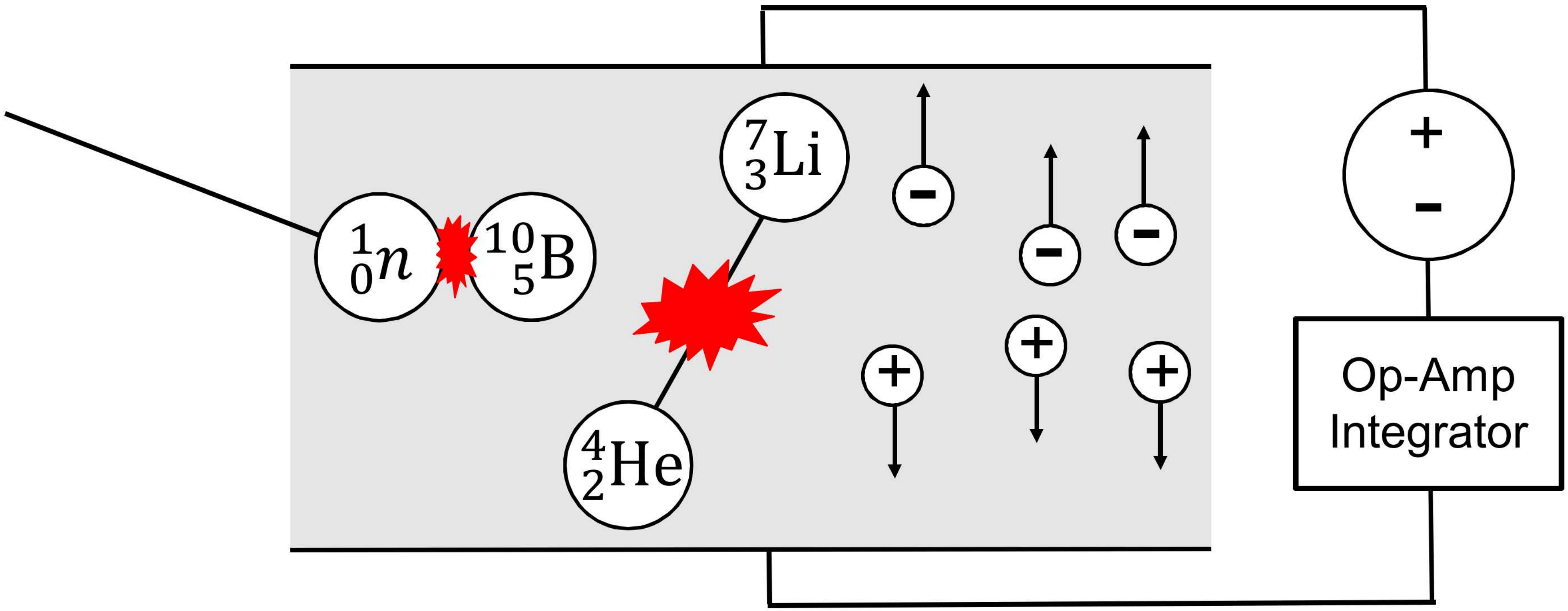
BN Neutron Detector



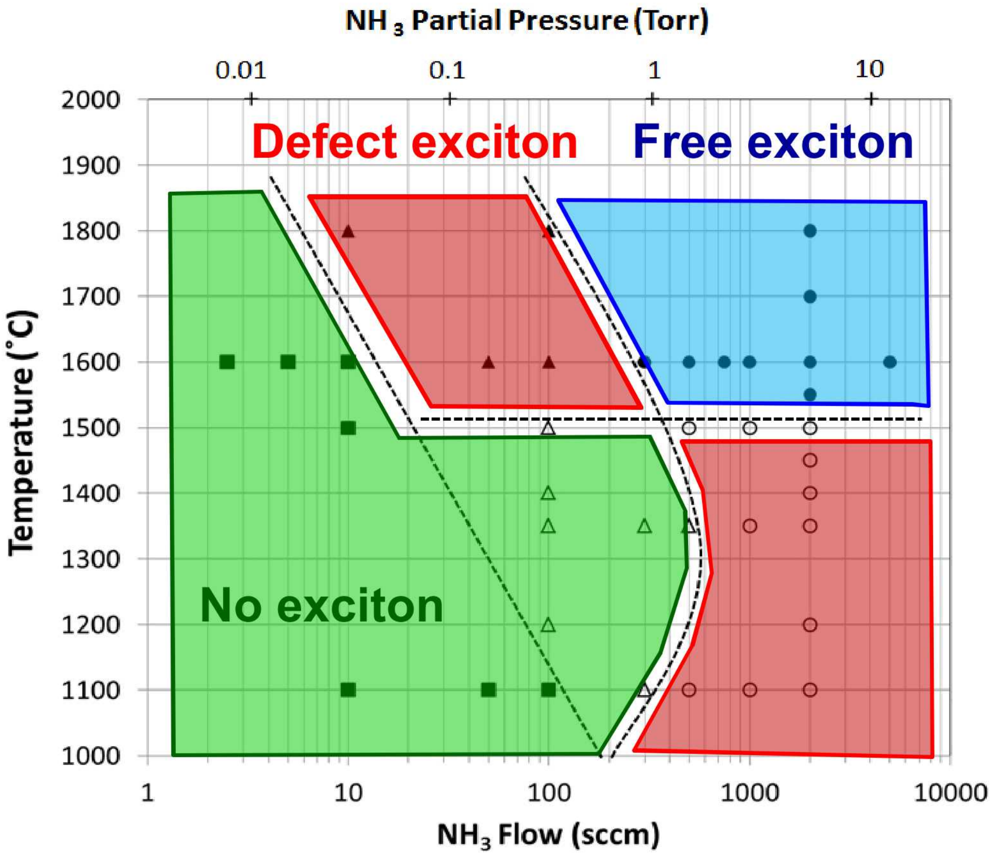
Reaction Chain for Detection

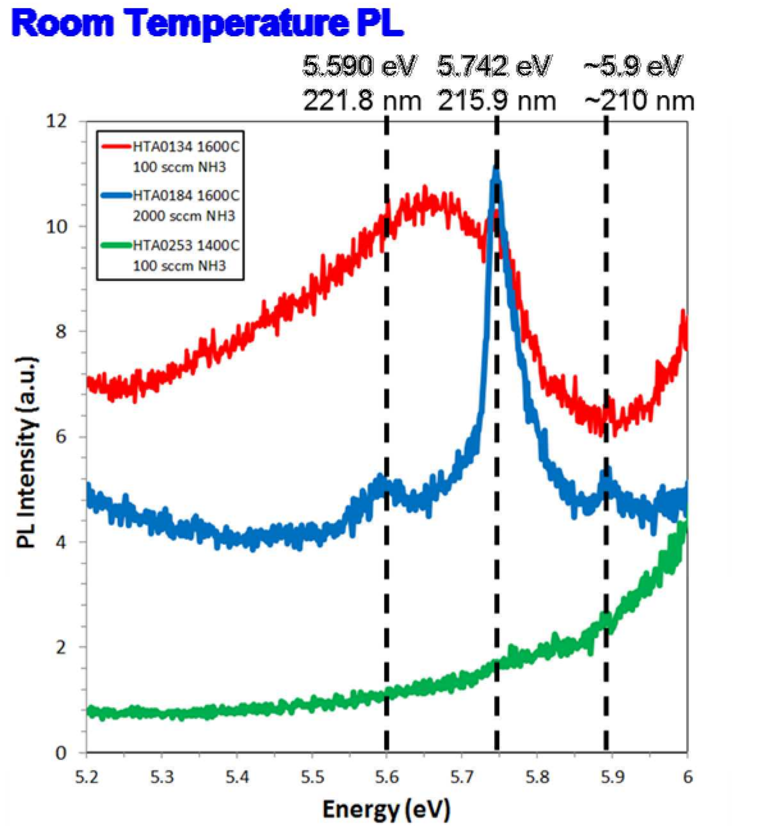
1. Neutron absorbed by ^{10}B
2. Li and He deposit ~2MeV of energy in BN
3. ~10^5 electron-hole pairs created
4. Charge is collected

Desirable Material Properties

- Large μτ: carrier mobility x life time
- Small leakage
- Thick film: ~100 um for 90% capture

