Modeling of MOCVD of GaN-based electronic devices

Outline :

1. Introduction

2. AlGaN buffer: parasitic reactions and uniformity

3. Carbon incorporation in GaN and AlGaN

4. AlGaN barrier layer: thickness and composition uniformity

5. Summary

Scope of modeling:

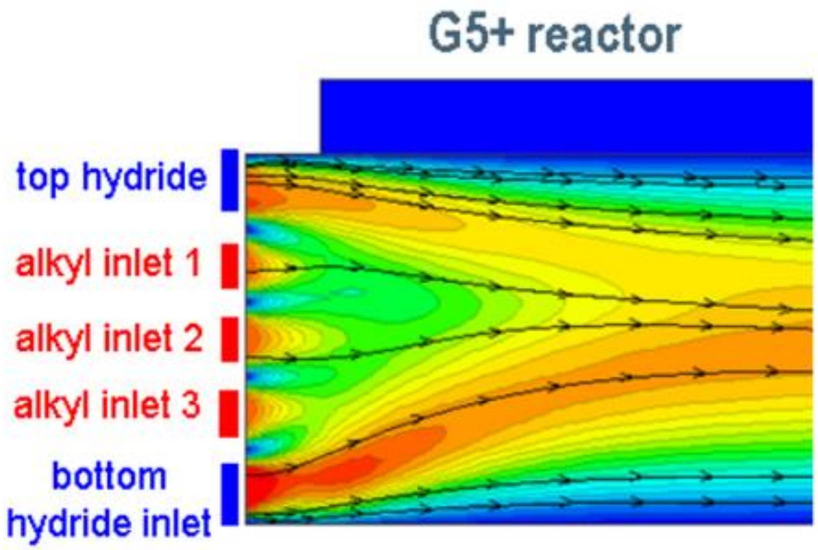
- Gas flow in the reactors
- Heat transfer and temperature distribution over the wafer
- Gas-phase and surface chemical reactions
- Prediction of the growth rate and layer composition, dopant concentration; distribution over the wafers
- Parasitic deposition and particle formation

Typical GaN-on-Si device structure

What is needed:

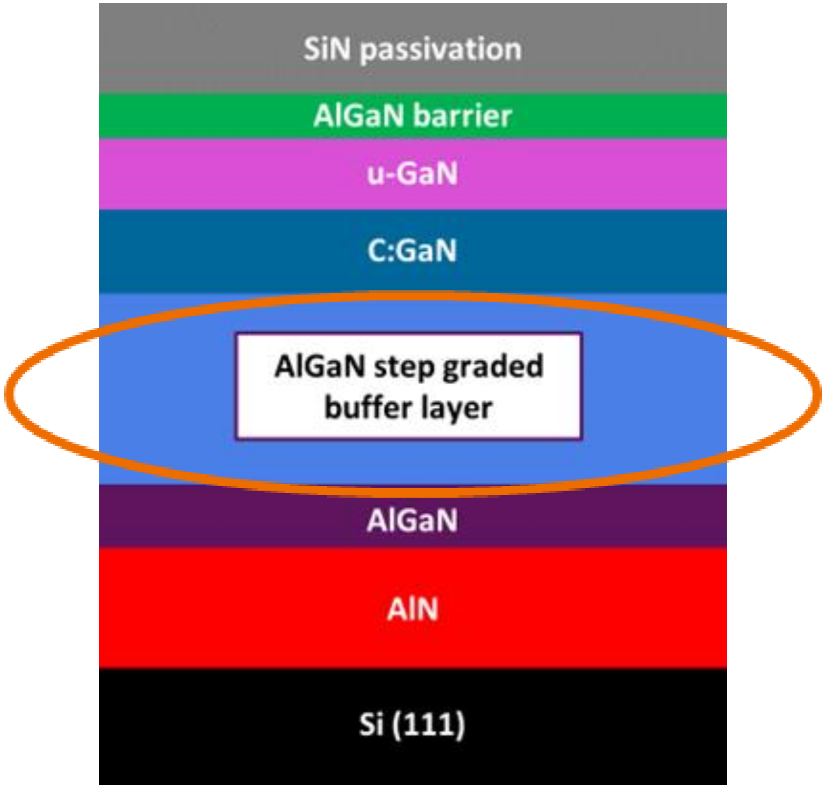
- Reasonable growth time
- Good uniformity
- Targeted electrical properties
- Strain control and crack suppression

Model of G5+C reactor:

