Modeling and experimental validation of a new gas injector design for III - Nitride growth in the 42x2” Planetary Reactor configuration

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This paper deals with the functionality and motivation behind a new gas delivery concept for the growth of III-Nitrides in the 42x2” Planetary Reactor®. Focus is on improvements to current state of the art injector design to enable reactor scale up from the 24x2” to 42x2” configuration, thereby improving reactor load capacity and by definition throughput and cost of ownership. The development of the new injector design using modeling and its subsequent validation by experiment is discussed, with particular emphasis on the resulting depletion curve within the process chamber. The flexibility of the new injector design with regard to changing process conditions will also be discussed along with its suitability to high Al content layer growth, and capability of Nitride growth at elevated process pressures of up to 1000 mbar.

Current state of the art technology for supply of group III and group V precursors for Nitride MOVPE involves the supply of G_{III} and G_V gas species separately to prevent premature cross-reactions during the process. Typically, this is performed using a two-flow gas injector with group III source gases plus carrier introduced from above and NH_3 introduced through the lower inlet closer to the hot substrate holder to enhance pyrolysis. The gas inlet is centered within the process chamber producing a symmetric flow profile directed towards the exhaust. In the Planetary Reactor®, this setup typically results in a linearly declining growth rate profile indicating optimum usage of precursors and high growth efficiency, with growth rate uniformity achieved via individual satellite rotation. When scaling up to larger reactor configurations e.g. from 24x2” up to 42x2”, a ramp up in process gas flow rates is necessary to compensate for the increased capacity and reactor chamber size. Therefore the gas entrance length, which is defined by the momentum of group V species through the bottom inlet and is necessary for supply of growth contributing species to the growing surface, becomes critical. This places a limitation on the process behaviour in terms of the position of the above-mentioned depletion curve.

A new injector design was developed to improve the overall method of delivery of gas into the process chamber. A third inlet above the MO for the supply of group V species was introduced, providing more control over the deposition process by shortening the so-called gas entrance length via re-distribution of some of the group V gas flow to the top inlet. The ratio of the hydride gas flows in the upper and lower group V inlets is now an extra tuning parameter to optimise the depletion curve position and therefore growth rate uniformity. Fig. 1 compares growth rate profiles for GaN using the new injector design and current state of the art. With better momentum balancing between all three gas inlets, a uniform stratified gas flow is supplied ensuring that at the point of gas mixing the flow field is stable and is more robust for a wide range of process conditions. The risk of return flows and / or dead zones within the gas volume is minimized and the likelihood of gas phase pre-reactions and adduct formation is now significantly less, therefore enhancing capabilities for III-Nitride growth at elevated process pressures. In addition, the presence of a third gas inlet above the MO pushes ceiling deposition further downstream away from the injector. The growth environment inside the process chamber is further optimized via a water-cooled injector head, which provides a more abrupt transition from the cold inlet zone to the process ambient. This ensures the injector head remains deposition free thereby promoting better growth conditions, in particular for high Al content layers where the risk of adduct formation is extremely high even at low gas phase temperatures. Fig. 2 illustrates the tunability of layer thickness uniformity using the new injector design by varying upper and lower NH_3 flow.

Experimental results using the new injector in the 42x2” configuration (with 7 wafers on single satellite) show typical peak PL wavelength uniformities of $\sigma_{wafer} = 1$ nm (σ_{wafer} = on-wafer standard deviation) at $\lambda = 470$ nm (blue spectral range), and $\sigma_{wafer} = 1$ nm at $\lambda = 492$ nm (blue / green spectral range) with wafer-to-wafer deviation of 1.44 nm. Run to run reproducibility is reported at 3.9 nm (blue range) and 4.4 nm (green range).

