Comparison of the uniformity of thickness and crystal quality of III-nitride films grown by ammonia source and plasma source MBE

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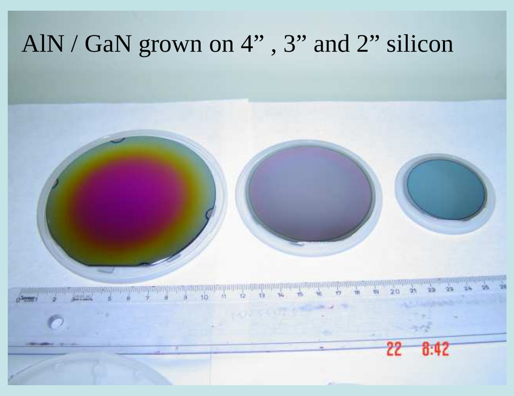
Introduction

GaN and AlN films grown by plasma assisted-MBE and by ammonia-MBE to study the influence of the nitrogen source and of the gas flow rate :

-on the uniformity of thickness

-on the surface and crystal quality



AlN grown on Si(111)

GaN grown on :

- Si (111) with GaN/AlN buffer layers
- GaN-on-sapphire templates grown by MOCVD (LUMILOG)

RIBER Compact 21T

Ammonia MBE :

Ts~800°C (GaN) to 920°C (AlN), nitrogen rich, growth rate limited by group III fluxes

Trapping of ammonia on cryo-panels ➔ recovery procedure

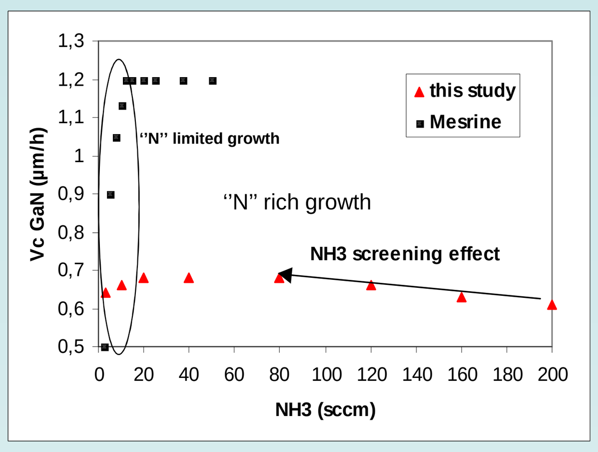
Interest for reducing NH_3 consumption

Plasma assisted MBE: Addon plasma cell (model RFN50/63)

GaN (Ts~720°C), usually metal rich, more complicated : necessary to tune group III fluxes, N_2 flow rate and RF power

AlN (Ts~830°C), metal or nitrogen rich

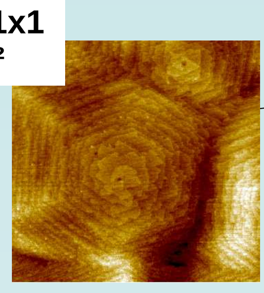
GaN ammonia growth : effect of flow rate



■ Mesrine et al. Appl. Phys. Lett. 72 (3) p.350 – 1998). Riber 32 reactor

- *from 200 to 80 sccm* : increase of the GaN growth rate ; reduction of the screening effect of NH_3. Vg: 0.61 – 0.68 µm/h
- *below 20 sccm* : decrease of GaN growth rate due to insufficient supply of nitrogen.