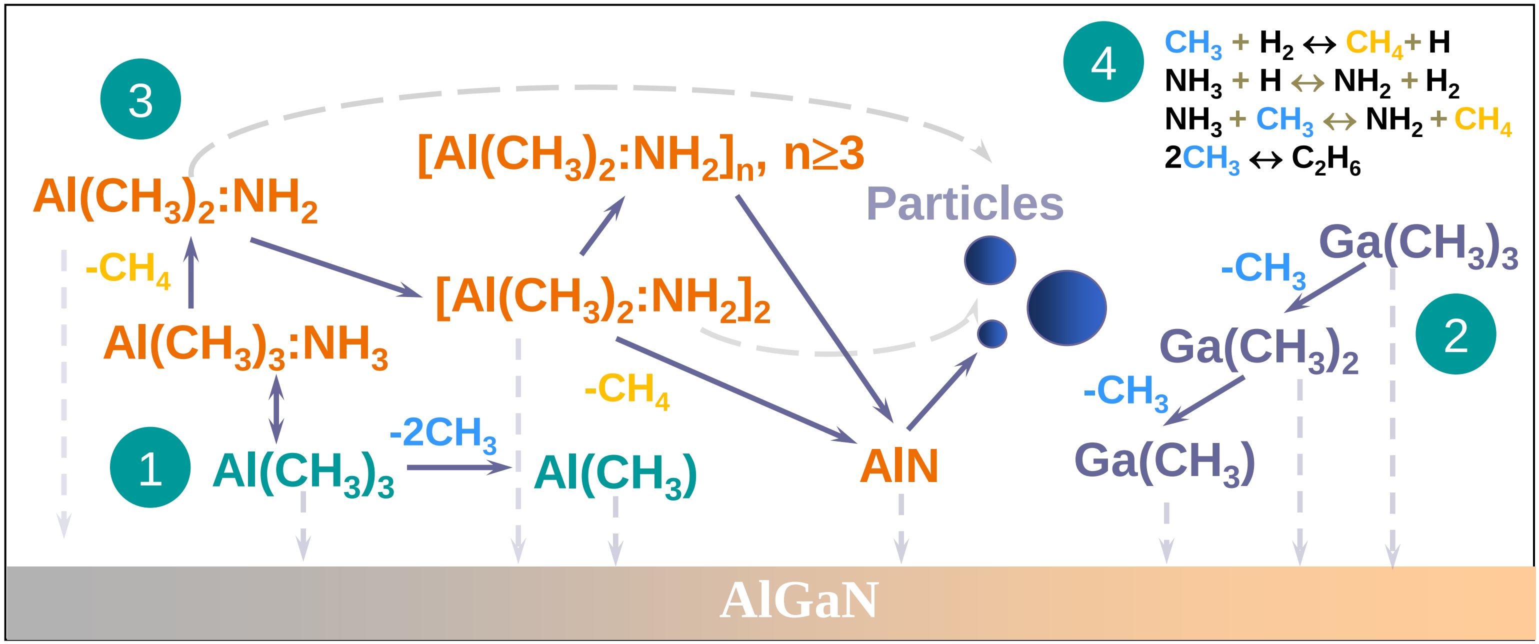


Detailed model of G5+C reactor is used to demonstrated simulation capabilities

Optimization of growth and uniformity of the buffer layers



Gas-phase and surface chemistry

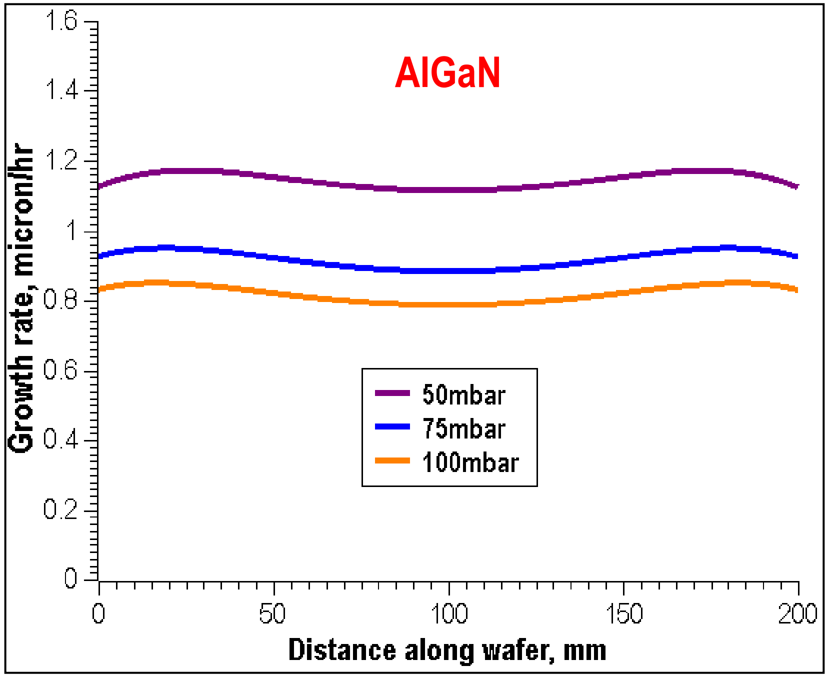


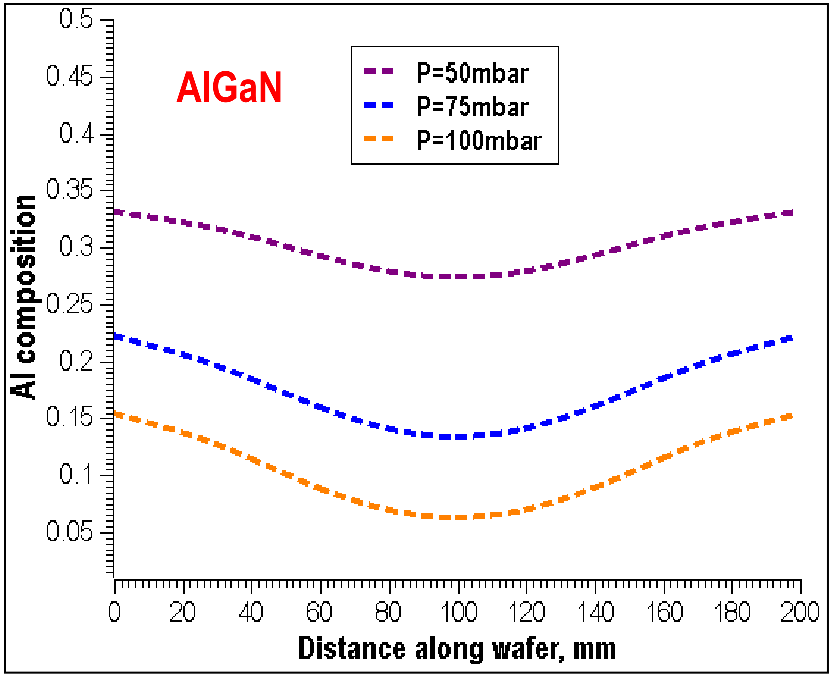
1 2 - TMAl and TMGa decomposition strongly temperature dependent

