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InGaN MBE growth of islands and thin film on epitaxial graphene

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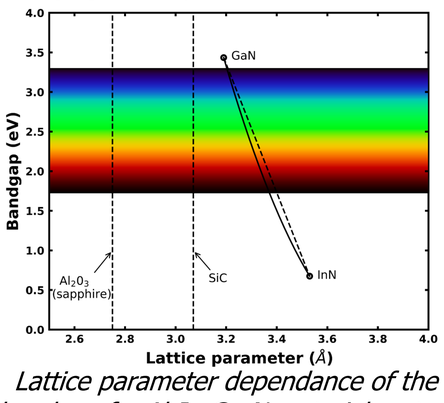
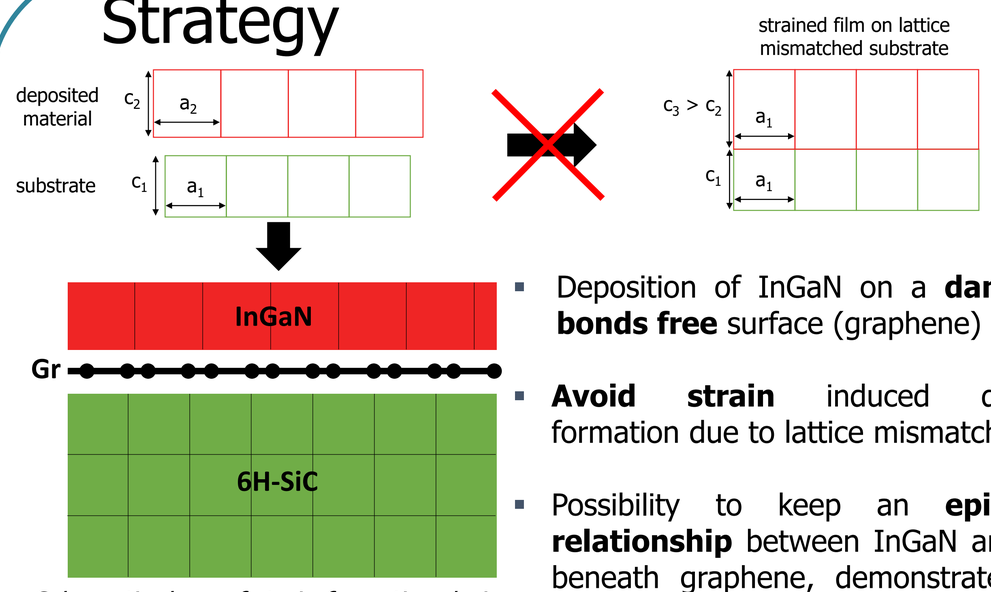
Context



Lattice parameter dependance of the bandgap for Al-In-Ga-N material system

- $In_{1-x}Ga_xN$ alloys for light emitting devices: possibility to cover the **whole visible range**
- **Difficulty** to reach homogeneous **high In content** in InGaN alloys necessary for red LEDs (low miscibility, pulling effect)
- High **defects** density induced by **lattice mismatch** between InGaN and common substrates (GaN, Al_2O_3, SiC…)

Strategy

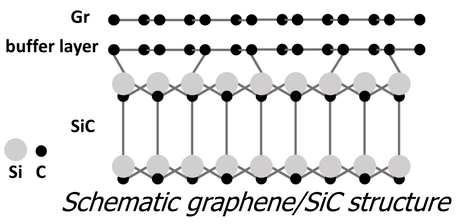


Schematic draw of strain formation during epitaxy and free-standing InGaN on graphene/SiC

- Deposition of InGaN on a **dangling bonds free** surface (graphene)
- **Avoid strain** induced defects formation due to lattice mismatch
- Possibility to keep an **epitaxial relationship** between InGaN and SiC beneath graphene, demonstrated for GaN/graphene/GaN [1]

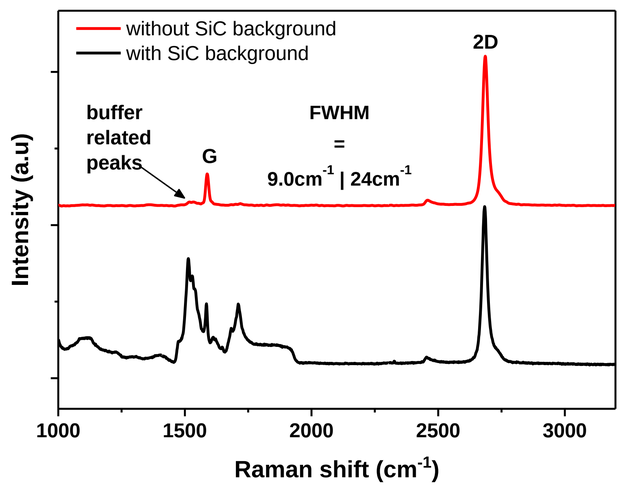
Growth of graphene on 6H-SiC (0001)

