High-temperature MOCVD growth of AlN on sapphire by controlling initial stage with in-situ monitoring

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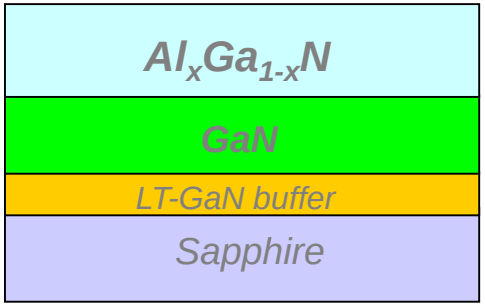
Outline

1. Motivation
2. Experiments
3. Results and Discussion
   (1) Growth of AlN by HT-MOCVD under different initial growth conditions
   (2) Mechanism of "two-step" HT-MOCVD growth of AlN
4. Summary

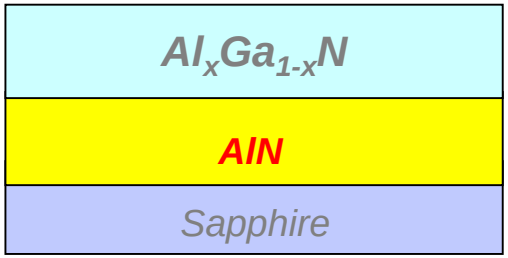
Motivation

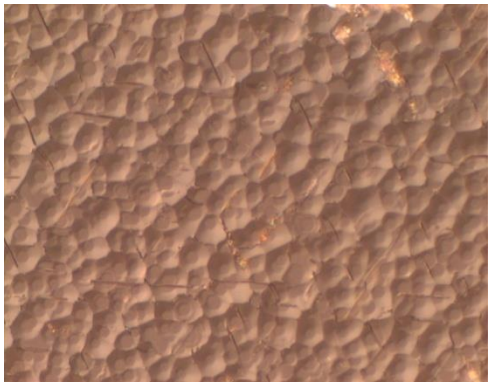
1. High-efficiency UV devices (e.g LEDs, LDs and detectors) need high-quality AlN

$Al_xGa_{1-x}N$ on GaN (x=0.49)



$Al_xGa_{1-x}N$ on AlN (x=0.57)