3 - Adduct formation and parasitic reactions: ammonia and pressure dependent

4 - Reactions with radicals

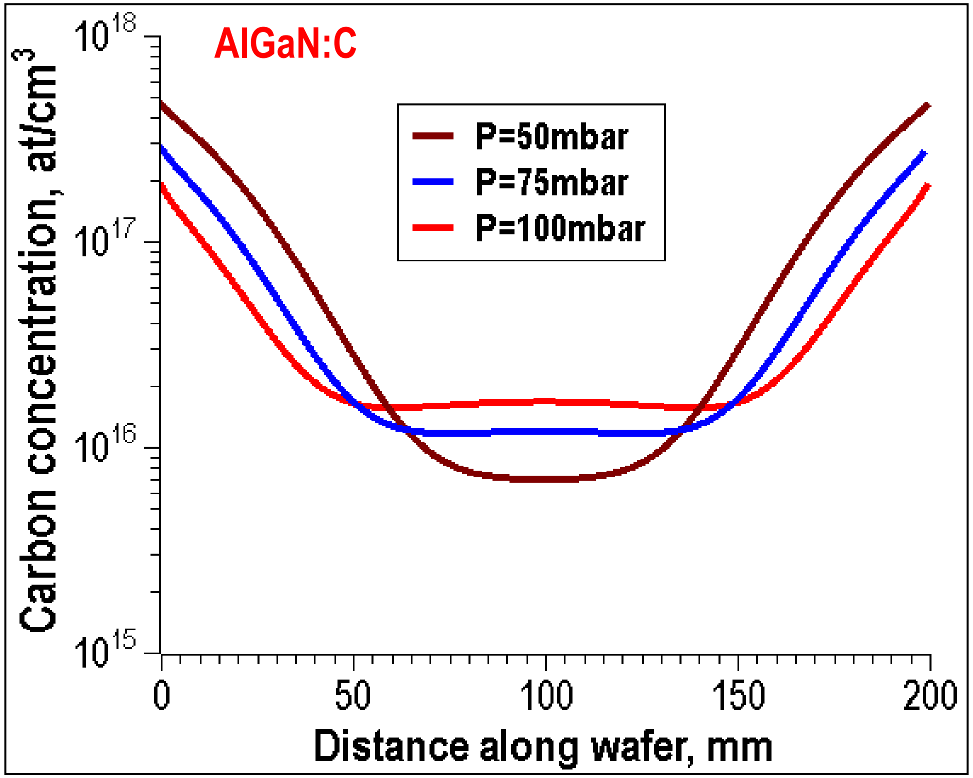
AlGaN buffer layer: growth rate and Al content





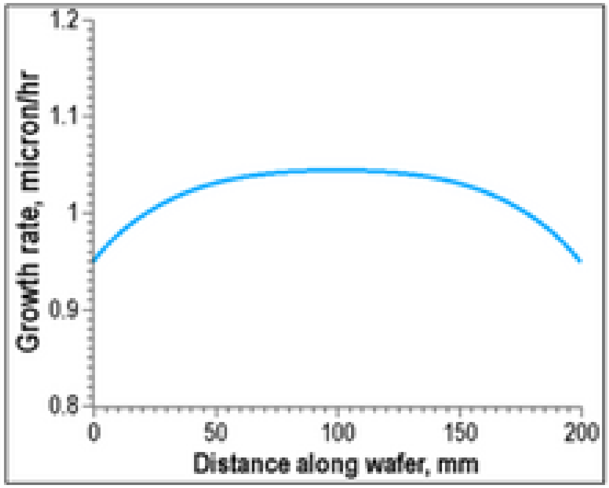
Growth rate and Al composition decrease due to parasitic reactions, uniformity gets worse

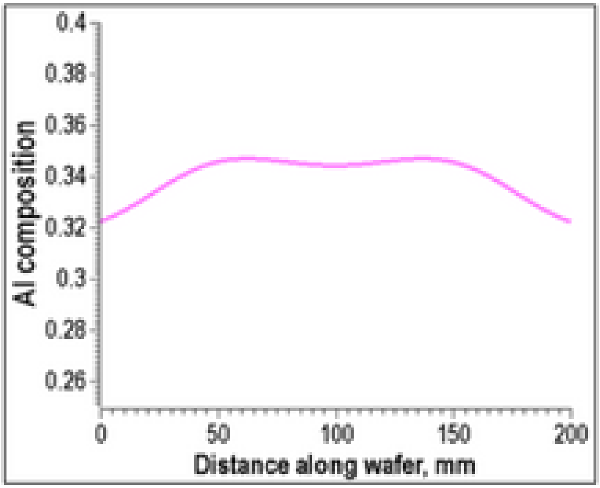
AlGaN buffer layer: carbon concentration vs P

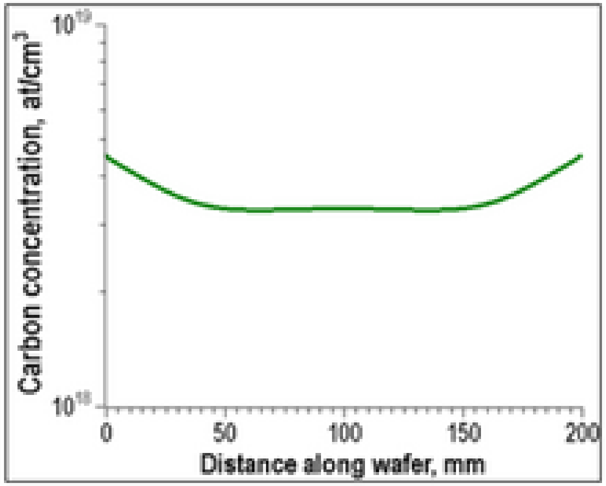


However carbon concentration uniformity gets better because of the difference in growth and doping mechanism