Photoluminescence Regimes

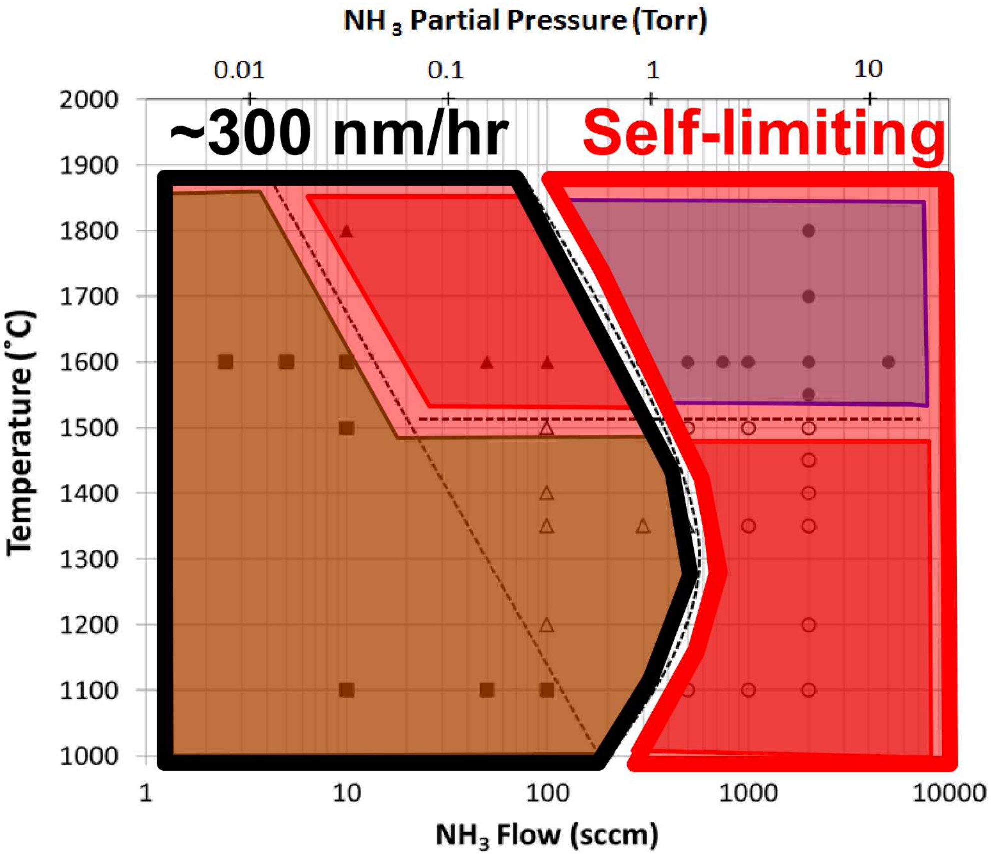


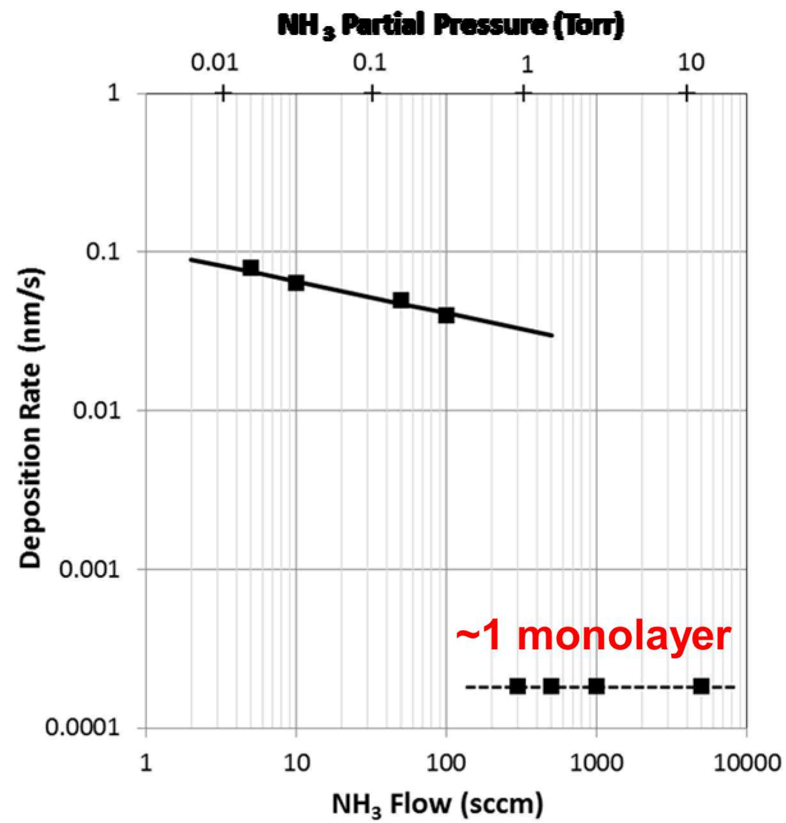


Room temperature free excitonic emission possible when growth combines high temperature and high NH3 flows

