# Blue LED MOCVD Manufacturing Yield Optimization

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**Abstract**

**This paper describes developments in mass production of InGaN based blue LEDs on dry-etched patterned sapphire substrates (DPSS) using MOCVD. Developments in the thermal uniformity through wafer carrier design and in-situ temperature control contribute to higher product yield.**

## INTRODUCTION

GaN based LED manufacturing for Solid State Lighting requires high performance high yield MOCVD production tools. DPSS wafers offer a cost effective method of increased light output [1-2]. The manufacturing Yield is predominantly determined by the uniformity and reproducibility of the active layer of the LED device structure, the InGaN MQW. Therefore the understanding and optimisation of the MOCVD tool uniformity and reproducibility for InGaN growth is presented.

## PARAMETER STUDY

TABLE I
SUMMARY OF THE STUDIED MQW DEPENDENCIES

| Growth Parameter | DWL (nm) | QW In content (%) |
|---|---|---|
| **Surface Temp.** (K) | -1.37 (nm/K) | -0.24 (%/K) |
| **$NH_3$ Flow** (slm) | -0.34 (nm/slm) | -0.07 (%/slm) |
| **TEGa Flow** (µmol/min) | 0.87 (nm/(µmol/min)) | - |
| **TMIn Flow** (µmol/min) | 0.28 (nm/(µmol/min)) | 0.001 (%/(µmol/min)) |
| **Pressure** (mBar) | -0.056 (nm/mBar) | -0.01 (%/mBar) |
| **Chamber Height** (mm) | -5.73 (nm/mm) | - |

Dependencies of InGaN MQW emission wavelength and growth rate on surface temperature, ammonia flow, group III molar flows, total flow, chamber height and total pressure were experimentally determined for a state of the art production reactor in Table I. A number of parameters have an impact on wavelength with the growth temperature being the strongest. These data serve as input to simulate, understand and improve the MOCVD tool uniformity and performance of LED produced.

## REACTOR DEVELOPMENT

Control of wafer temperature is challenging due to the DPSS being transparent to infrared pyrometry. In this study the temperature of all 4 heater zones were independently controlled using 4 infrared pyrometers measuring on the graphite between the wafers to enable a flat temperature profile across the wafer carrier.

To improve run to run stability TEQualizer correction was developed. The actual wafer temperature was sampled using a 405 nm pyrometer after a minimum of 1.5 µm of GaN growth. This temperature was compared to a reference and the setpoint temperatures were corrected of subsequent layers, including the InGaN QWs. A run to run reproducibility of σ <1 nm was achieved which together with the radial profile control resulted in over 95% of wafers with average wavelength within a 6 nm bin, as shown in Figure 1.

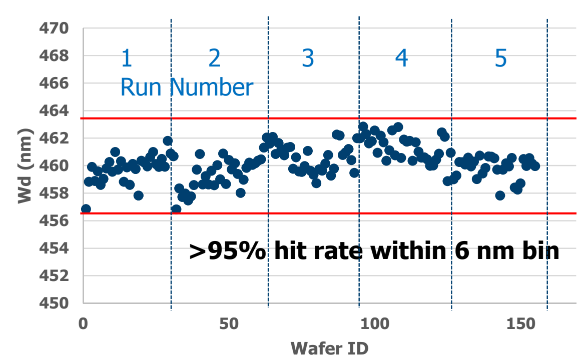


Fig. 1. Graph of PL average wafer wavelength for a series of 5 fully loaded 31x4" PSS blue LED growth runs. Run to run reproducibility of s = 0.6 nm and >96% of wafer averages in a 6 nm bin were achieved.