AlGaN buffer layer: optimized conditions

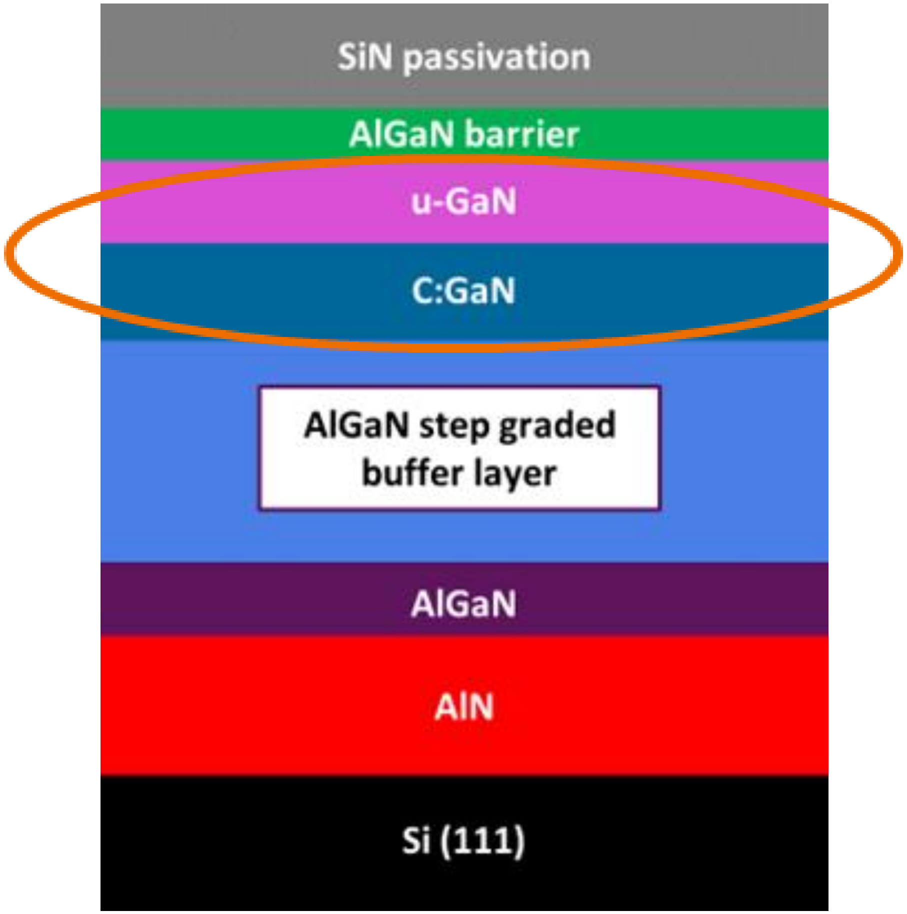






Optimized conditions allow to improve the uniformity and keep reasonable growth rate

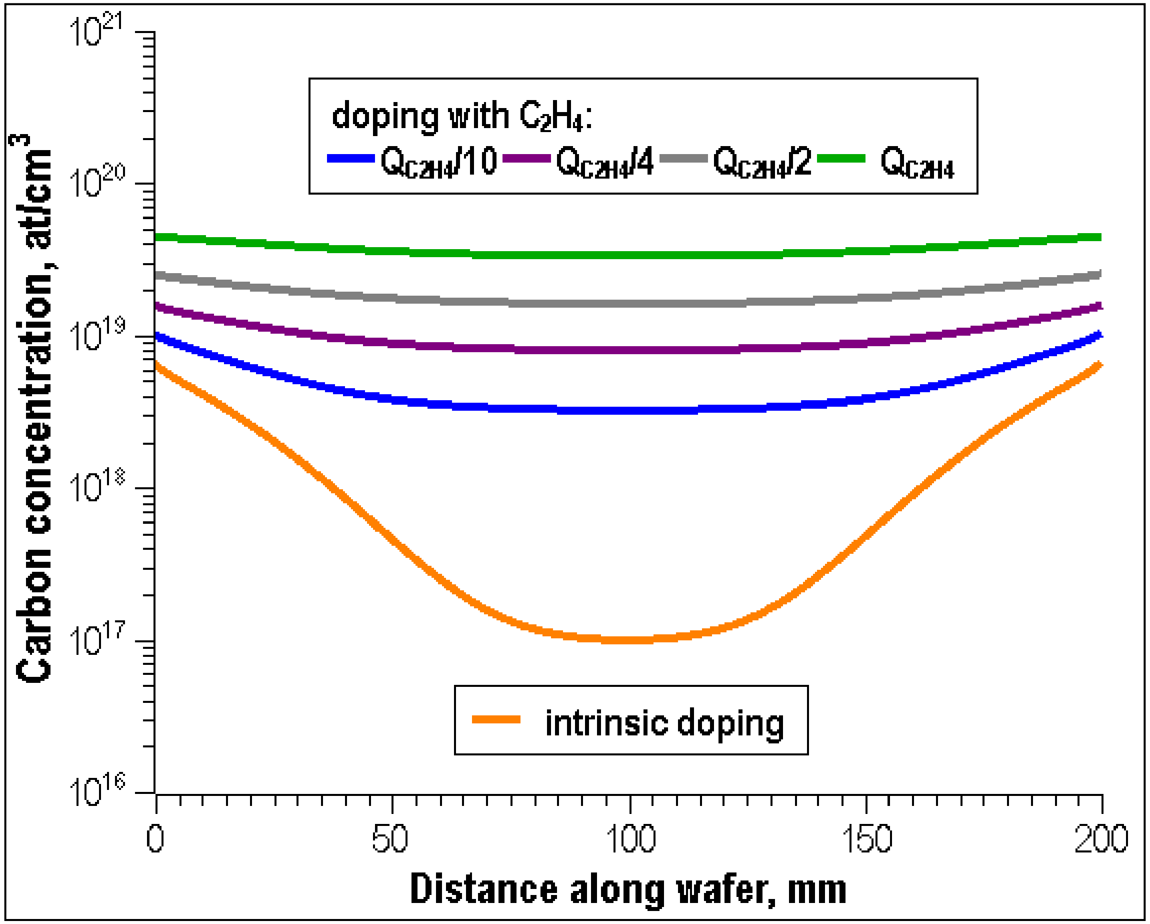
GaN: doping and uniformity



Carbon incorporation to GaN is sensitive to:

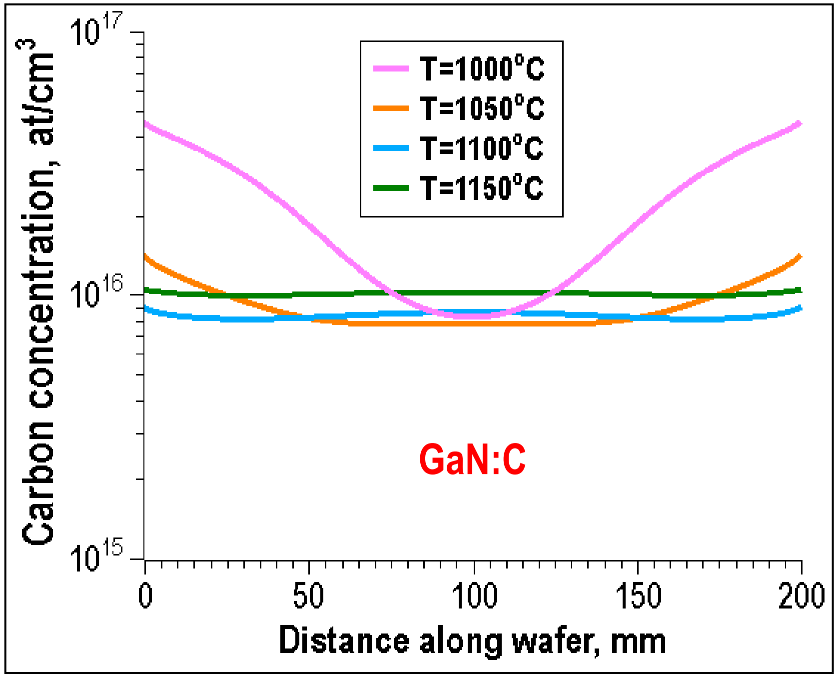
- Temperature
- Carrier gas
- Precursor flow rates
- Pressure
- Reactor type

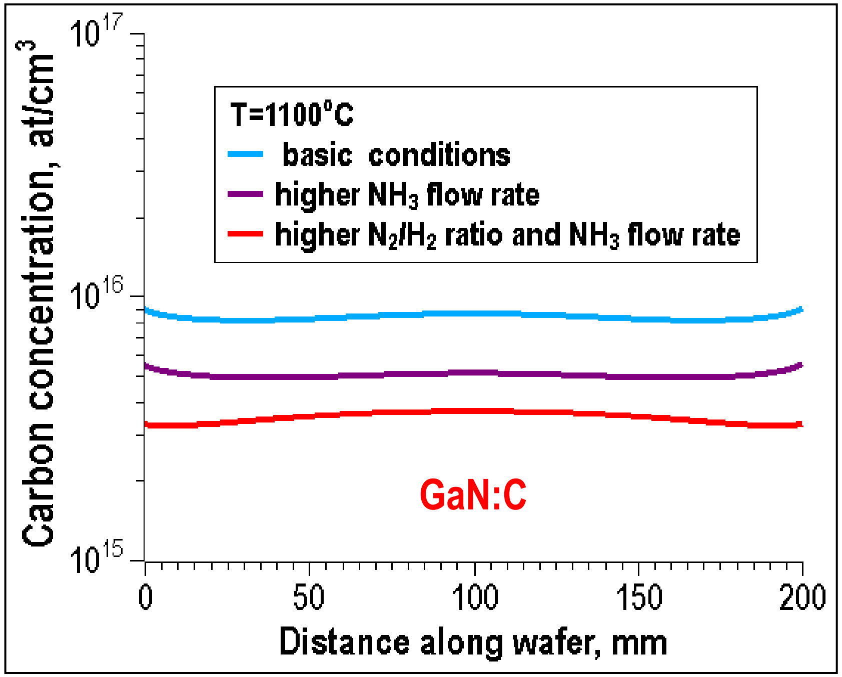
GaN:C layer: carbon incorporation



Desired carbon concentration and uniformity can be reached by using external doping source

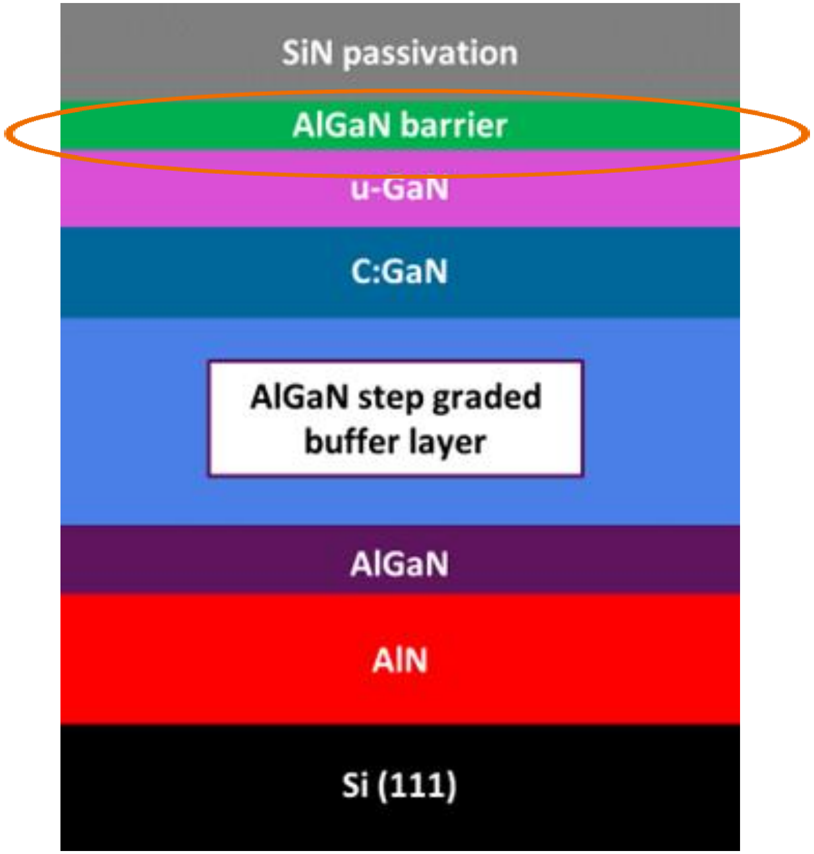
Undoped GaN channel: carbon incorporation