Rice et al., Journal of Crystal Growth, 485, 90, 2018.

Growth Regimes

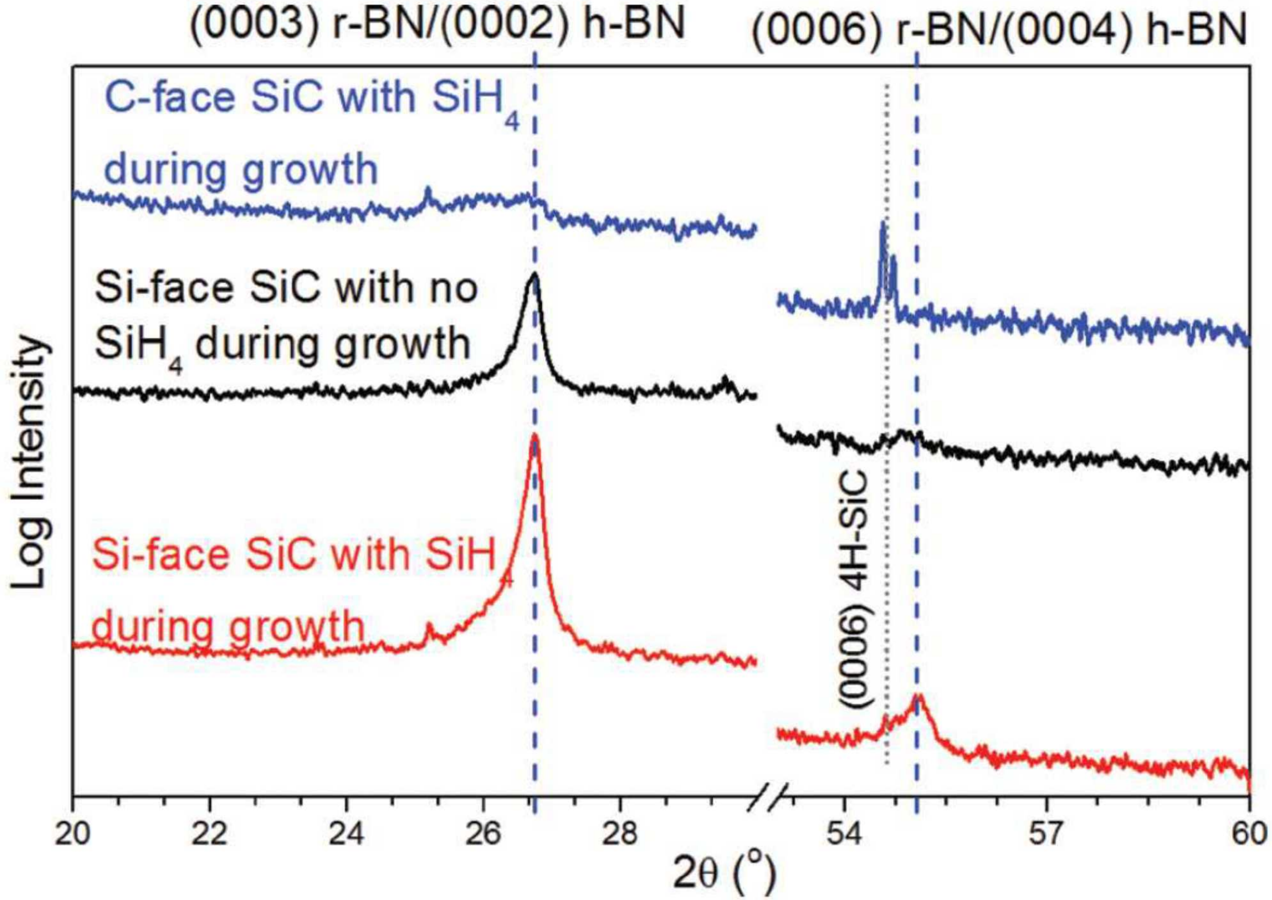




Conditions needed for free excitonic emission result in growth that self-limits at ~1 monolayer of BN.

Rice et al., Journal of Crystal Growth, 485, 90, 2018.