AFM 1x1 µm²



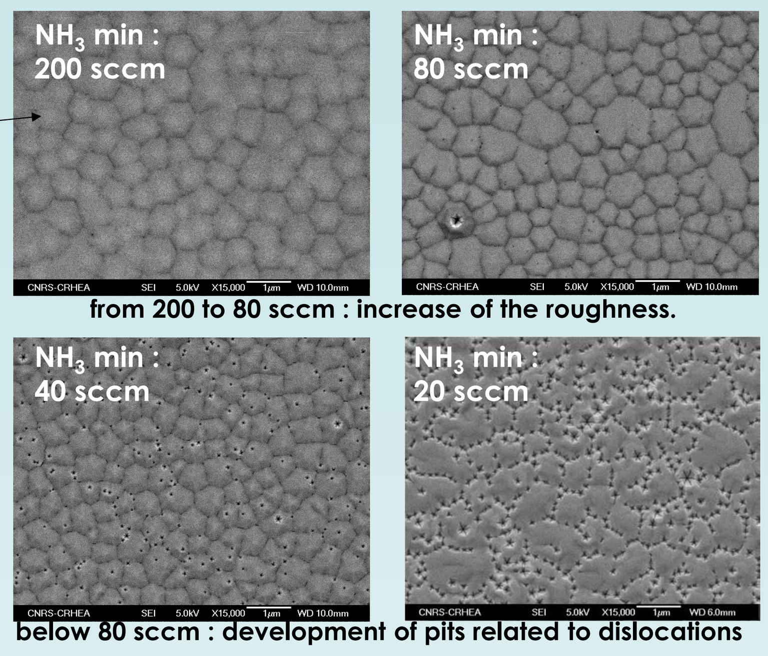
growth mode intermediate between 2D nucleation and step flow

⇨ Step height 1 ML (0.25 nm)

Ga : BEP ~ 5E-7 Torr

NH_3 20 sccm : BEP ~ 7E-5 Torr

➔NH_3 cracking efficiency of a few %

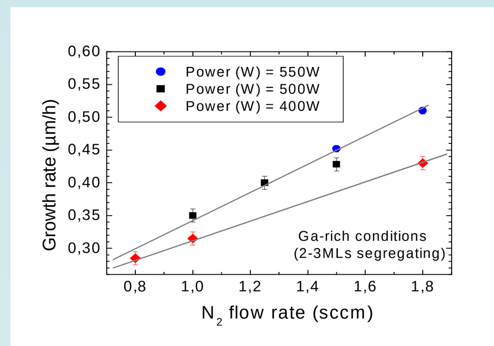


from 200 to 80 sccm : increase of the roughness.

below 80 sccm : development of pits related to dislocations

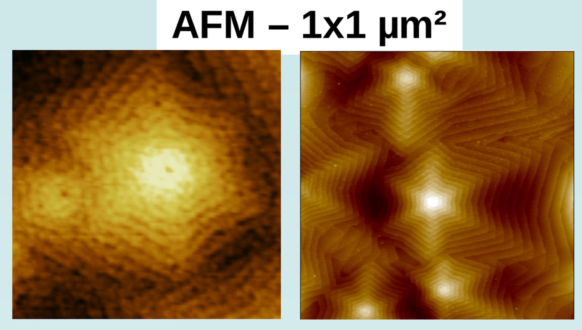
GaN plasma assisted growth :

Growth using a nitrogen plasma source (Ga-rich growth regime) T > 700°C



Effect of nitrogen flow rate and RF power.

AFM – 1x1 µm²

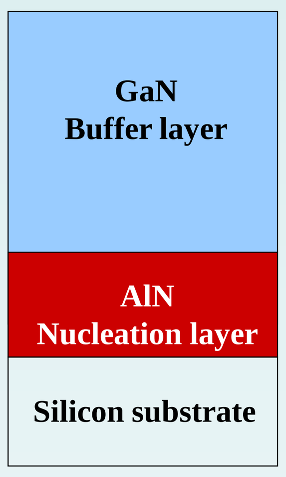


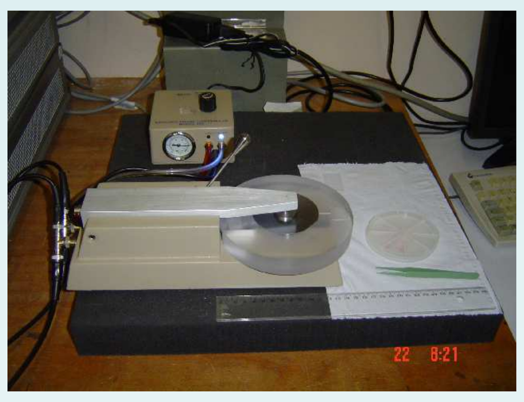
Depending on growth conditions, AFM shows terraces with a mean height of step of 1 molecular monolayer (left) and 2 monolayers (right)