Propane based CVD growth at 1450°C under H_2/Ar atmosphere

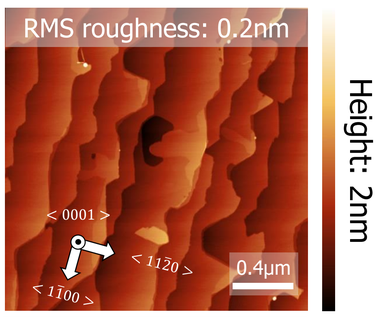


Schematic graphene/SiC structure

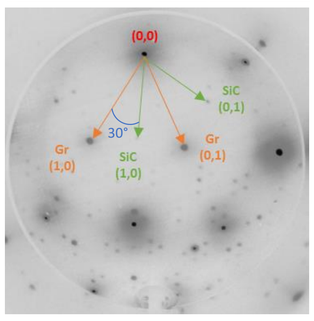
Raman spectroscopy



AFM



LEED



- Smooth surface of stepped SiC covered with graphene rotated by 30°
- High quality evidenced by Raman spectroscopy:
  - -narrow 2D/G peaks FWHM
  - -**no D** (defect related) **peak** around 1350cm^{-1}

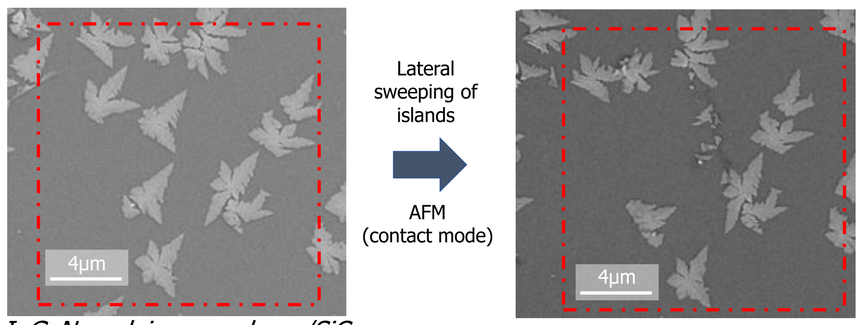
InGaN nucleation on graphene

Ammonia assisted MBE at 685°C

C. Paillet et al., Nanotechnology. 31, 405601 (2020).

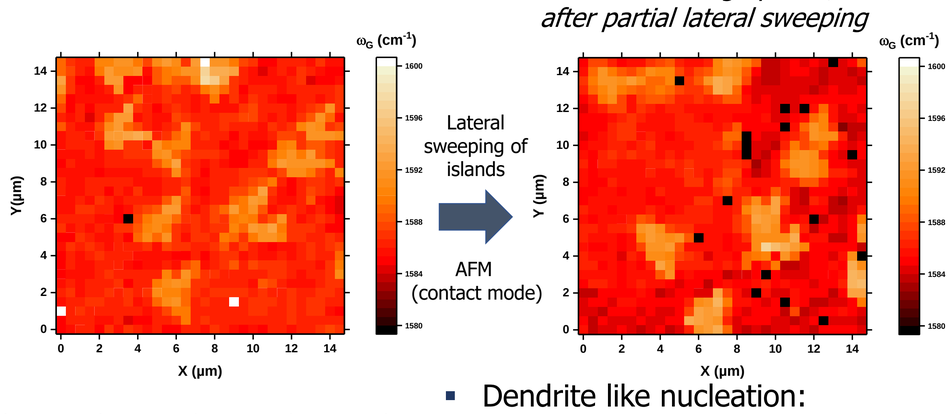
15min growth

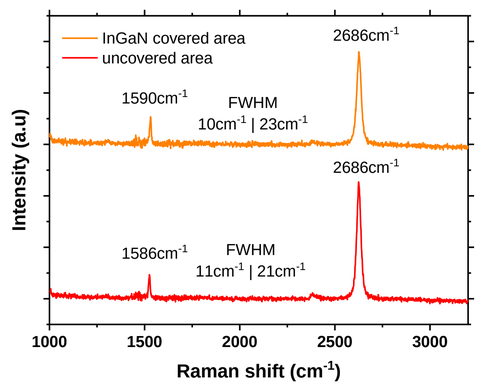
SEM



InGaN nuclei on graphene/SiC — *InGaN nuclei on graphene/SiC after partial lateral sweeping*