Si in sp2-BN

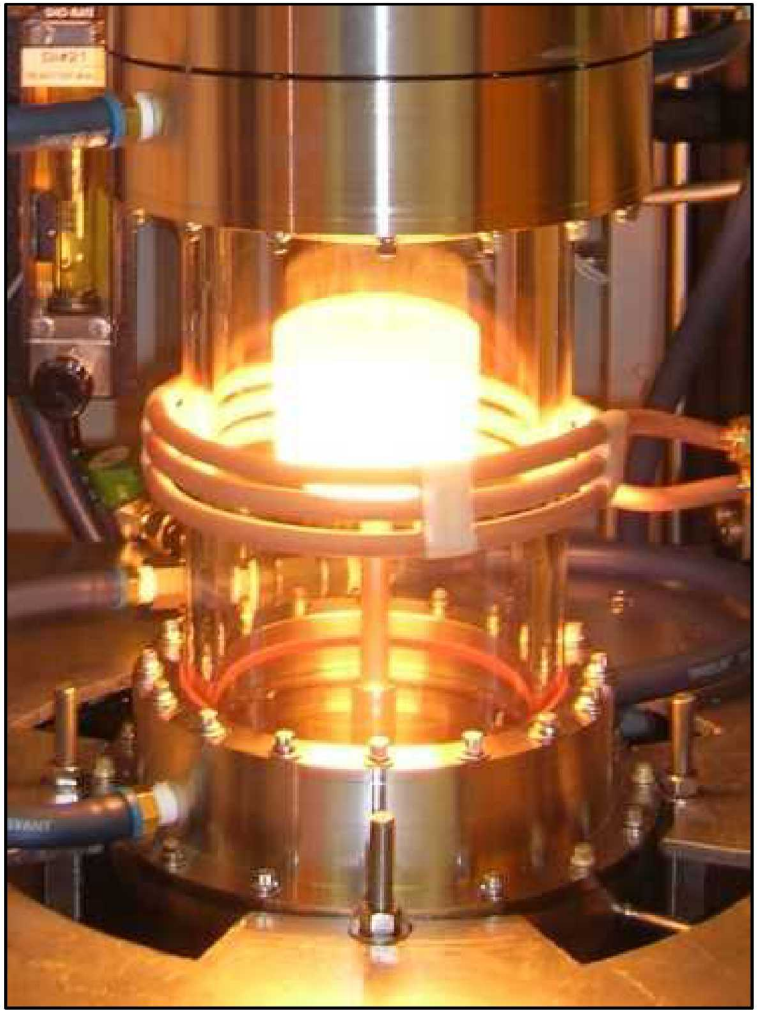


- **The addition of Si improves sp2-BN crystallinity**
  - **SiH_4/TEB molar flow ratio = 0.04**

Chubarov et al., CrystEngComm, 16, 5430, 2014.

Growth

The authors would like to thank Prof. Z. Sitar at NCSU for sharing reactor chamber design