Optical Microscopy

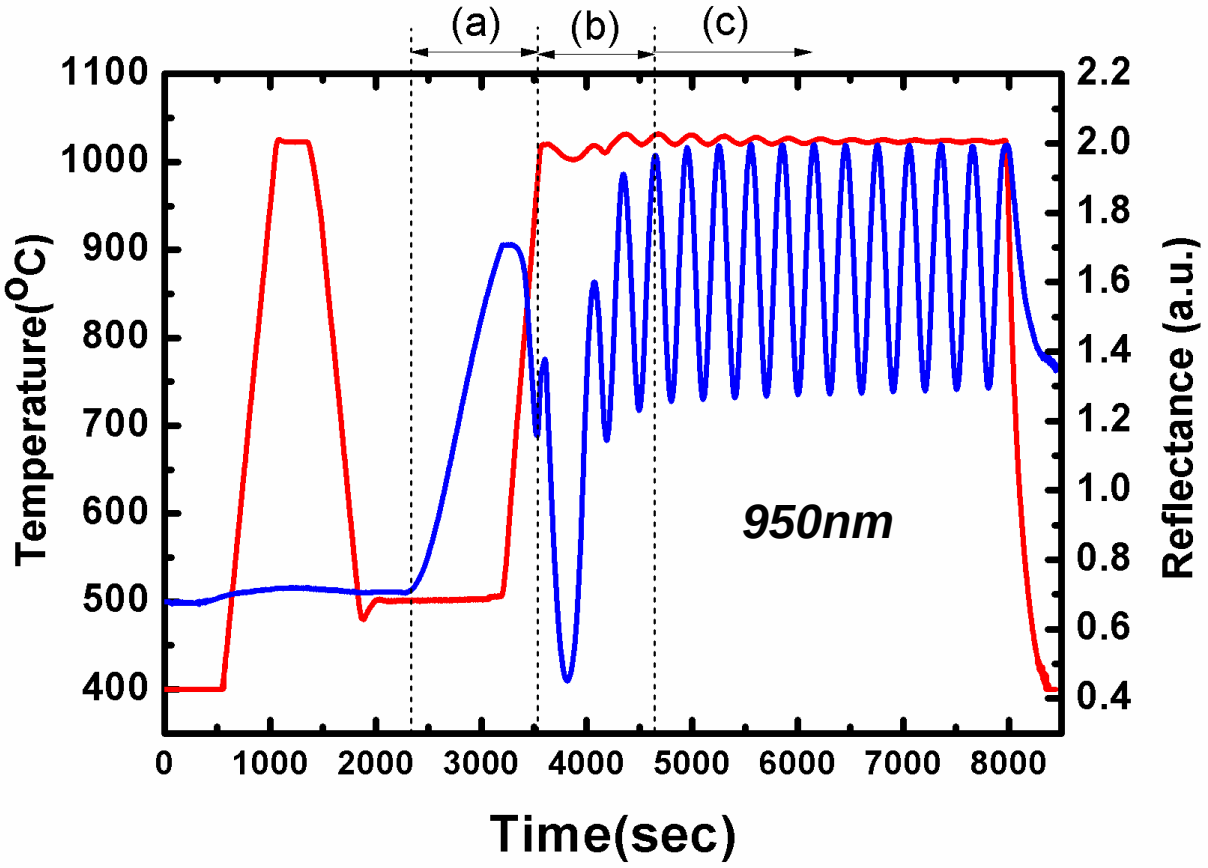
Crack & rough surface

Crack Free & smooth surface

Motivation

2. To explore the growth mechanism of AlN by two-step HT-MOCVD.

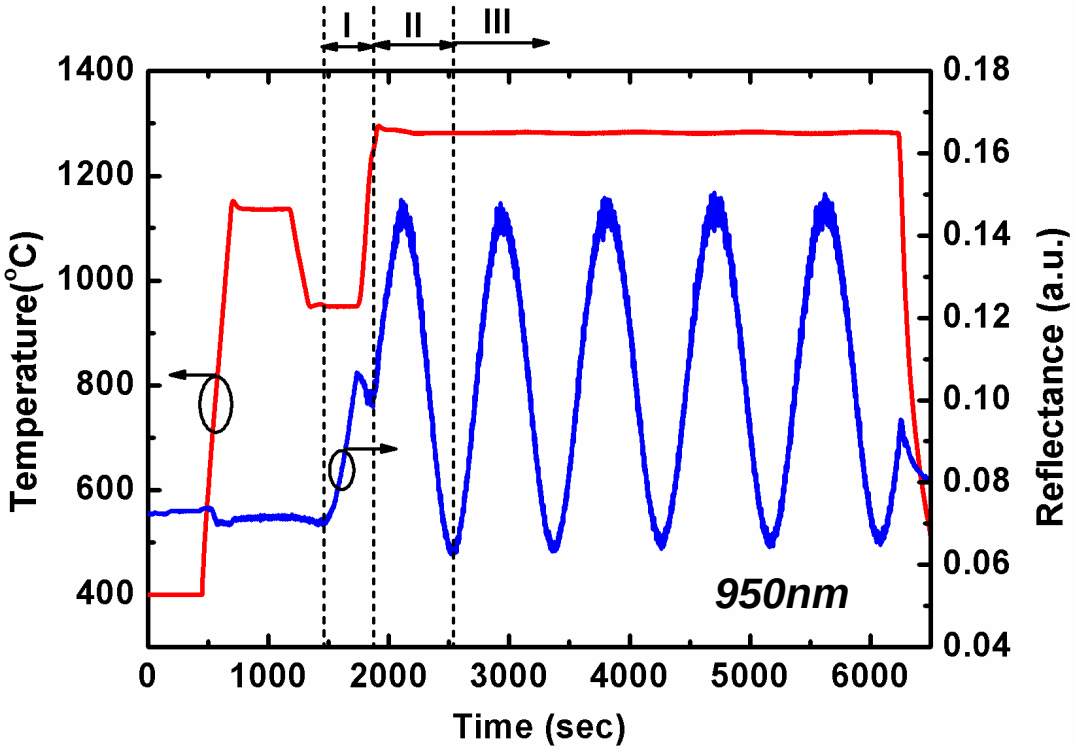
In-situ monitoring curves of "two-step" growth of GaN



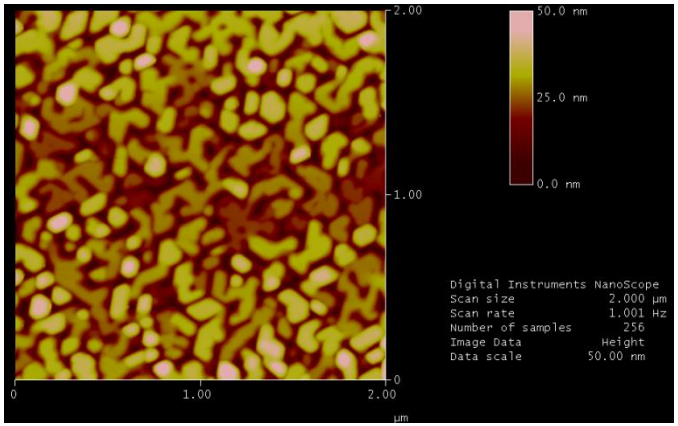
(a): GaN nucleation & annealing
(b): Coalescence (3D)
(c): 2D growth

Motivation

In-situ monitoring curves of "two-step" growth of AlN



I: AlN nucleation & annealing
II: Coalescence finished (?)
III: 2D growth (?)