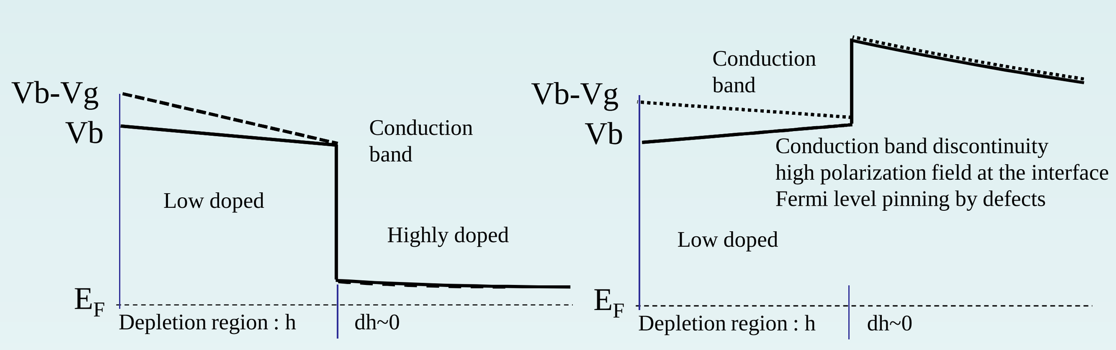
Trade-off : growth rate – quality ➔ P ~ 400-450 W, 1-1.8 sccm, Ts ~ 720 °C

Thickness uniformity

Mercury probe CV (Hg-CV)







The capacitance is almost independent with Vb, Nd-Na

$$C = \frac{\epsilon S}{h}$$

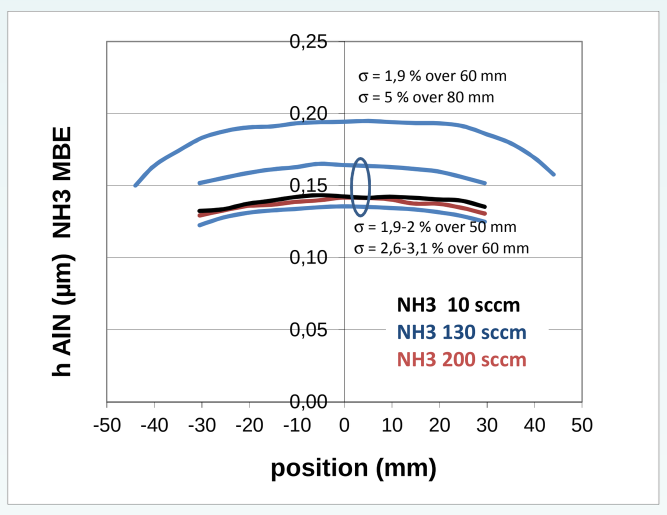
Fourier Transform InfraRed spectroscopy (FTIR)

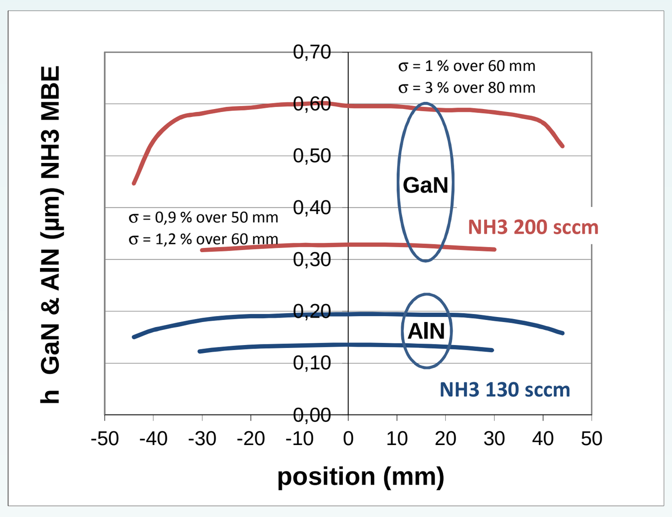
Advantages:
-Contactless
-Fast measurements
-Tunable probe size ~2-6 mm