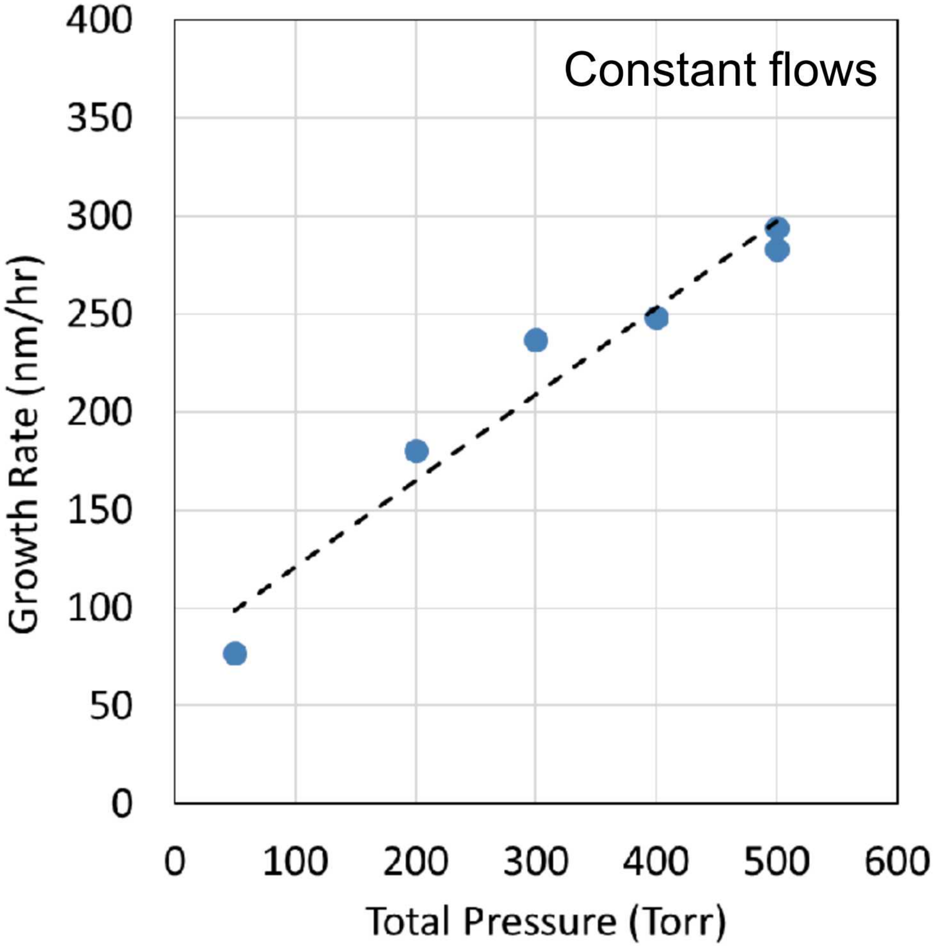
MOCVD System

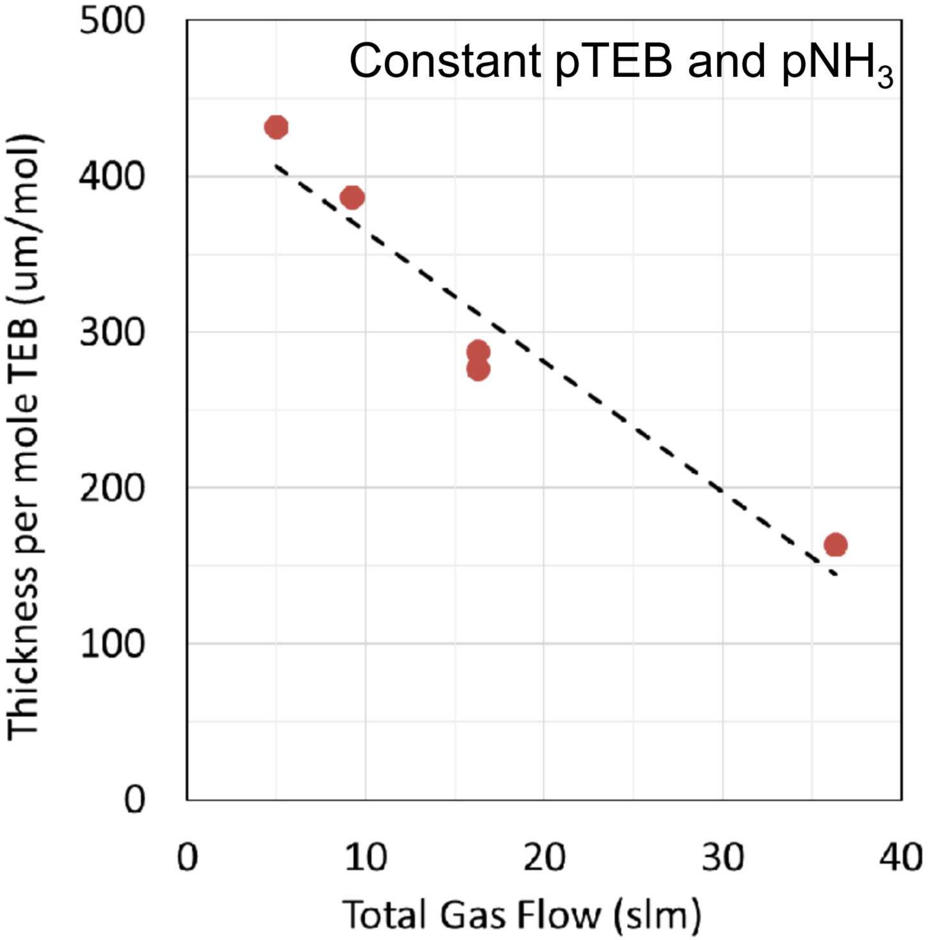
- Refitted Veeco D125 with new chamber
    - Cold walled, RF heated
    - Temperatures up ~1900 ˚C
- *In situ* reflectance monitor

Growth

- Sapphire or SiC substrates
- Triethylboron (TEB) and NH_3 precursors
- N_2 diluent and carrier gas
- SiH_4 for Si doping