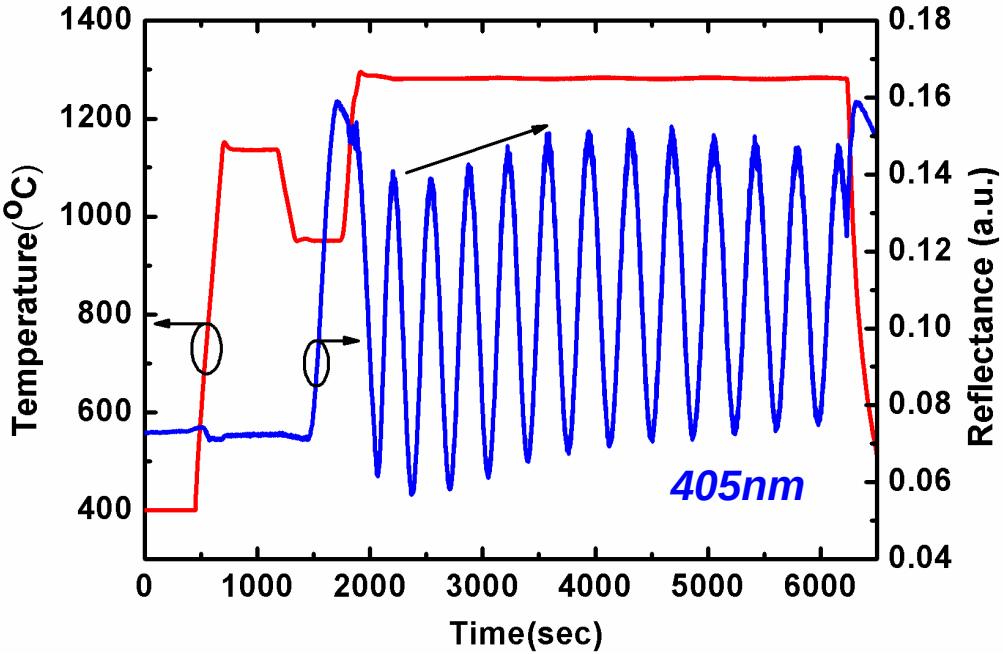
AFM image of AlN at the stage II

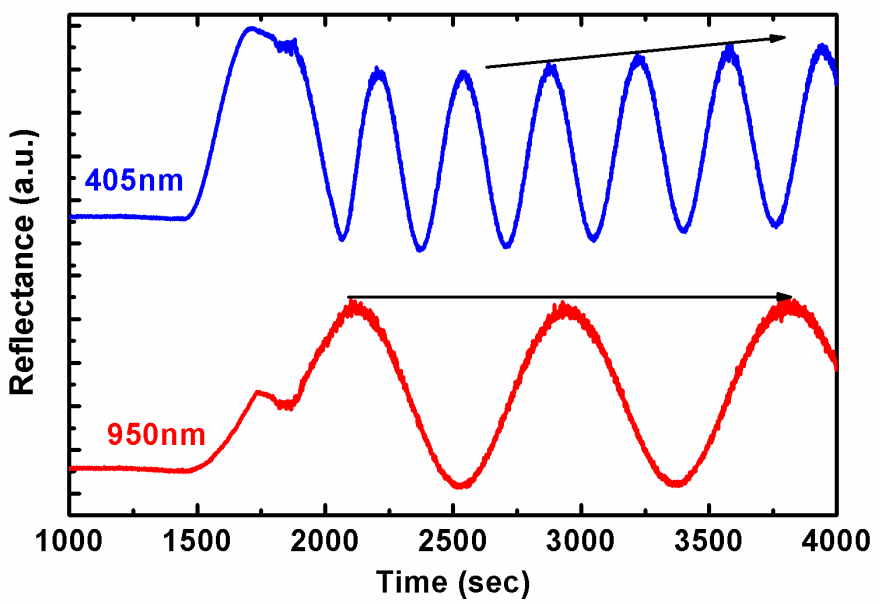
After stage II, it is still 3D growth

Light beam of 950nm wavelength is not good for in-situ monitoring of AlN.

Motivation

In-situ monitoring curves of "two-step" growth of AlN





Light beam of 405nm wavelength is powerful to Monitor the initial stage of AlN.

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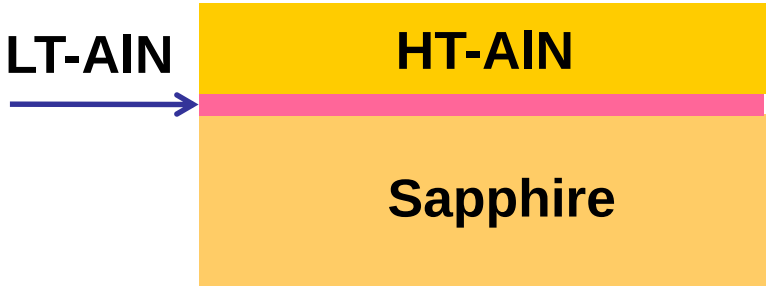
Experiments

AlN was grown by HT-MOCVD.