Drawbacks:
-Accuracy decreases when thickness decreases in the interference regime (necessitates the simulation of TO mode broadening)

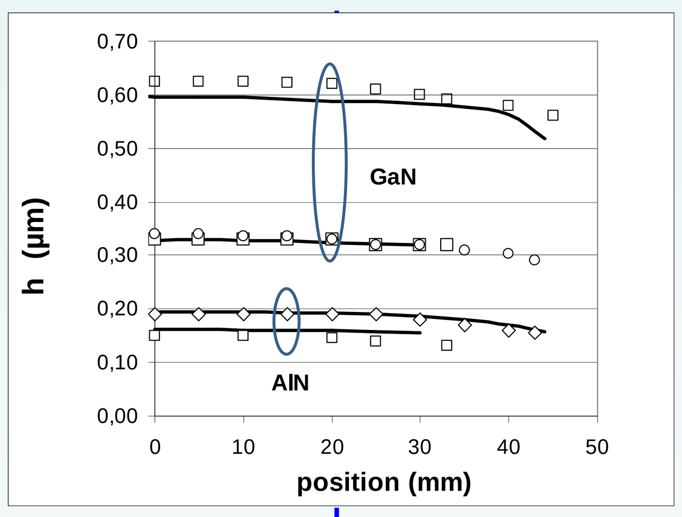
Set up bench
-IR source : 50-9000cm^{-1}
-Detector range (DGTS) : 380 – 7500cm^{-1}