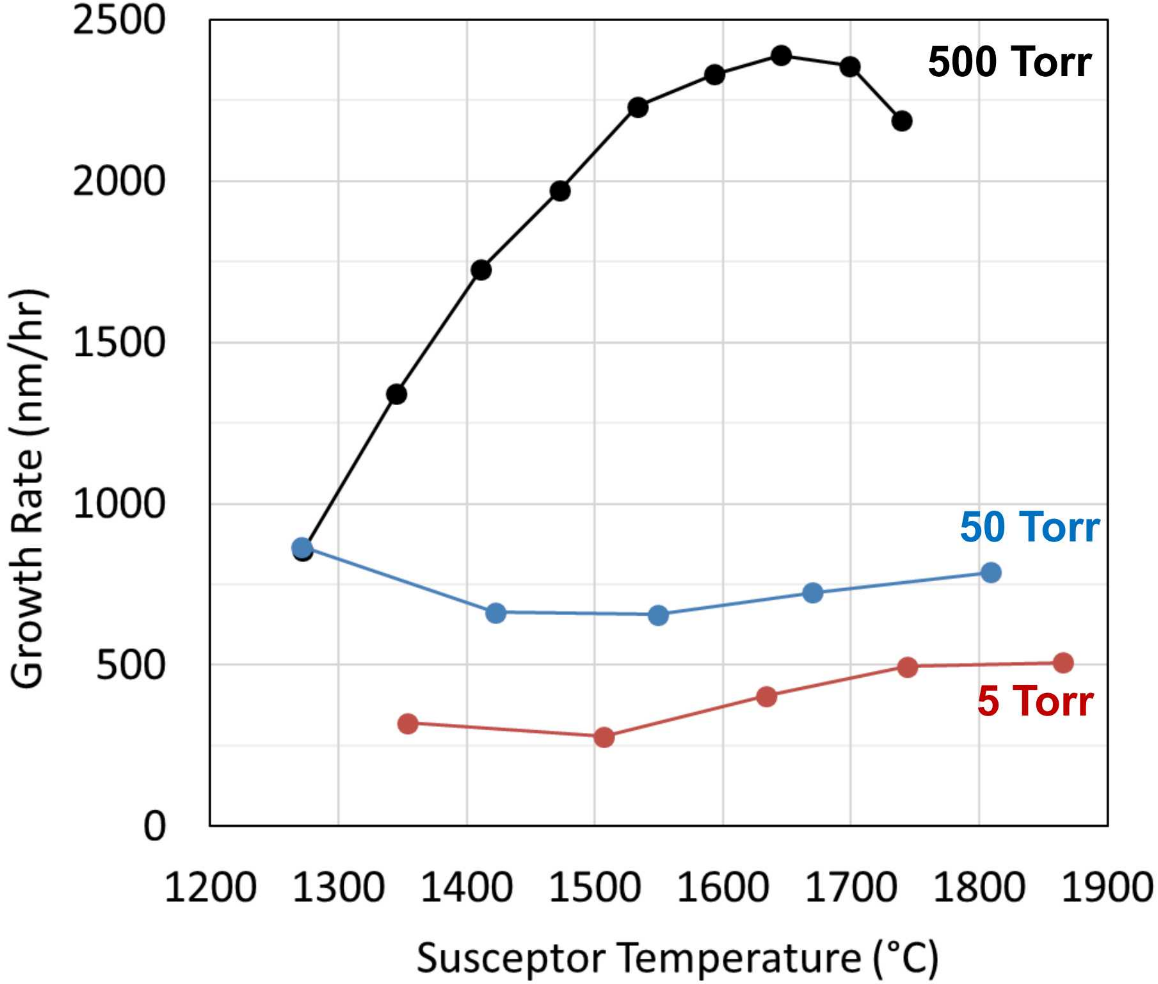
Survey of Growth Space





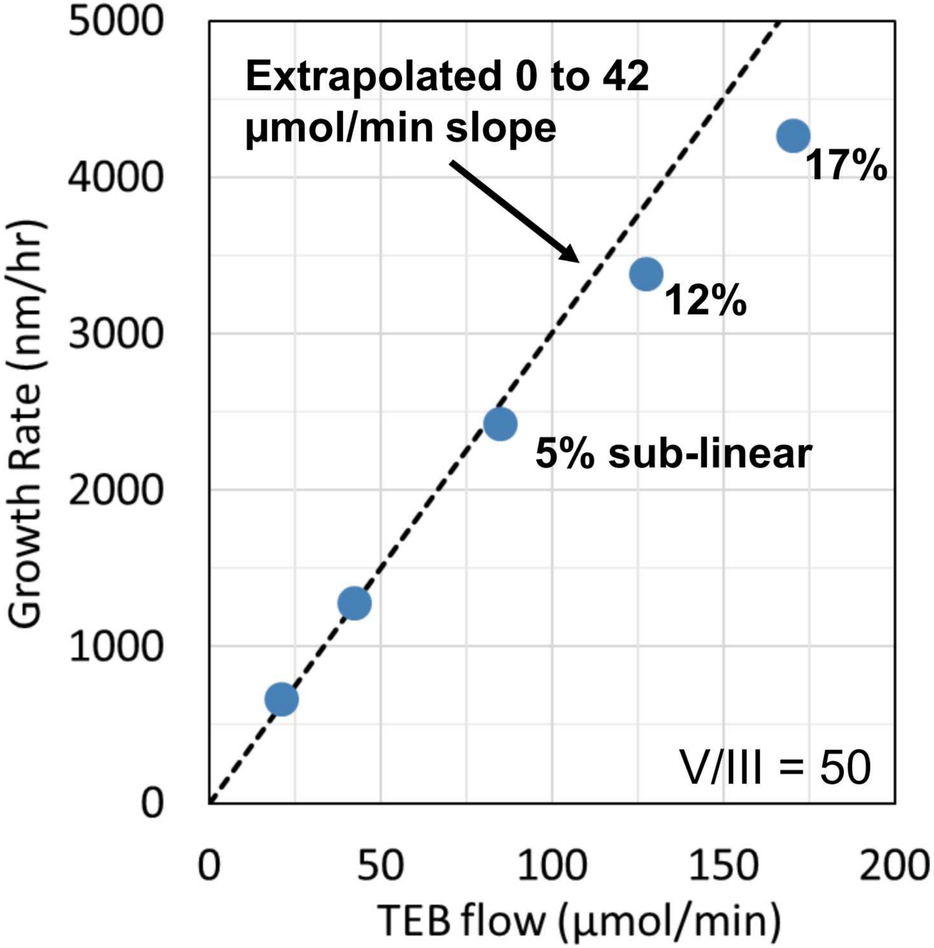
- **Increased growth rate with increased total pressure**
- **Increased TEB efficiency with decreased total flow**