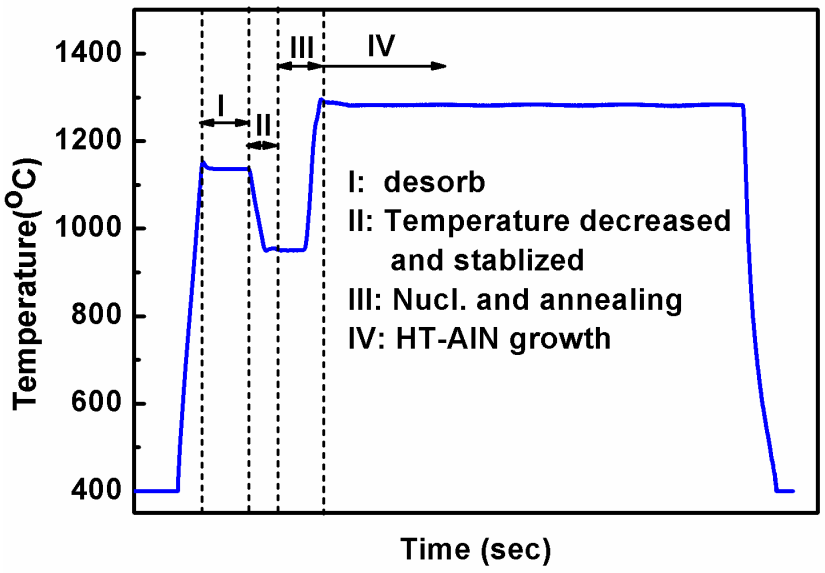
The in-situ monitoring system with two light beams was used to monitor the growth rates and surface morphology.

AFM and XRD were employed to characterize the surface state and crystalline quality.



Growth conditions

Temp. for LT-AlN: 950°C
Temp. for HT-AlN: 1300°C
Reactor Pressure: 40Pa
V/III ratio for HT-AlN: 250
V/III ratio for LT-AlN: 7500



Time sequence for growth of AlN

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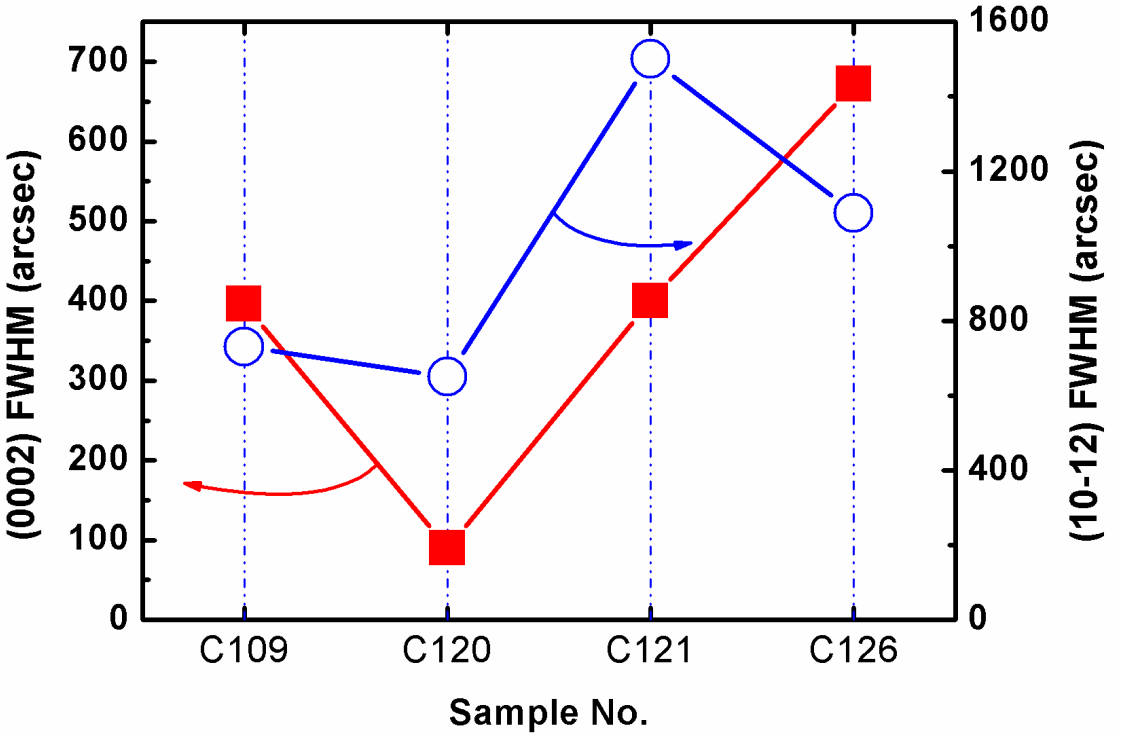
Results and Discussion:

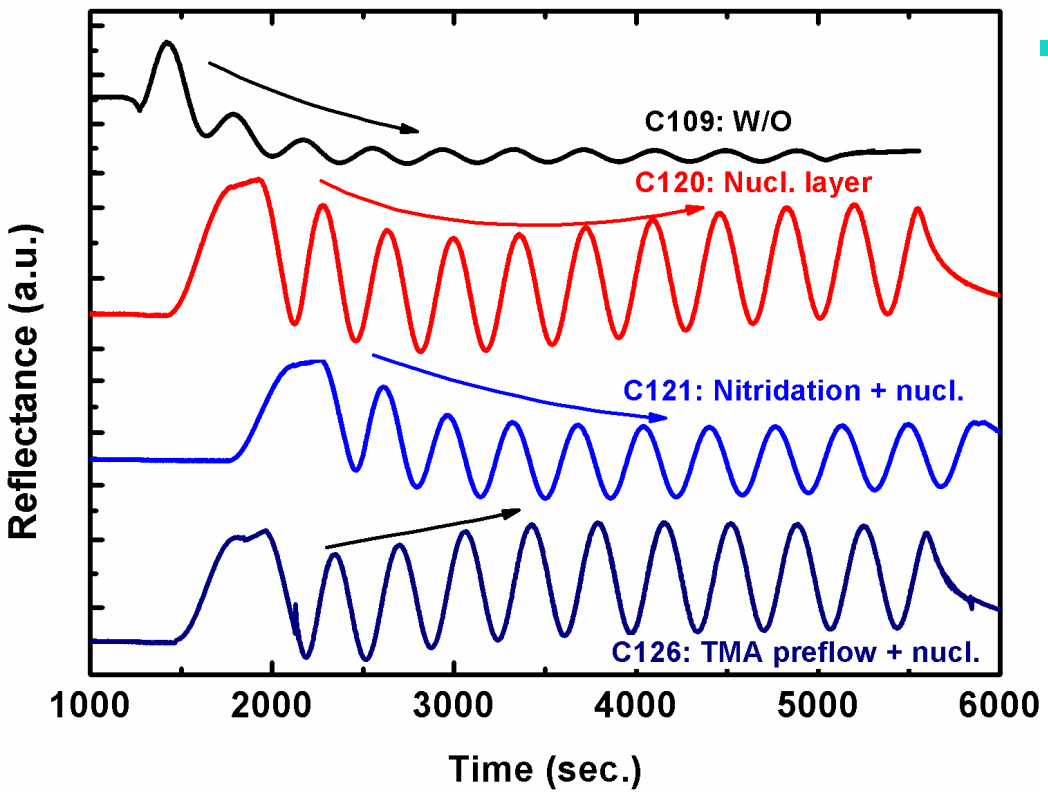
Growth of AlN by HT-MOCVD under different initial conditions

Sample No.	Initial conditions
C109	Without nucl. layer, No treatment
C120	With nucl. layer
C121	Nitridation (@950^{o}C for 5min)+ nucl. layer
C126	TMAl preflow treatment (2sec)+ nucl. Layer



The smallest FWHM value was achieved when growth of HT-AlN with only nucleation layer

Results and Discussion:



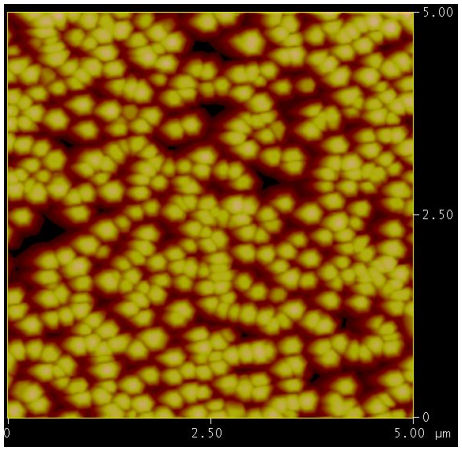
C109: 3D

C120: 3D → 2D

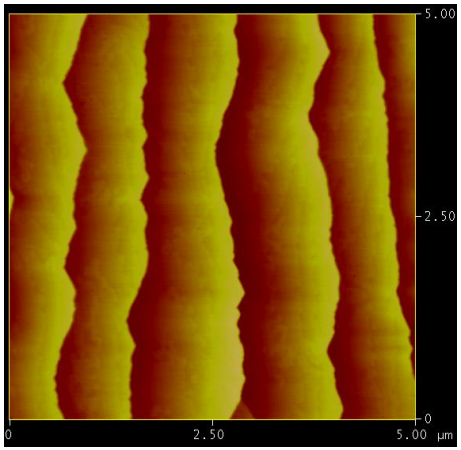
C121: 3D → 3D+2D

C126: 2D

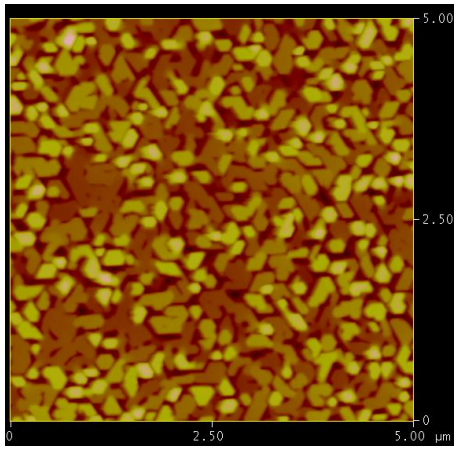
C109



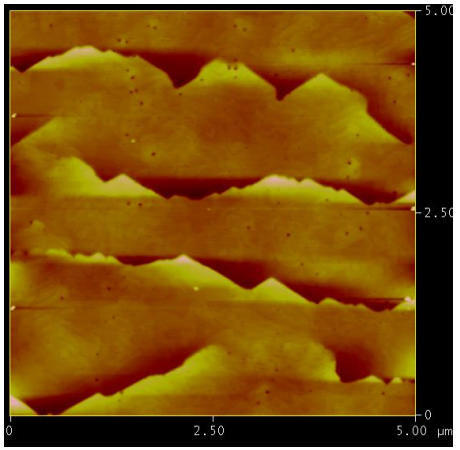
C120



C121



C126

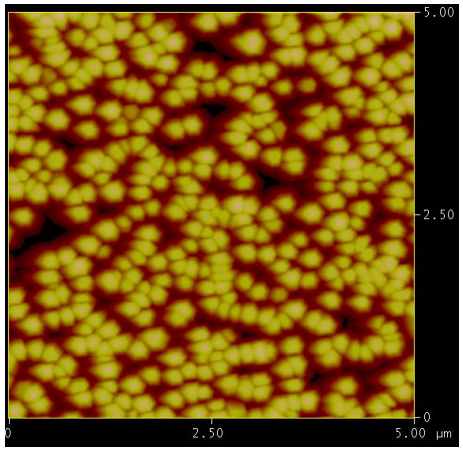


AFM images of sample C109 and C121 before and after etching

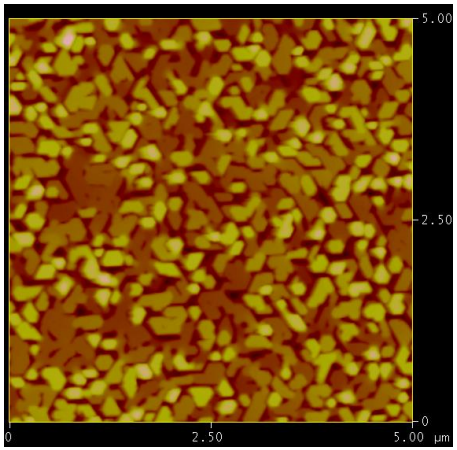
C109

C121

Before

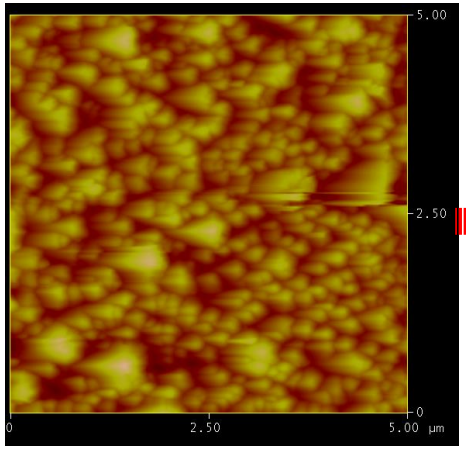


RMS: 42.229nm



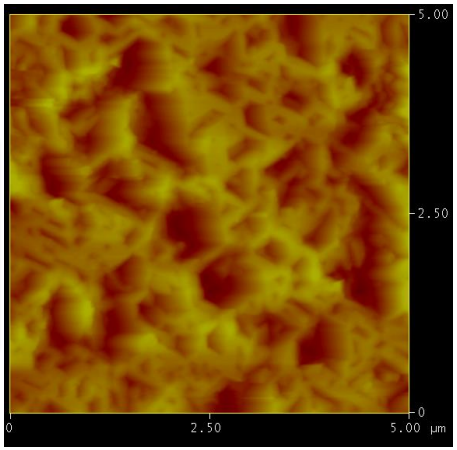
RMS: 15.269nm

After



RMS: 73.484nm

Mainly Al-polar



RMS:60.089nm

Mainly N-polar

For Sample C109, the etching happened from the sidewall of the island; for sample C121, the etching happened on the surface

