Structural and Spectroscopic Properties of AlN Layers Grown by MOVPE

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Motivation:

AlN:

Properties:	High band gap (≈ 6.2eV), Good chemical and thermal stability
Application:	High temperature, high power/ voltage electronic devices Opto-electronic devices

Challenge:

High quality epitaxial growth of AlN: More difficult than GaN
- Strong parasitic reactions between precursors
- Presence of hexagonal pits and dislocations

Approach:

Optimization of growth parameters of both, AlN bulk and nucleation layers

Epitaxial growth: Undoped AlN layer (≈500 nm thick) on LT-AlN nucleation layer

LP-MOVPE:

System: Aixtron AIX 200RF MOVPE
Precursors: TMAl and NH_3
Carrier gas: H_2
Growth atmosphere: N_2+H_2
Substrate: One half of 2 inch c-plane Sapphire

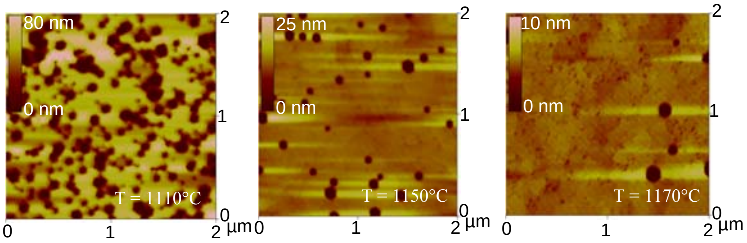
Growth parameters:	Bulk layer	Nucleation layer
Pressure:	35 mbar	35 to 100 mbar
Temperature:	1110°C to 1170°C	830°C to 930°C
N2-H2 gas composition:	0.2 to 3.0	0.8 to 4.0
Total flow:	1500 to 4000 sccm	1500 to 5000 sccm
V-III ratio:	600 to 4000	500 to 18000

Characterization:

Surface morphology: AFM, SEM
Crystal quality: HRXRD, TEM
Optical property: LT-Cathodoluminsence

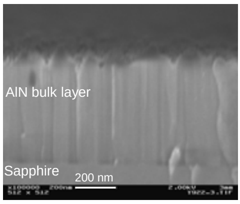
Structural Properties:

Influence of growth temperature:



Temperature	1110°C	1150°C	1170°C
rms surface roughness of 2*2 µm scan	22 nm	4.5 nm	1.5 nm
Hexagonal pit density	>10^{10} cm^{-2}	≈8* 10^9 cm^{-2}	≈3* 10^8 cm^{-2}

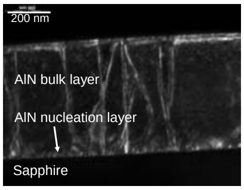
Increasing growth temperature:
- Reduction of hexagonal pits
- Increases surface smoothness



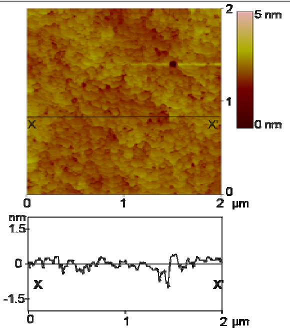
SEM image before optimization:
- Columns protruding through the entire layer of AlN

Optimized Growth Condition

Growth parameters:	Bulk layer	Nucleation layer
Pressure:	35 mbar	70 mbar
Temperature:	1150°C	870°C
N2-H2 gas composition:	3.1	1.86
Total flow:	1700 sccm	2000 sccm
V-III ratio:	1200	2500



TEM image after optimization:
- Dislocations emerging from nucleation layer
- Half of them threading the entire layer

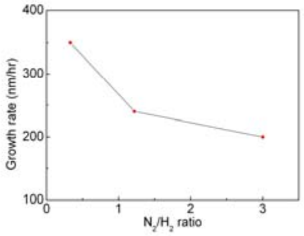


AFM image after optimization:
- Very smooth surface
- Quasi 2D growth

Results

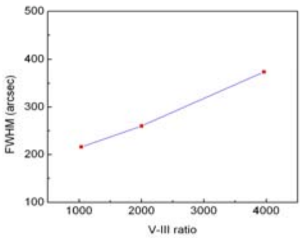
Rms surface roughness: <0.4 nm
FWHM of x-ray rocking curve for (0002) reflection: 200 arcseconds
Hexagonal pit density: 3* 10^7 cm^{-2}
Threading dislocation density: < 10^9 cm^{-2}

Influence of N2-H2 ratio:



Increasing N_2-H_2 ratio:
- Decreases the transport of group III species
- Reduces the substrate temperature
- Decreases the growth rate

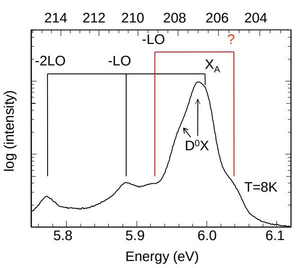
Influence of V-III ratio:

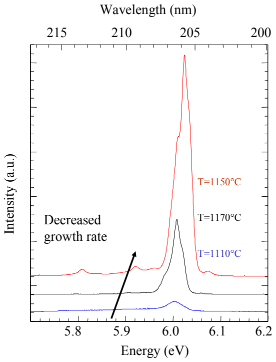


Decreasing V-III ratio:
- Decreases the parasitic reactions
- Increases growth rate
- Decreases FWHM of x-ray rocking curve for (0002) reflection

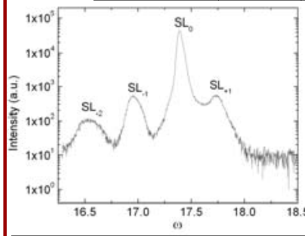
Spectroscopic Properties

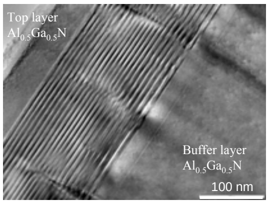
Low temperature cathodoluminescence spectra :
- A band edge excitonic emission with a FWHM of ≈ 20 meV.
- CL intensity higher to the lower growth rate sample.
- The LO phonon replica confirm the good optical quality
- The neutral donor bound excitons D°X and a free exciton X_A resolved.

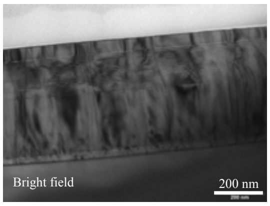




AlN/GaN (4/4 nm) Superlattice Structure (21 periods)







HRXRD of the ω-2θ scan (0002 reflection):
- Satellite peaks confirming the good periodicity of the layers.

TEM:
- Uniform superlattice structure
- Many of the threading dislocations coming from buffer layer stopped at superlattice interfaces.

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