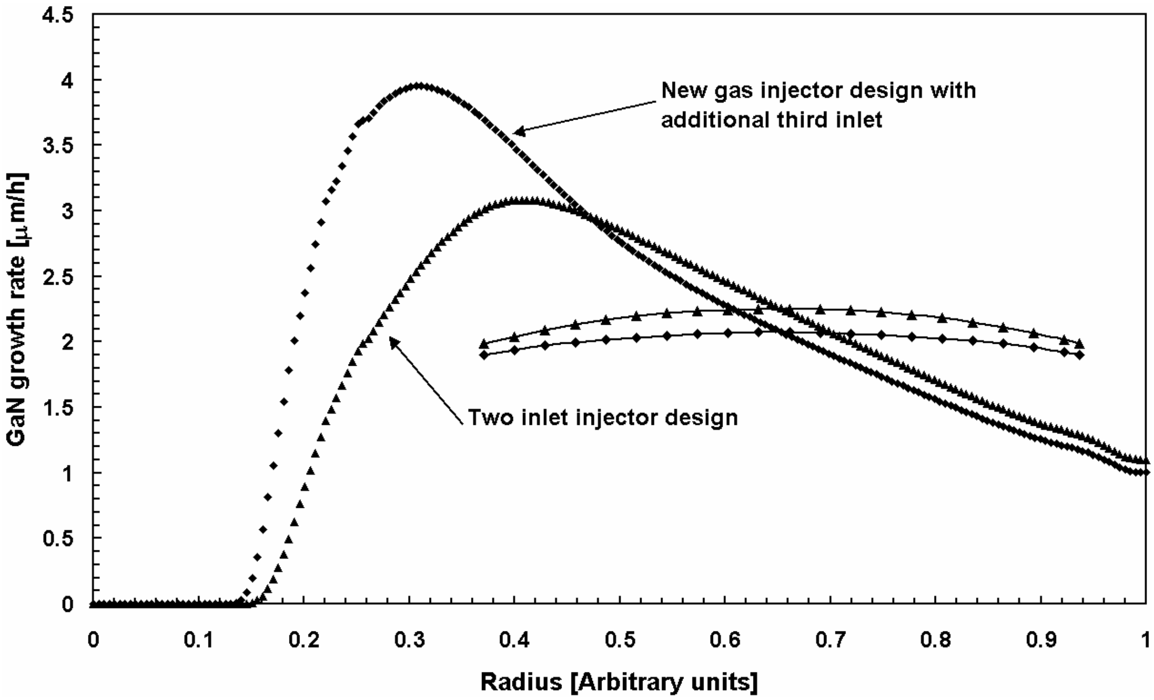

Figure 1. Motivation behind development of new injector design using modeling. Computed GaN growth rate profile as a function of reactor radius (susceptor and rotated satellite) for the two-inlet design and new three-inlet design.

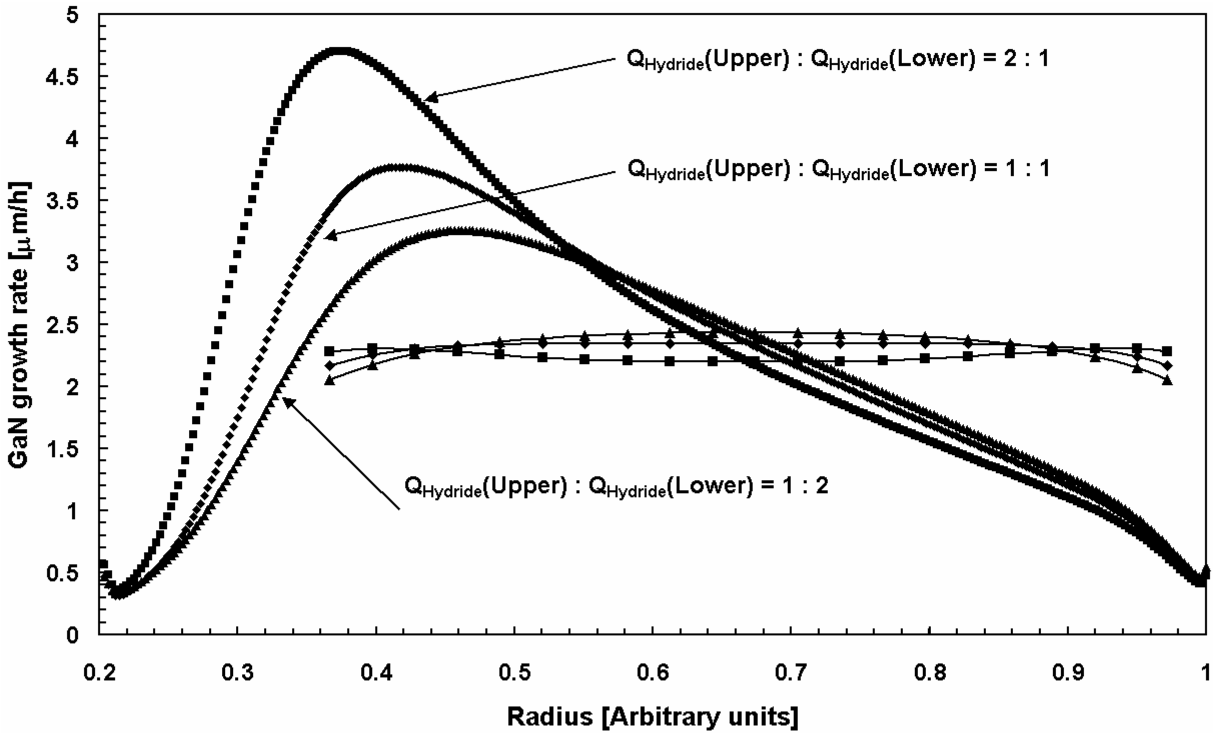

Figure 2. Flexibility of new injector design with respect to position of depletion curve. Computed growth rate profile for GaN as a function of radius (susceptor and rotated satellite). Ratio of upper to lower G_V flow is varied to demonstrate tunability.