Modeling and experimental validation of a new gas injector design in the 42x2“ Planetary Reactor® configuration

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Introduction – functionality and motivation

- Planetary Reactor® scale-up from 24x2“ to 42x2“ configuration.
- Functionality of current injector design and application to 42x2“ Planetary Reactor® configuration.
- Development of new gas injector using modeling and subsequent experimental validation.
- Process flexibility of new gas injector.

AIX2800G4 HT 42x2“ configuration

- Scale up from 24x2“ to 42x2“ configuration :
  - ⇒ Improvement of reactor load capacity and wafer throughput. CoO for system is further reduced.

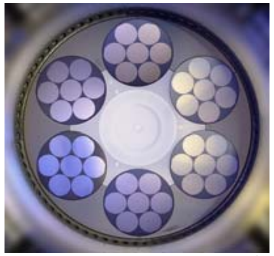

Fig. 1 : AIX2800G4 HT 42x2“ Planetary Reactor® configuration.

- Simulations of reactor based on a 2D axis-symmetric approach limited to process chamber.
- Major model features include :
  - Flow of chemically reacting gas mixture.
  - Heat transfer through reactor parts via conduction, convection and radiation.
  - Precursor decomposition and mass transfer to substrate surface.
  - Thin film deposition of III-Nitride structures.

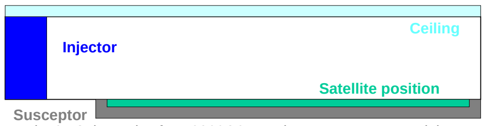

Fig. 2 : Schematic of AIX2800G3 HT Planetary Reactor model.

Existing nozzle design for G3 systems

- Existing two-flow injector for III-Nitride applications on AIX2600G3 HT 24x2“ configuration :
  - Separate injection of G_{III} and G_V species. Group III species + carrier gas are injected through the top inlet preventing premature cross-reactions with hydride precursors.
  - High momentum of NH_3 entering via bottom inlet determines the supply of group III species to growing surface – so-called „gas entrance length“.

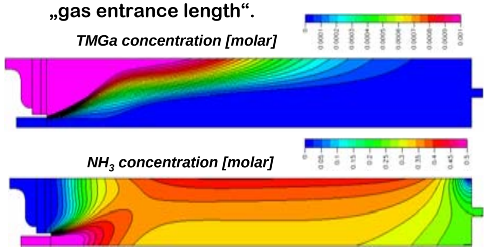

Fig. 3 : Resulting precursor molar concentration for existing two-flow nozzle design on AIX2600G3 HT 24x2“. TMGa (top) and NH_3 (bottom).

- Quartz nozzle heats up to a temperature of approximately 200°C via radiative heat transfer.

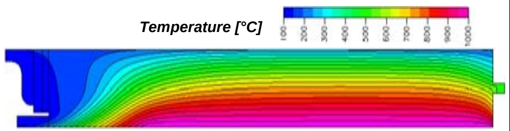

Fig. 4 : Temperature within process chamber for AIX2600G3 HT 24x2“.

- Consumption of growth nutrients in the process chamber results in a linearly declining growth rate profile giving optimum precursor efficiency.

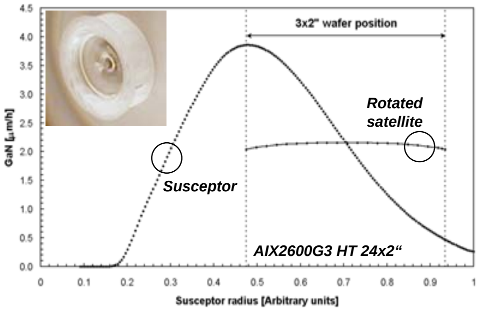

Fig. 5 : GaN growth rate profile for AIX2600G3 HT 24x2“ configuration.