Raman spectroscopy





- Dendrite like nucleation:
  - -density ≈ 5.5x10^{6}cm^{-2}
  - -height ≈ 25 - 40nm
- No apparent damaging of the graphene probed by Raman spectroscopy:
  - -No D peak after growth
  - -**G peak position shift** by contact with InGaN (n-doping)[2]
- **Weak InGaN/graphene bonding** evidenced by AFM sweeping

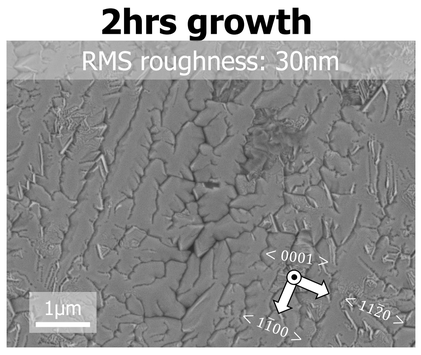
Toward the formation of a film

Ammonia assisted MBE at 615°C

C. Paillet et al., Nanotechnology. 31, 405601 (2020).

2hrs growth

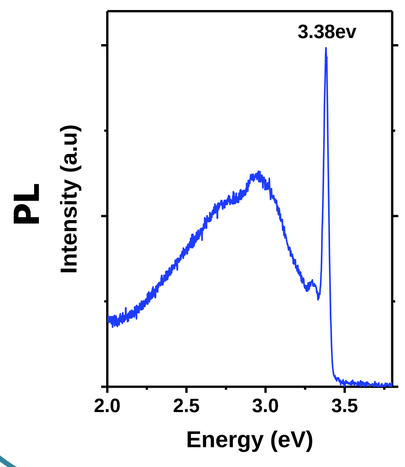
SEM



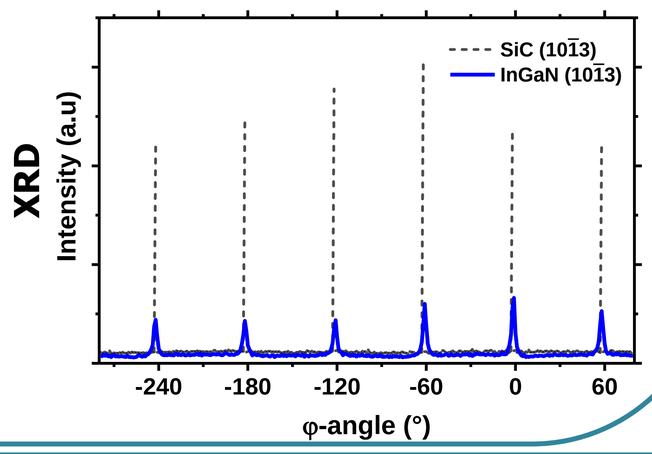
InGaN layer deposited on graphene

- Non-fully coalesced InGaN film observed with SEM (thickness:70nm)
- **Epitaxial relationship** between InGaN and SiC shown by φ-scan
- (0002) **rocking curve** FWHM=**515arcsec**: -commensurate with InGaN (6%at In) on InGaNOS (395 arcsec)[3] and GaN on graphene/Si (680 arcsec)[4]
- **Low In incorporation** (≈2%at) according to InGaN band edge PL emission wavelength

PL



XRD



Summary

- ❑ Direct nucleation of weakly bonded InGaN islands on graphene without degradation
- ❑ High roughness InGaN film with low In incorporation in epitaxial relationship with SiC substrate
- ❑ Lower growth temperature tested to enhance In incorporation (up to ≈25%at In) resulting in a much lower material quality

Perspectives

- ❑ Improve the nucleation process
- ❑ Indentation tests to probe the InGaN/graphene interaction forces

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REFERENCES

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2. G. Froehlicher, S. Berciaud, Phys. Rev. B. 91, 205413 (2015).
3. A. Even et al., Appl. Phys. Lett. 110, 262103 (2017).
4. T. Araki et al., Appl. Phys. Express. 7, 071001 (2014).

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