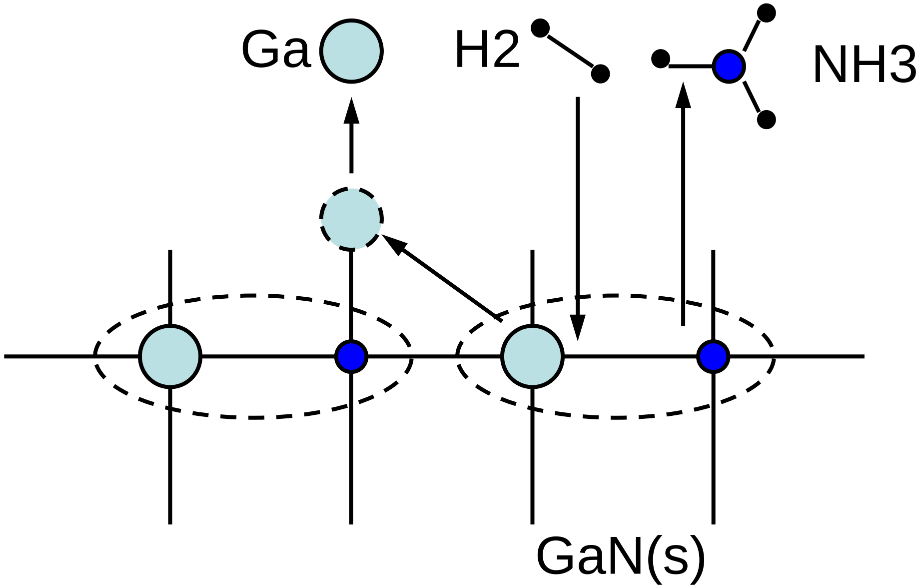


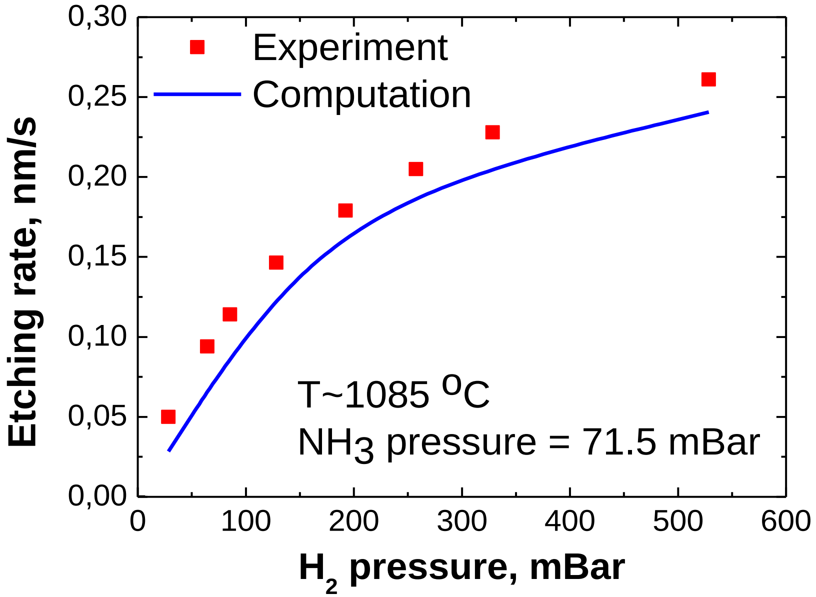
Highly pure and uniforms layers can be grown by applying proper growth conditions

AlGaN barrier layer: thickness and composition uniformity



GaN surface chemistry: etching by H_2





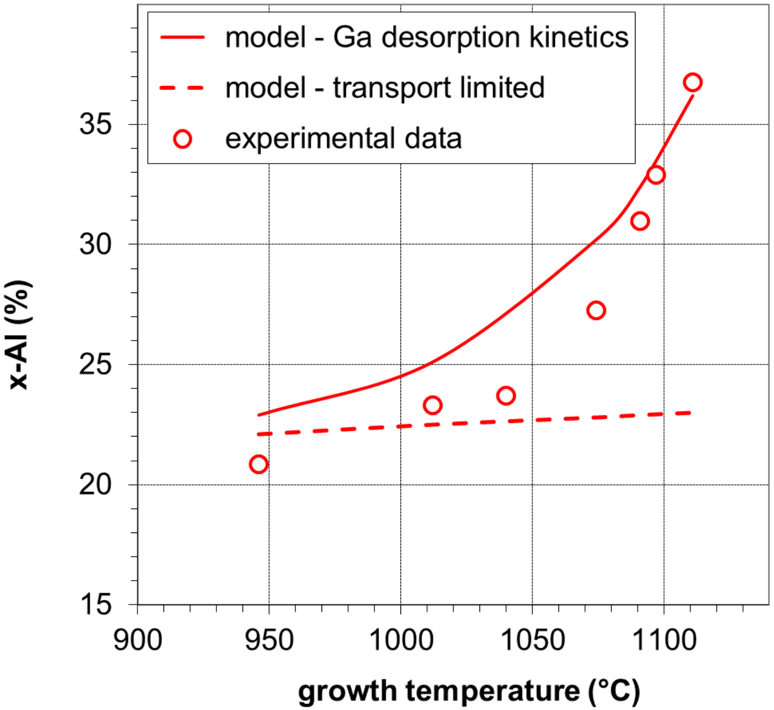
GaN(s) + _V + (3/2)H_2 ⇔ Ga_V + NH_3 – Ga is removed form bulk to surface

