Growth of InGaN MQW Structures in an Optimized 24x2 inch Planetary Reactor®

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Motivation

- The AIX 2600G3 HT is the market leading MOCVD tool for mass production of LEDs.
- Cost of Ownership (CoO) of the production equipment directly influences market profitabilty for the manufacturer of devices.
- CoO is influenced by
  - wafer yield
  - precursor efficiency
  - tool flexibility
  - stability of reactor hardware
- The AIX 2600G3 HT Yield ⊕ configuration addresses CoO by design.

The AIX 2600G3 HT with Yield ⊕

Details of the Reactor Hardware

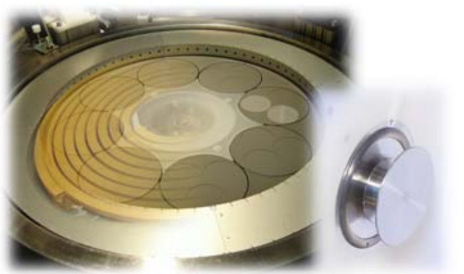


Fig. 1: The AIX 2600G3 HT in the Yield ⊕ configuration with larger RF coil for better radial temperature uniformity, large quartz center and water cooled stainless steel Triple Gas Injector (TGI).

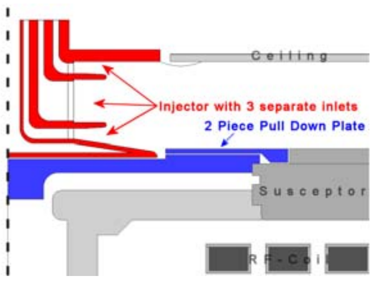


Fig. 2: Schematic cross section of the reactor center showing the water cooled, stainless steel Triple Gas Injector (TGI) and the 2-piece quartz pull down plate with exchangable cover.

Design of the Yield ⊕ Configuration

Numerical Modelling of the Gas Flow

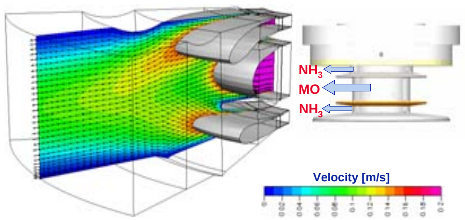


Fig. 3: CFD modelling of the flow dynamics of the Triple Gas Injector. In gray the iso-surface for the gas velocity of 0.15 m/s is shown. No return flows can be seen and the deposition free zone around the reactor center is enlarged compared to the conventional design (not shown here).

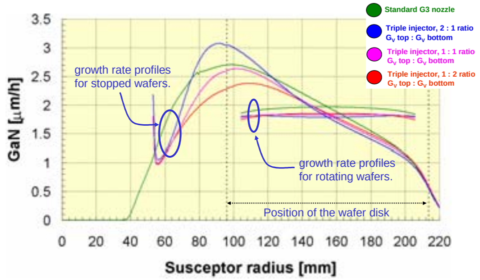


Fig. 4: Growth rate as a function of radial position on the susceptor for the conventional and the TGI for different ratios of upper/lower inlet flows. As can be seen, the growth profile on the rotated wafer can be tuned from concave to convex indicating the presence of an optimum flow ratio.

Numerical Modelling of the Temperature Distribution in the Reactor (Comparative to the Conventional Design)

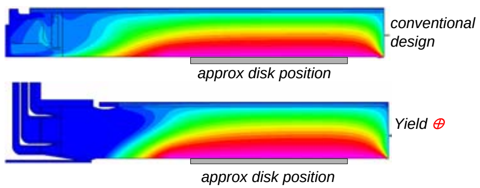


Fig. 5: Numerical modelling of the temperature distribution in the gas phase for a cross section of the reactor. Left: inlet area, right: collector ring. The Yield ⊕ features a steeper temperature gradient from cold center to the growth zone, effectively reducing undesired reactions.