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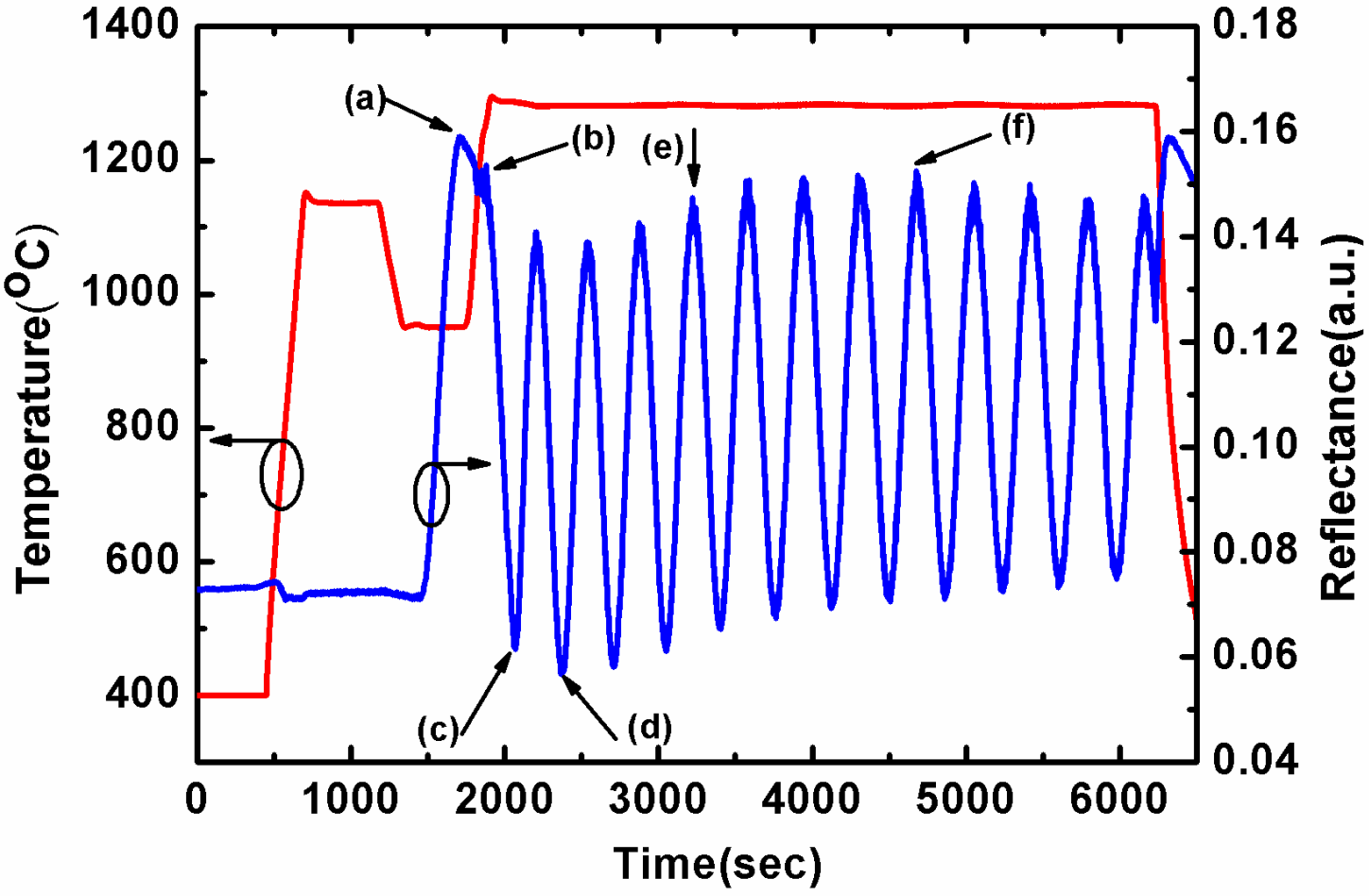
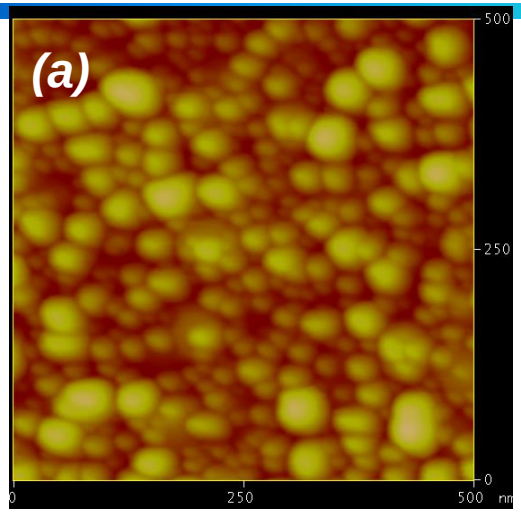
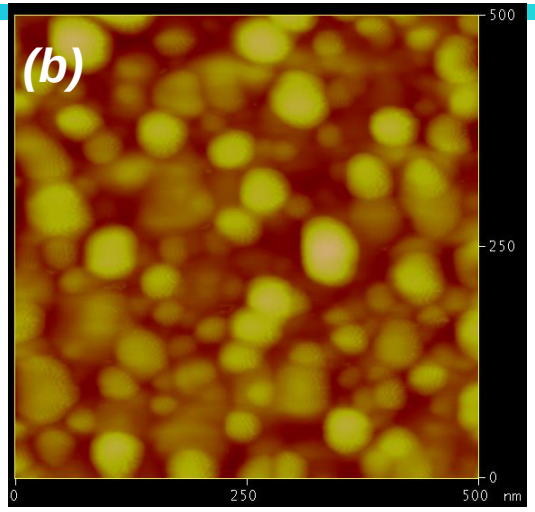
Mechanism of "two-step" HT-MOCVD growth of AlN