Ga_V ⇔ Ga + _V – Ga desorption

E.E. Zavarin et al, ECS Proc, 2005-09 (2005) 299

AlGaN etching by H_2

M. Daulesberg et al, JCG 393 103 (2014)



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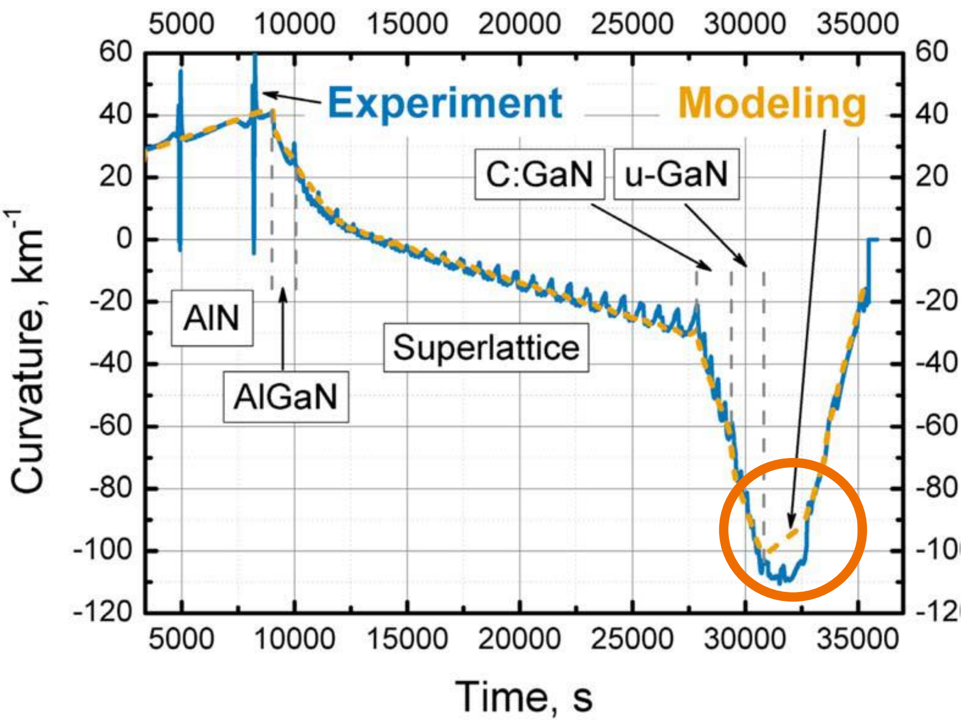
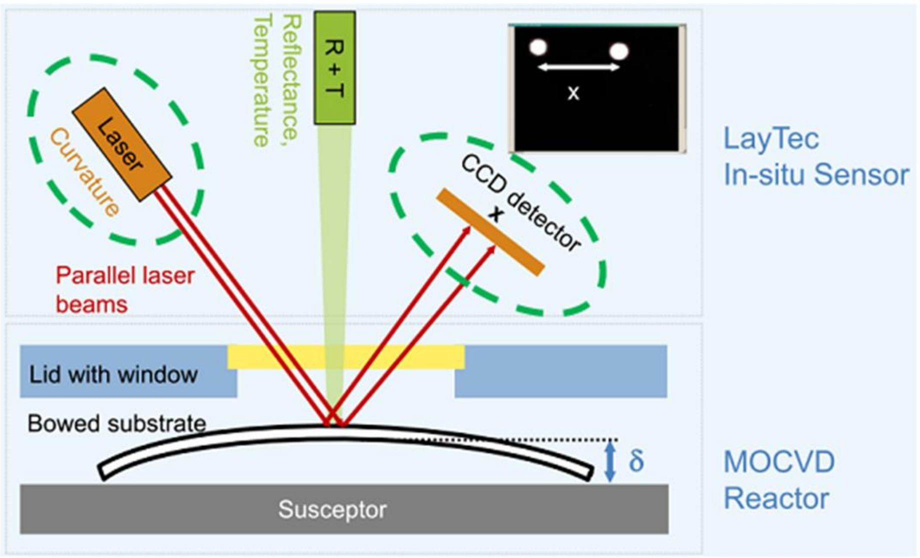
- **Dependence of AlGaN composition and thickness on temperatures is caused by hydrogen etching reaction**