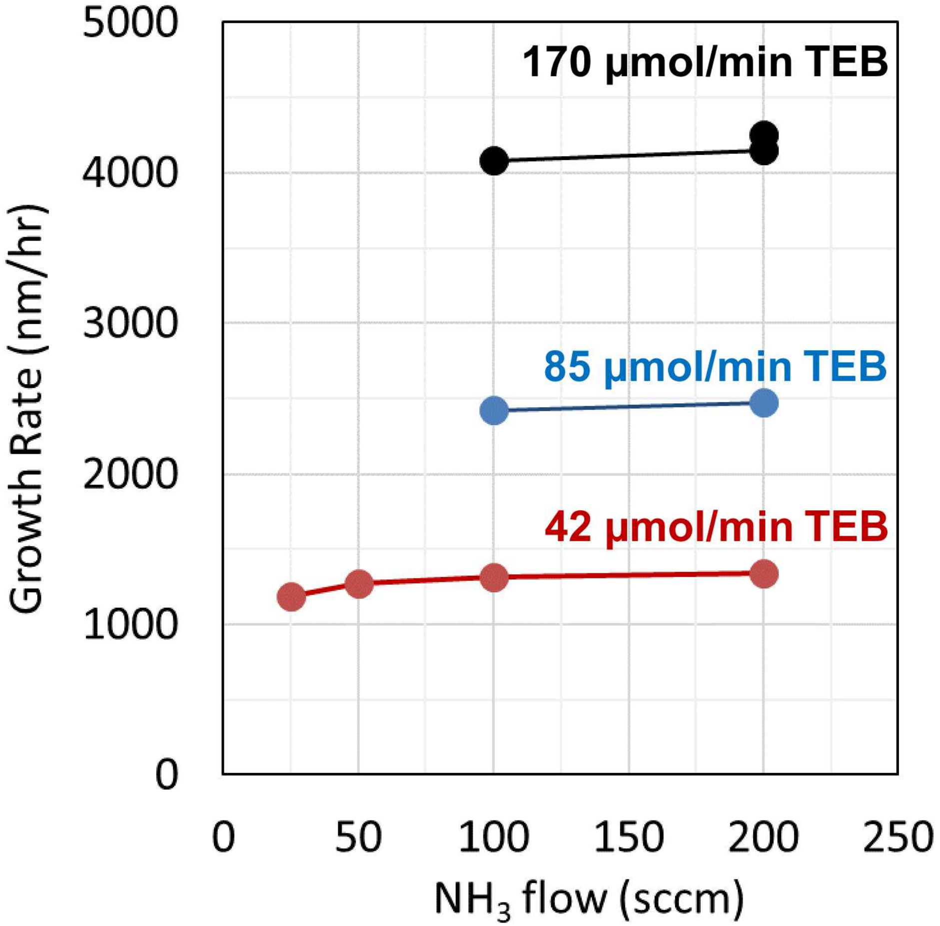
Survey of Growth Space



High temperature increases growth rate, but only at high pressure

Survey of Growth Space

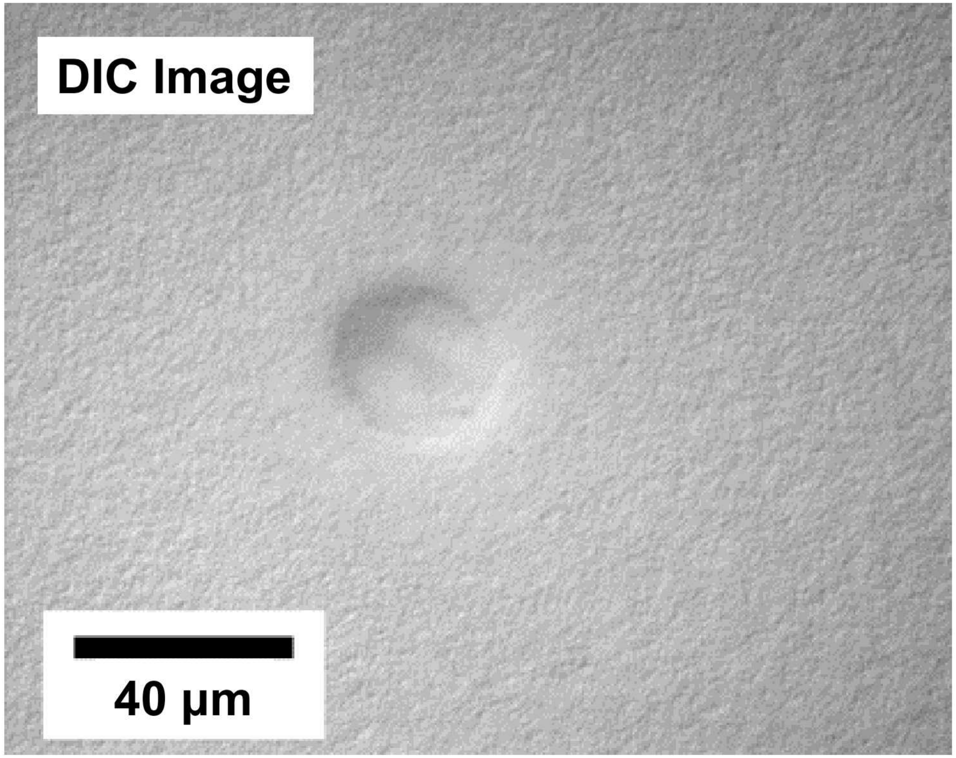




At 500 Torr and 1600 °C, growth rate somewhat sub-linear with TEB flow and independent of NH_3 flow