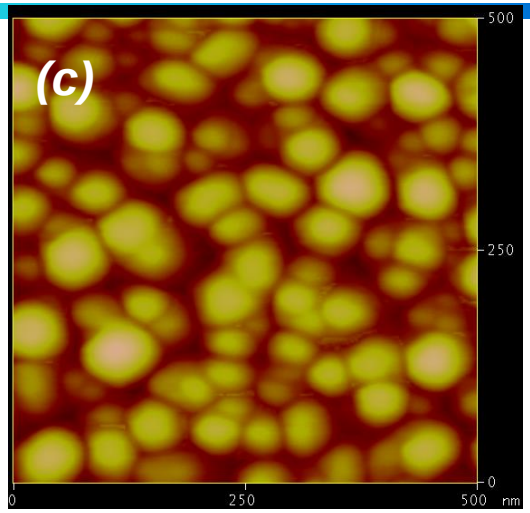


(a) nucl. layer *(b) nucl. layer after annealing*
(c) 2min growth for HT-AlN
(d) The lowest point of reflectance intensity (8min)
(e) Coalescence(22min) *(f) 47min growth*

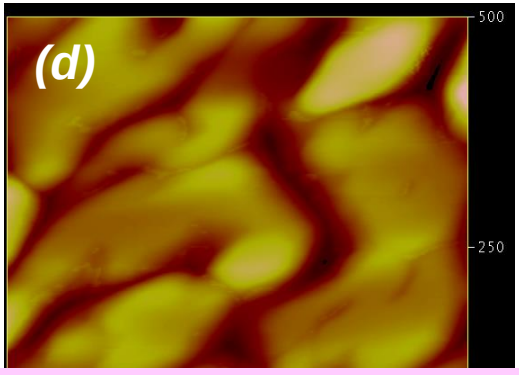
Mechanism of "two-step" HT-MOCVD growth of AlN

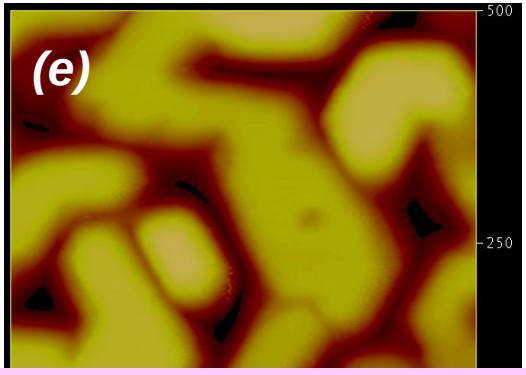


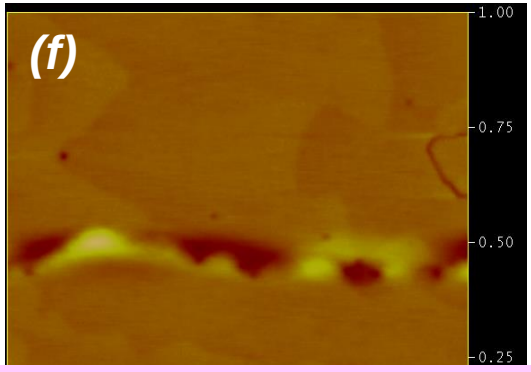




Island density: high
Island size: small







The two-step growth of AlN experienced a transition from nuclei (3D island), nuclei decomposed and coalescence , and layer-by-layer (2D) growth.

Summary

The high crystalline quality AlN was grown by "two-step" HT-MOCVD with in-situ monitoring system. The Laytec in-situ monitoring system is very useful for growth high-quality AlN.

The crystalline quality of HT-AlN was strongly affected by the Initial growth conditions. The main reason is that different initial growth conditions caused different growth mode of HT-AlN.

The two-step growth of AlN experienced a transition from 3D island growth to 2D growth.