Techniques of GaN crystal growth

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Outline

- Major properties of GaN
- Significance of growing bulk GaN crystal
- Methods we have achieved
- Challenges we still have
- GaN devices impact on the future

Properties of GaN

- 1.high melting point (2791K) at a correspondingly high equilibrium pressure of nitrogen(45Kbar)
- 2. wide, direct bandgap of 3.39ev
- 3.high thermal conductivity
- 4.high electron saturation velocity

Why GaN ?

- Great potential applications in high-power electronics capable of operation at elevated temperatures and high frequencies

Difficulties we have met

- Difficult to get native substrates in high quality and large quantities
- Even the slight lattice mismatch induce misfit dislocations at the interface,which could develop cracks in crystals that degrade the performance of devices.

Substrates we have used

- Have tried sapphire(Al_2O_3), SiC, MgO, $MgAl_2O_4$, $LiAlO_2$,$LIGaO_2$, ZnO, MoS_2 et al.
- Most common use: sapphire
  - Better quality in many cases
  - Available up to inches in diameter
  - Inexpensive

Main Methods we have got

- Vapor phase epitaxy(HVPE)
- Molecular beam epitaxy (MBE)
- Metalorganic chemical vapor deposition(MOCVD)

Crytal growth of GaN (HVPE)

- Long history and widely used because of high growth rate
- Hydride vapour phase epitaxy(HVPE) attract renewed interest to produce thick, strain-relieved buffer layers

Comments on VPE

- Highly suitable for GaN films due to high growth rate and bandgap engineering in near-UV spectral range is possible
- However, the very high growth temperature of VPE processes, between 1000 and 1200 degrees make Si and O impurity concentration high, which makes electron concentration high
- Growth rate:100um/h have been achieved

Crystal growth of GaN(MBE)

- 1. Nitrogen gas cannot be directly used for GaN growth. Nitrogen (N_2) must be dissociated prior to reaching the surface of the substrate in order to incorporate in GaN.
- 2. Low temperature

Comments on MBE

- Advantages:
- High purity growth
- Hydrogen free environment
- Possibility to use plasma or Laser assisted growth
- Disadvantages:
- Need ultra-high vacuum
- Low growth rate
- Very expensive

Crystal growth of GaN(MOCVD)

- Basic MOCVD reaction describing GaN deposition process: $Ga(CH_3)_3+NH_3 \rightarrow GaN$
- For high optical quality material it's necessary to grow GaN at temperatures as high as 1080 degrees.
- The deposition of a low temperature "buffer"layer of AlN on sapphire substrates was a key discovery in improving surface morphology and crystalline quality of GaN

Comment on MOCVD

- Advantages:
- High growth rate
- Large-area growth capability
- Very high quality film
- Intermediate cost
- Disadvantages:
- High temperature
- Tendency to preact

Various new technologies

- Modified VPE process: Sublimation sandwich method(SSM):
- good structural quality for films grown at very high rates
- Lateral epitaxial overgrowth(LEO) by MOCVD:
- Reduce defect density tremendously, but only in the windows, not on the mask
- enable the controlled deposition of low-dimensional microstructures such as quantum wires and dots, don’t cause any damage or contamination at sample surface

Challenges

Need maturer technology:

- Larger size
- Defect free (Has been reduced from 10^{8}–10^{10} cm^{-2} to 10^{7} cm^{-2} not low enough)
- Low cost
- Doping issues

Impact on the future

- Enable the fabrication of LEDS, lasers, detectors, transistors and so on
- Save lots of energy
- Harmless

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Thanks for your kind attention!