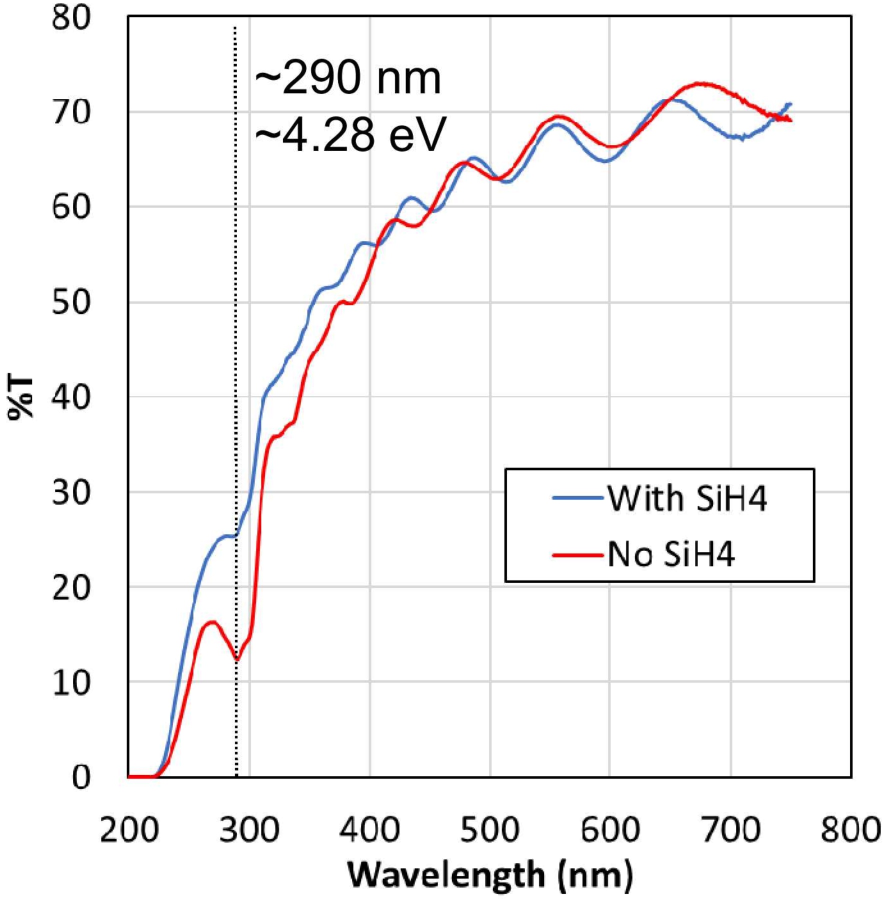
Transparency

40 µm BN on SiC



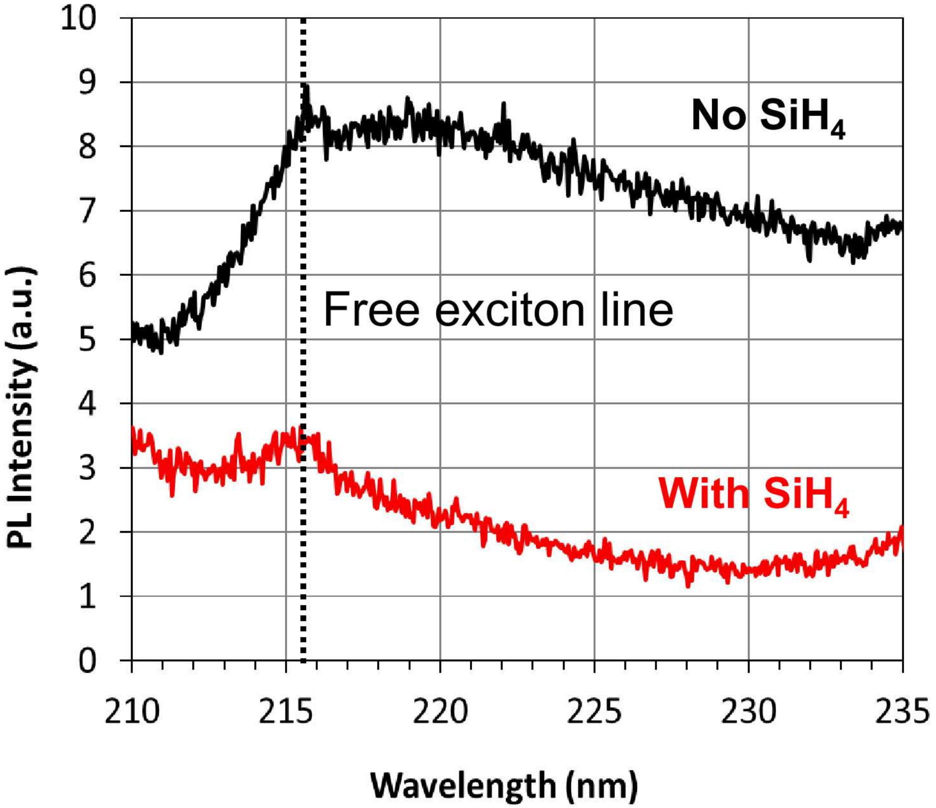
Etch pit in SiC substrate visible through 40 µm of BN

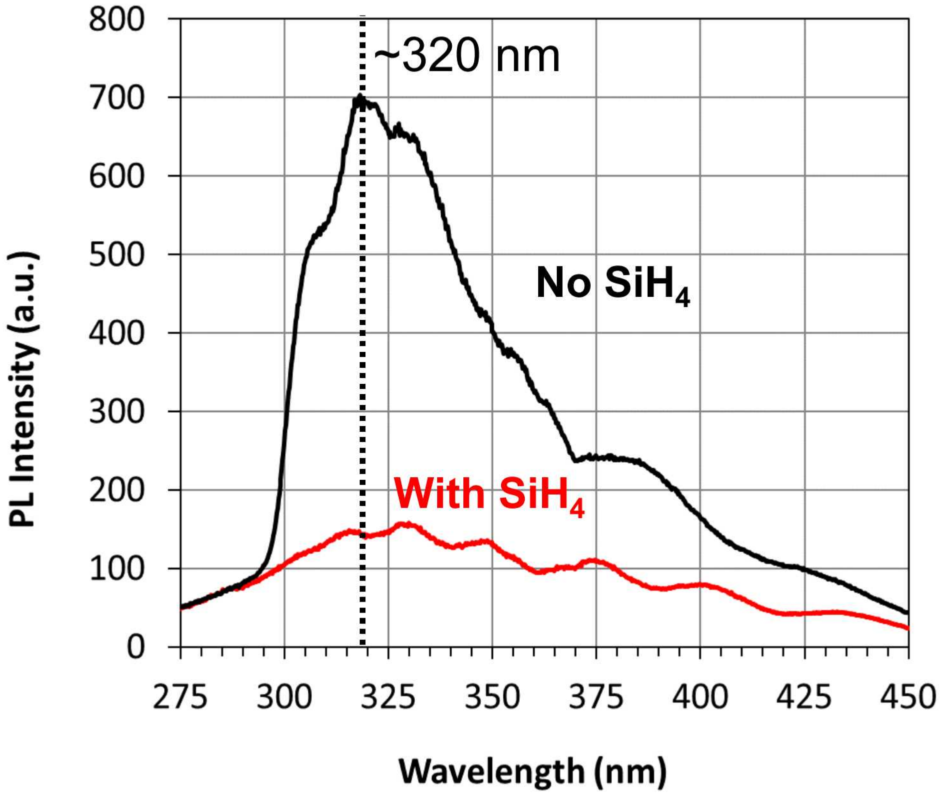
1 µm BN on sapphire



Addition of SiH_4 reduces ~290 nm absorption band

Photoluminescence





- **Room temperature free exciton emission in films grown at 4.3 µm/hr with or without SiH_4**
- **The addition of SiH_4/TEB = 0.01 suppresses both defect bound exciton emission and deep level emission at ~320 nm**

Summary

- Maximum BN deposition rate increased to 4.3 μm/hr

- Room temperature free exciton emission still possible in thick films

- The addition of SiH4 improves UV transparency and suppresses defect bound exciton emission and deep level emission