Experimental Results

Growth of MQW Structures in the Green Spectral Range (5 Consecutive Runs)

	λ [nm]	σ [nm]
#1	526.6	1.13
#2	526.8	1.2
#3	526.6	1.27
avg.	526.7	1.2
Δλ	0.2	

	λ [nm]	σ [nm]
#1	528.4	0.46
#2	528.1	0.58
#3	527.7	1.39
avg.	528.1	0.81
Δλ	0.7	

	λ [nm]	σ [nm]
#1	524.2	1.69
#2	522.7	0.68
#3	523	0.47
avg.	523.3	0.95
Δλ	1.5	

	λ [nm]	σ [nm]
#1	524.1	0.9
#2	523.1	0.8
#3	524.2	1.7
avg.	526.7	1.13
Δλ	3.6	

	λ [nm]	σ [nm]
#1	523.2	1.5
#2	524.5	1.8
#3	523.8	1.5
avg.	526.7	1.7
Δλ	1.3	

Fig. 6: Photoluminescence mappings for five consecutive runs (one exemplary disk each) without any change of hardware or recipe.

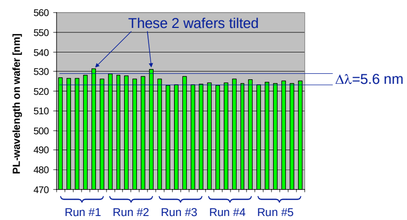
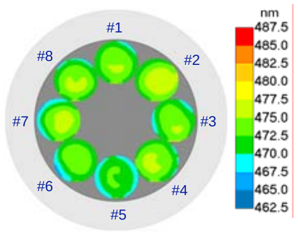


Fig. 7: Average wavelength of photoluminescence mappings for all wafers from 5 consecutive runs (2 disks/6 wafers loaded per run). The average wavelength over all wafers was λ_{avg} = 525.4 nm (excluding two tilted wafers). $\Delta_{max-min}$ = 5.6 nm.

Growth of MQW Structures in the Blue Spectral Range in the 8x4 inch Yield ⊕ Configuration



	λ [nm]	σ [nm]
#1	473	1.59
#2	474.5	1.73
#3	472.2	1.78
#4	473.4	1.65
#5	470.9	1.3
#6	472.2	1.88
#7	473.2	2.32
#8	473.2	1.73
avg.	472.8	1.75
Δλ	3.6	

Fig. 8: Photoluminescence mapping results for a fully loaded run on 4 inch in the blue spectral range. Wafers had typical wavelength standard distributions below 2 nm. At an average wavelength of λ_{avg} = 472.8 nm a $\Delta_{max-min}$ = 3.6 nm was measured.

Investigation of Process Flexibility

Uniformity Tuning of InGaN MQW Structures – Additional Degree of Freedom

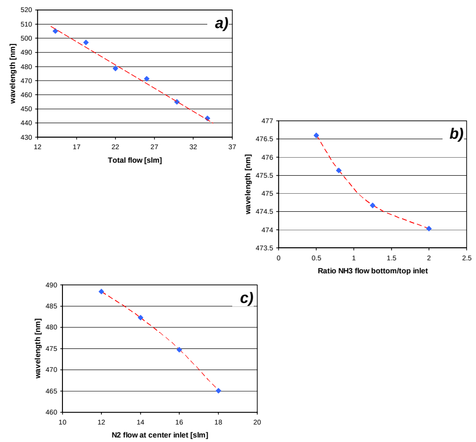


Fig. 9: In Planetary Reactors® the total flow Q_{tot} is used for precise thickness uniformity tuning. The Yield ⊕ configuration with the Triple Gas Injector allows additional degrees of freedom for the concurrent adjustment of the emission wavelength while tuning the thickness with Q_{tot}. a) Influence of Q_{tot} on wavelength. b) Influence of the ratio of NH_3 flows at the lower and upper inlet on the wavelength. c) Influence of the N_2 pusher flow at the center MO inlet on the wavelength.

Conclusion

- The AIX 2600G3 HT in the Yield ⊕ configuration was numerically modelled and experimentally verified.
- Improvements with respect to wafer yield (on wafer, wafer to wafer and run to run) for 2 inch and 4 inch could be demonstrated.
- The Triple Gas Injector (TGI) design offers additional degrees of freedom for process tuning.
- The water cooled stainless steel TGI provides a cold reactor center enhancing utilization of precursors and decreasing deposition at the reactor ceiling.

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