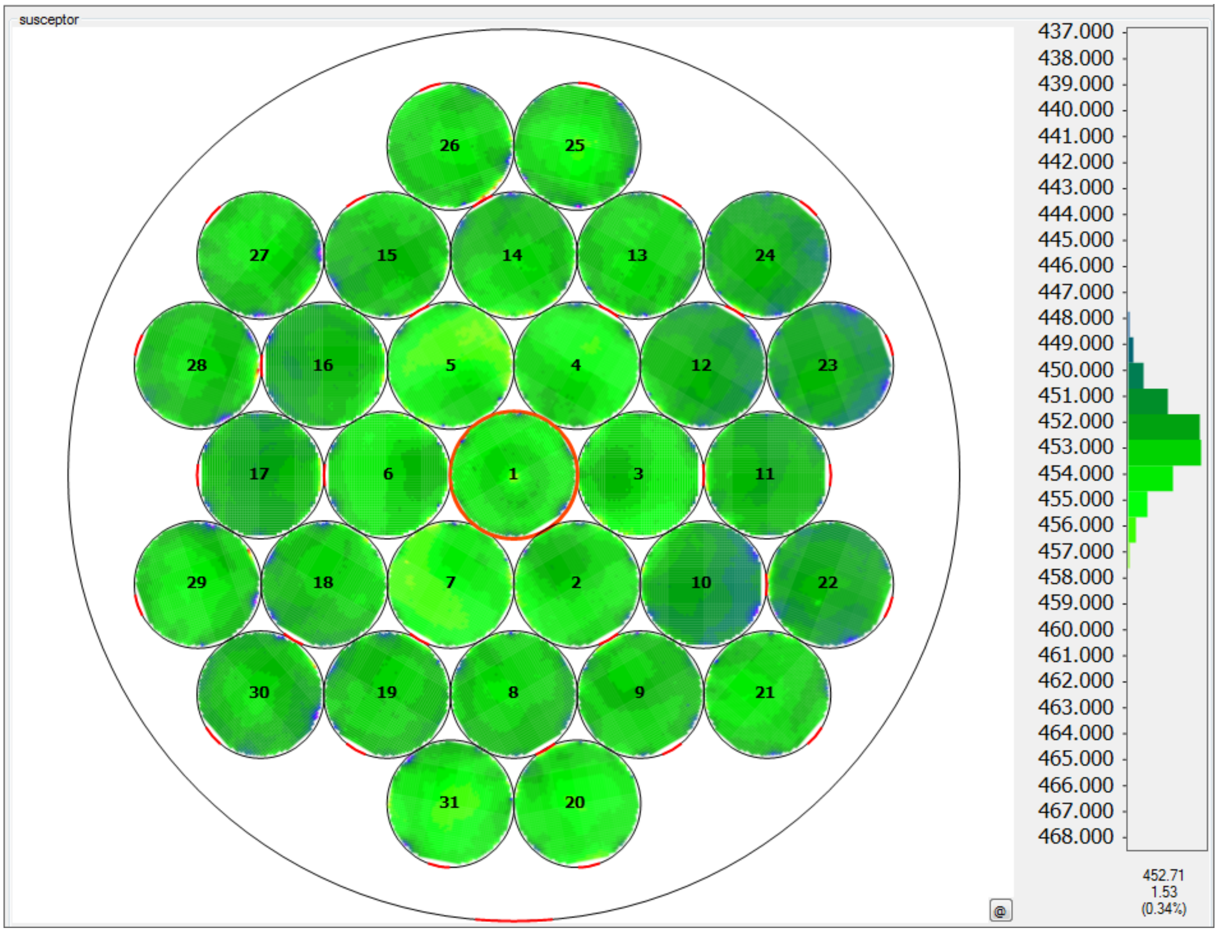


Fig. 2. PL wavelength uniformity of a 31x4" PSS blue LED growth run. Average on wafer uniformity was σ = 1.1 nm with 2 mm edge exclusion and wafer-to-wafer uniformity was σ = 1.1 nm.

The wafer carrier design was also optimized to maintain wafer uniformity during the entire growth process. Uniformities of σ = 1.1 nm were achieved for both wafer-to-wafer and within wafer (with 2 mm edge exclusion) at a mean wavelength of 452.7 nm as shown in Figure 2.

In the series described above, centered at 460 nm wavelength, on wafer uniformities of σ ~1.5 nm were achieved over 5 runs. Combined with the run to run and wafer to wafer stability corresponds to a wafer area yield of >90% in a 6 nm bin.

## Conclusions

Detailed studies were conducted to identify sensitivity to key process parameters. Based on this, technologies were introduced to improve yield performance. State of the art in-situ monitoring combined with thermal optimization has been shown to deliver over 90% yield in a 6 nm bin.

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## References

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## Acronyms

LED: Light Emitting diode
MOCVD: Metal Organic Chemical Vapor Deposition
DPSS: Dry Etched Patterned Sapphire Substrate
MQW: Multiple Quantum Well
DWL: Dominant Wavelength