Thickness uniformity from Hg-CV



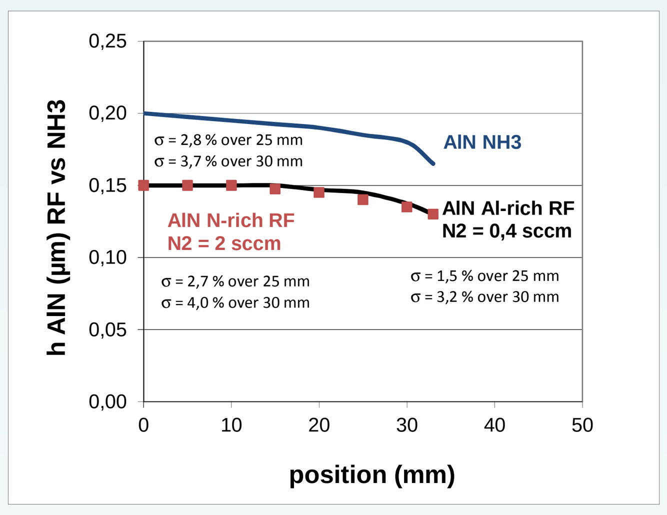


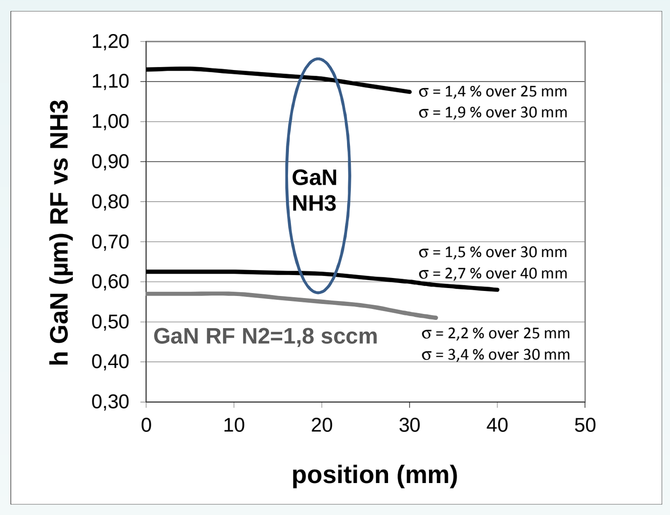
Comparison Hg-CV vs FTIR



— Continuous lines are data from Hg-CV

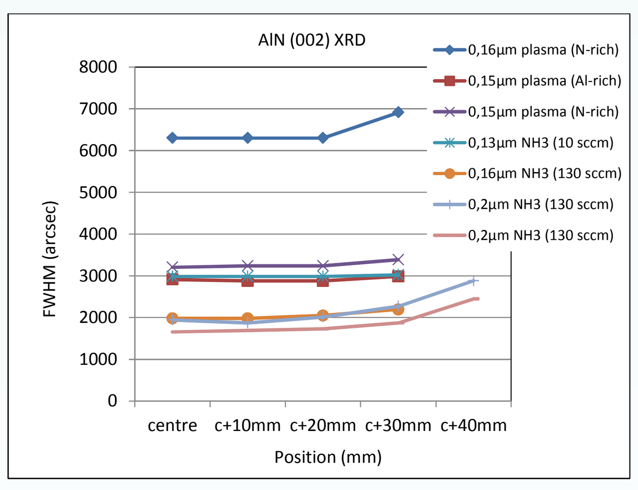
Thickness uniformity from FTIR

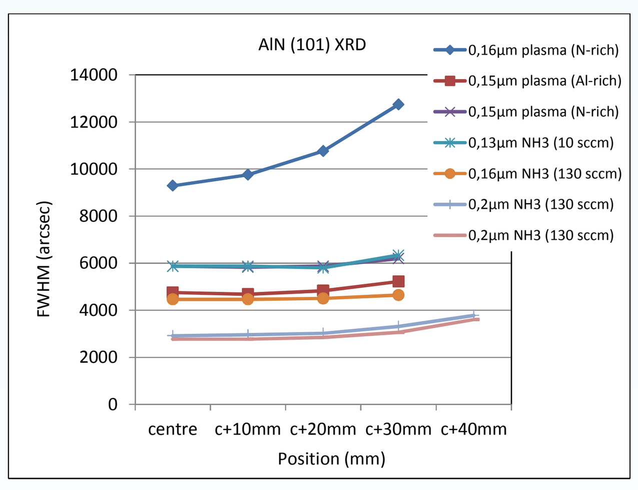


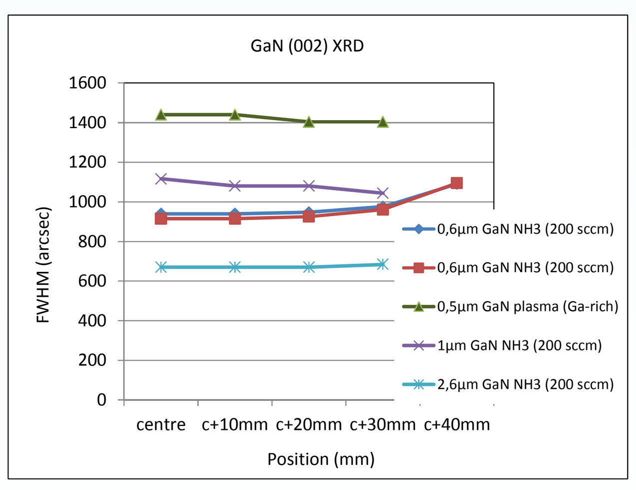


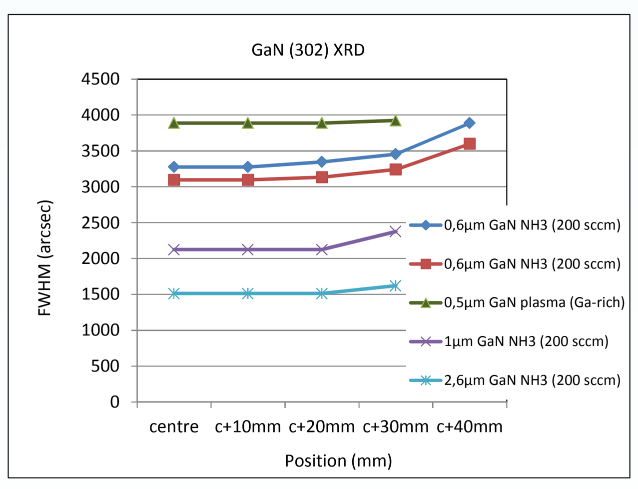
XRD results

Uniformity

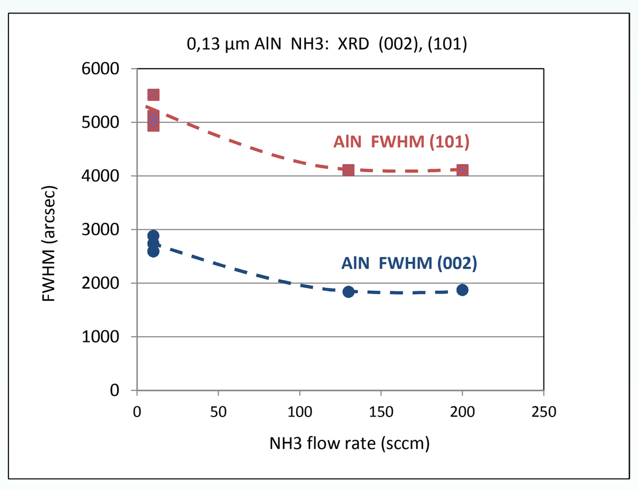


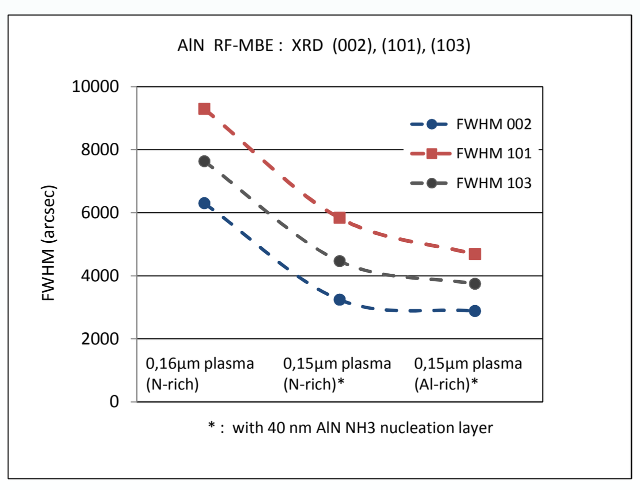




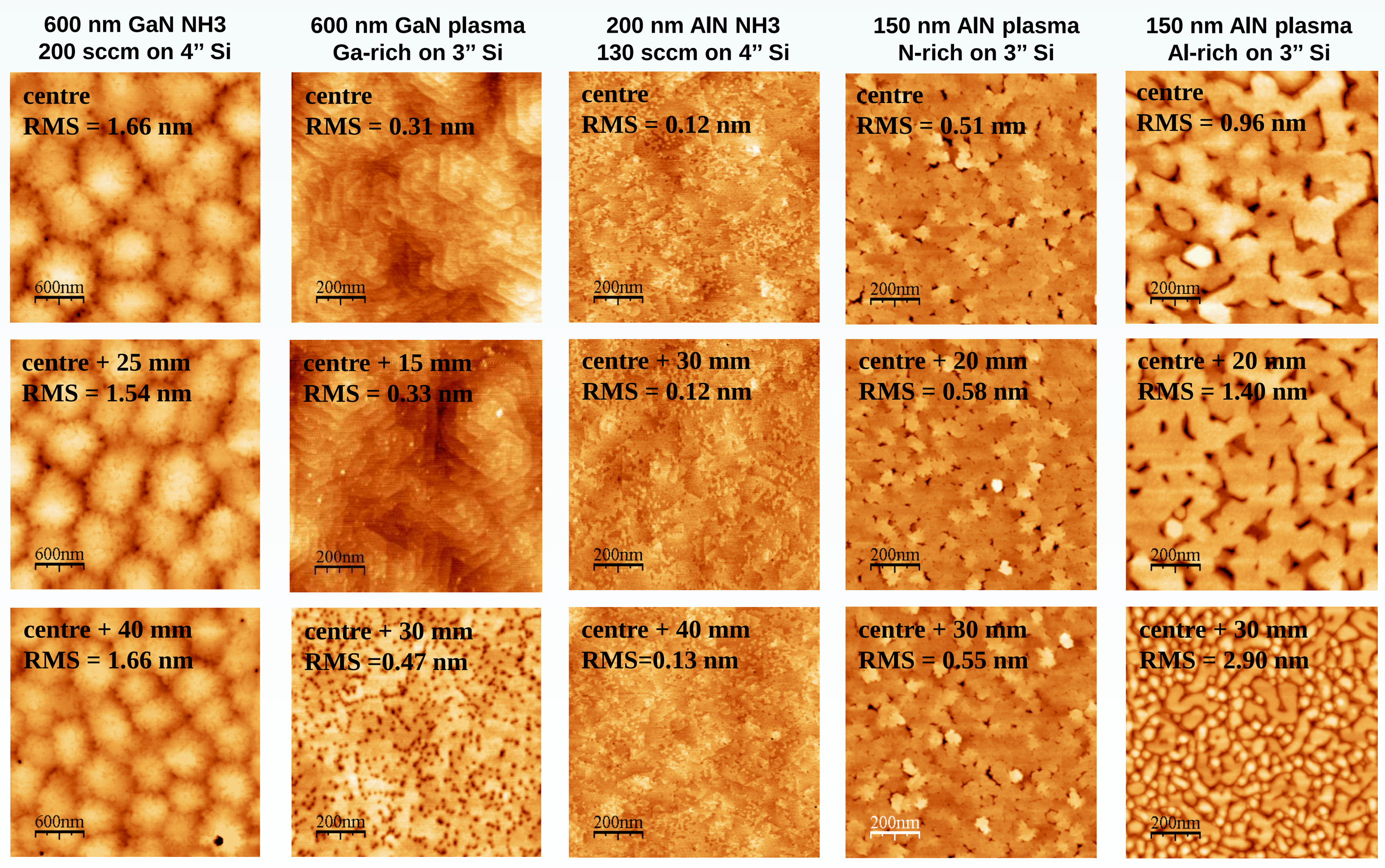


Influence of nitrogen source and flow rate