Development of new injector design

- When scaling to larger reactor configurations e.g. 24x2“ to 42x2“, a ramp up in process gas flow rates is necessary to account for the increased capacity and process chamber size :
  - Higher total flow pushes decomposition of precursors further downstream. Use of standard two-flow nozzle on 42x2“, the high momentum of group V flow limits diffusion of III-precursors towards the growing surface.
  - Resulting position of growth rate peak for 42x2“ configuration is not optimized.
  - Solution is introduce a third inlet above the MO for the supply of group V species. Resulting growth rate „peak“ pulled upstream towards reactor centre giving better uniformity due to reduction of so- called „gas entrance length.“
- Actively cooled injector head remains deposition free. Pre-reactions and adduct risk reduced via cooled gas inlet zone.

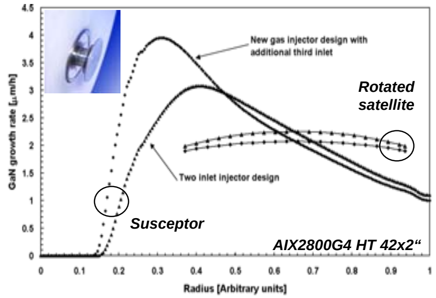

Fig. 6 : Resulting growth rate profile for AIX2800G4 HT 42x2“ Planetary Reactor® using standard two-flow nozzle and new nozzle design.

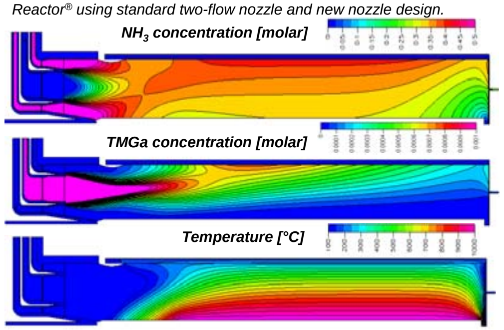

Fig. 7 : NH_3 concentration, velocity magnitude and temperature distribution using new „three-flow“ nozzle design.

Flexibility of new „triple“ injector

- Additional hydride inlet gives added process flexibility to optimize growth rate profile and uniformity. Ratio of upper to lower hydride gas flow is an additional tuning parameter.

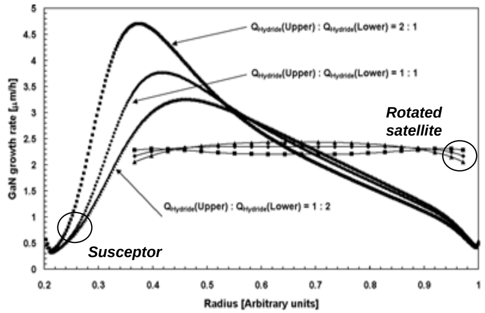

Fig. 8 : Flexibility of new injector design with respect to position of depletion curve. Ratio of upper to lower hydride gas flow is varied.

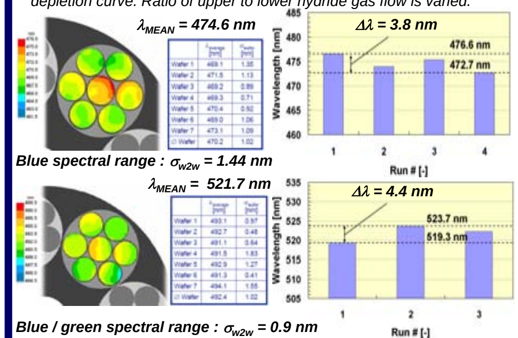

Fig. 9 : Fully loaded MQW run for blue (top) and blue / green (bottom) spectral range in AIX2800G4 HT 42x2“ configuration.

Conclusions

- New gas injector design to improve overall method of delivery of gas into process chamber :
  - ⇒ Increased process flexibility via the upper to lower hydride gas flow ratio.
  - ⇒ Actively cooled injector head provides an abrupt transition from cooled inlet zone to process ambient temperature.
  - ⇒ Injector head remains depositon free giving enhanced capability of GaN growth at high pressure, and for AlN and AlGaN structures.

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