

# Growth and characterization of GaN nanocolumns grown on graphene using a thin AlN buffer layer

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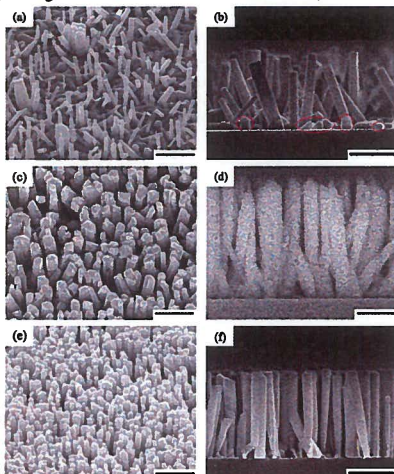
## Background

The inadequate compatibility of conventional substrates (Si, SiC and Al<sub>2</sub>O<sub>3</sub>) with the III-N system, such as GaN, urges the search for alternative substrate material. In this case, graphene might lead the way due to its near lattice match with GaN [1]. However, graphene's lack of dangling bonds can generate stacking faults in the grown GaN thin-film [2].

This issue has been tried to overcome by growing GaN nanowires/nanocolumns [3-5]. In these cases, the nanocolumns were generally observed to be either low density [3] or the growth required multi-layer graphene in order to withstand the etch of graphene by the nitrogen plasma [4]. Also, the use of multi-layer graphene [5] does not fit with the flip-chip device scheme as it is highly absorbing, in which case one of graphene's unique properties being transparent conductive electrode is not exploited.

## RF-PAMBE growth

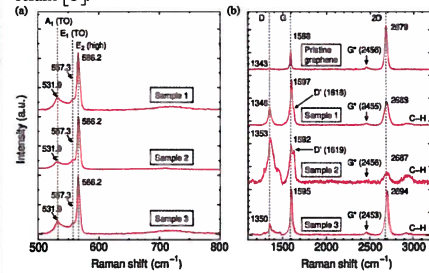
Cu-CVD graphene (transferred onto 0.5 mm thick silica glass) was used as a substrate for nanocolumn growth. General growth conditions were similar with our previous work [6], where nanocolumns were grown on silica glass. Sample 1 (a & b) was a direct GaN growth, while sample 2 (c & d) and sample 3 (e & f) used respectively GaN and AlN buffer layer before growing the nanocolumns. Scale bars are 1  $\mu$ m.



## Raman measurements

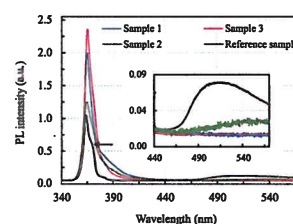
In (a), all of the GaN nanocolumn samples show the same wave number for the A<sub>1</sub>(TO), E<sub>1</sub>(TO) and E<sub>2</sub> (high) phonon, all of which indicate stress-free wurtzite GaN with no existence of zinc-blende crystal structure.

In (b), sample 1 and 2 have higher damage (I<sub>D</sub> and I<sub>D'</sub>) compared to sample 3, suggesting AlN could be used to reduce damage on the graphene due to impinging active N species and in-plane strain caused by GaN nucleation [7]. Notice that there is a blue-shift in all three samples, suggesting doping and/or compressive strain [8].



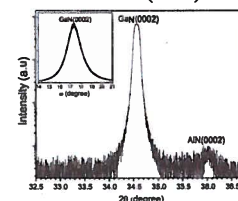
## Optical properties at RT

All samples, including ref. sample (HVPE-GaN) exhibit emission at  $\sim$ 364 nm. Sample 3 has the most intense emission. Also, no yellow- nor exciton bound to structural defect emission is observed in sample 3.



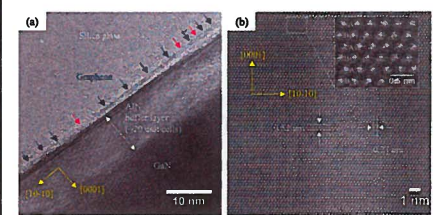
## XRD on sample 3

Peak at 34.56° is assigned to the 0002 reflection from GaN, confirming that the nanocolumns grow along the c-axis of the wurtzite structure. Weak peak of 0002 reflection from wurtzite AlN is also detected. Inset shows rocking curve measurement where the FWHM of GaN (0002) is  $\sim$ 1.60°.



## TEM on sample 3

In (a), graphene layer is observed on top of silica glass (blue arrows). Interestingly, the contrast from graphene disappears at a few locations (red arrows) due to roughness of the silica glass surface. The graphene itself appears two/three layers due to projections that average through the thickness of the TEM lamella. The AlN buffer layer is composed of  $\sim$ 20 unit cells ( $\sim$ 10 nm) thick layer with predominantly bright contrast. Strain (dark contrast) is distributed non-uniformly along the interface between AlN and graphene. No indication of defect propagating to the nanocolumn and the crystallinity of GaN exhibits a perfect wurtzite structure (b) without observable defects.



## Summary

High-quality and stress-free self-assembled vertical GaN nanocolumns are successfully grown on graphene/silica glass using a thin AlN buffer layer. The AlN does not only serve as nucleation sites for the nanocolumns, but also provides considerable protection to the graphene from the nitrogen plasma and in-plane strain generated by GaN nucleation. These results are very encouraging for further establishing graphene as an alternative substrate to enhance performance and functionalities of III-N-based semiconductor devices in general [9].

## Literature cited

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