AFM : surface morphology



Complementary information

-*Influence of nitrogen precursor and its flow rate on the quality and the residual doping in GaN grown by molecular beam epitaxy,* Y.Cordier, F.Natali, M.Chmielowska, M.Leroux, C.Chaix, P.Bouchaib, Physica Status Solidi C 9, 523–526 (2012).

-*Advances in quality and uniformity of (Al,Ga)N/GaN quantum wells grown by molecular beam epitaxy with plasma source,* F.Natali, Y.Cordier, C. Chaix, P.Bouchaib, Journal of Crystal Growth (311) 2029–2032 (2009).

-*Signature of monolayer and bilayer fluctuations in the width of (Al,Ga)N/GaN quantum wells,* F.Natali, Y.Cordier, J.Massies, S.Vezian, B.Damilano, M.Leroux, Physical Review B 79, 035328 (2009).

-*Developments for the production of high quality and high uniformity AlGaN/GaN heterostructures by Ammonia MBE,* Y.Cordier, F.Semond, J.Massies, M.Leroux, P.Lorenzini, C.Chaix, Journal of Crystal Growth (301/302) 434-436 (2007).

-*Quality and uniformity assessment of AlGaN/GaN Quantum Wells and HEMT heterostructures grown by molecular beam epitaxy with ammonia source,* Y.Cordier, F.Pruvost, F.Semond, J.Massies, M.Leroux, P.Lorenzini, C.Chaix, Physica Status Solidi C 3, 2325-2328 (2006).