- **This effect is critical for barrier layer uniformity**

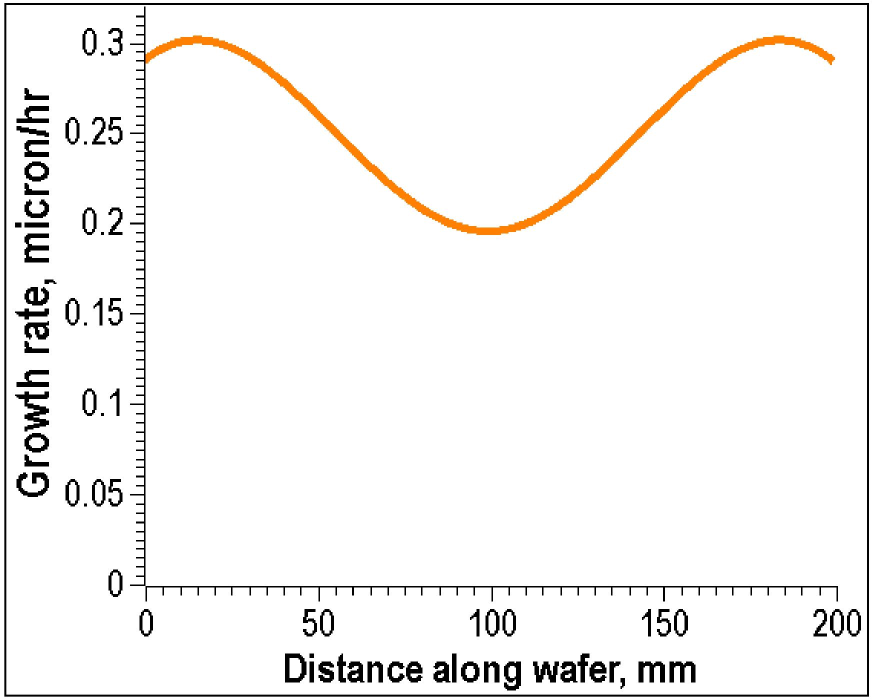
Temperature distribution on the wafer

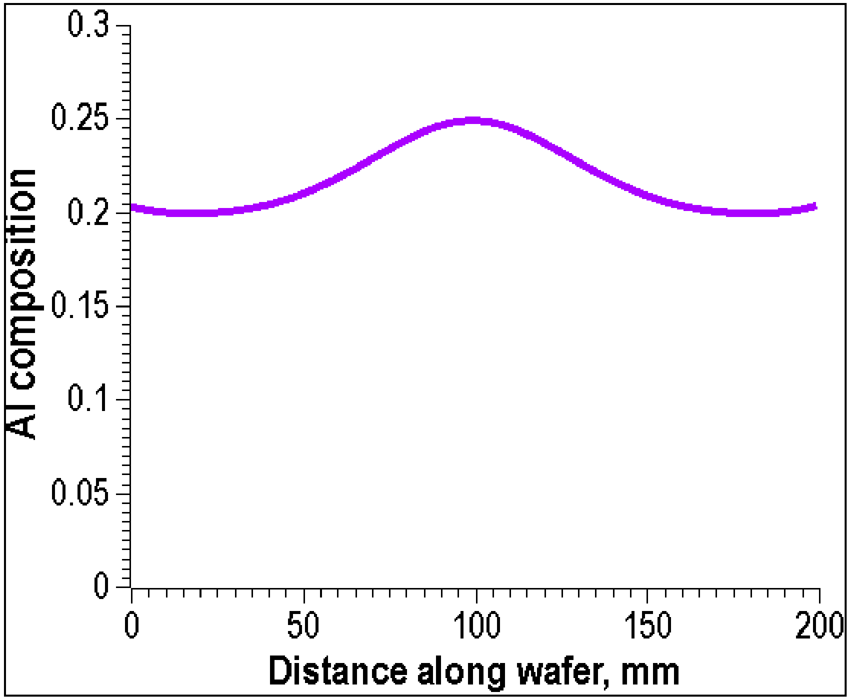




Strong convex bowing results in non-uniform wafer temperature

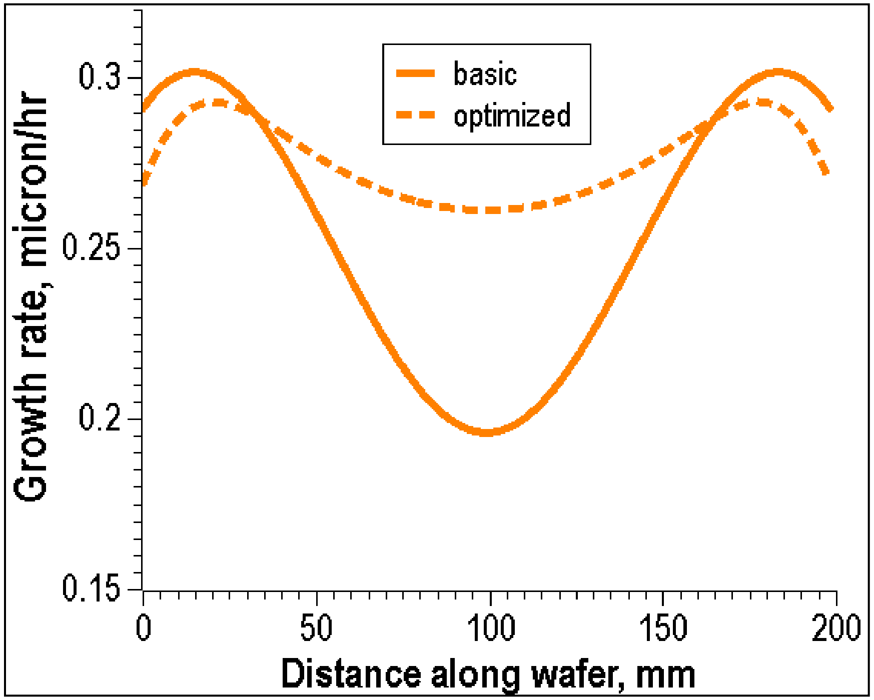
Barrier layer uniformity: basic conditions

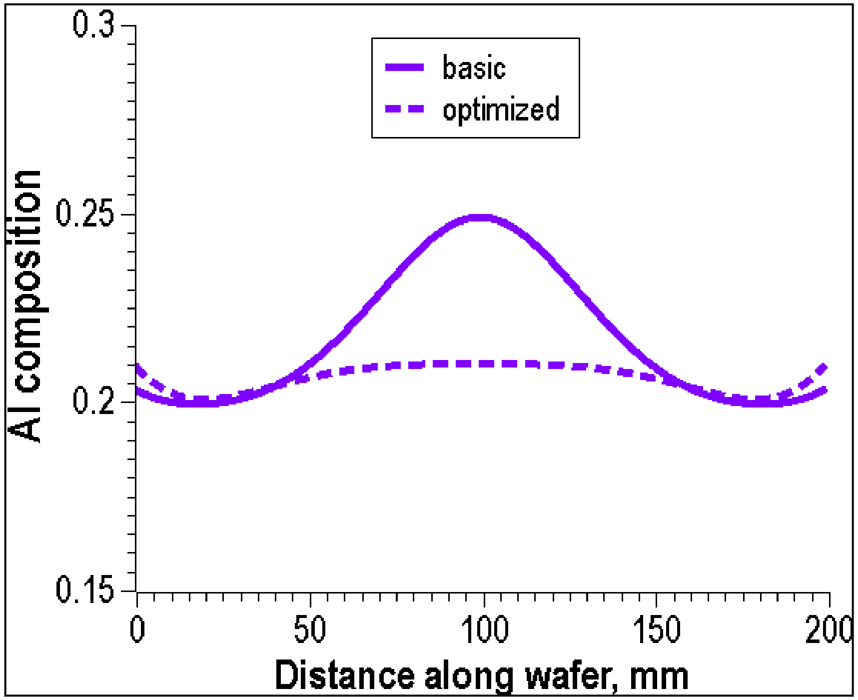




Temperature non-uniformity in non-uniform thickness and composition distribution of the barrier

Barrier layer uniformity: optimized conditions





Optimized conditions allow improving barrier layer uniformity

Summary:

- MOCVD process model can be used to analyze the productivity and uniformity at all stages of GaN-on-Si epiwafer growth
- AlGaN composition uniformity depends on gas-phase parasitic reactions and temperature distribution over the wafer and can be optimized by proper growth conditions
- Carbon concentration in GaN and AlGaN strongly depends on process parameters
- MOCVD modeling can be effectively used to improve the process characteristics and reduce the cost of production of GaN-based electronic devices