Investigation of a Triple Gas Inlet for the Growth of InGaN MQW Structures in a Large Production Scale 24x2 inch MOCVD Reactor

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The growth of InGaN multi-quantum well (MQW) structures for optoelectronic applications requires the accurate control of the flow patterns in the reactor to avoid unwanted gas phase reactions and to assure a symmetrical distribution of the gases. To decouple the gas inlet from the reactor hardware setup a new inlet design was developed which allows precise mixing, avoids unwanted gas phase reactions and provides additional process tuning capabilities independent of the reactor inlet area properties. The new **T**riple **G**as **I**nlet (TGI) features a second, independent group-V channel at the top of the reactor, allowing for an additional degree of freedom for process tuning (Fig. 1).

The TGI design consists of a stainless steel water cooled body with three inlets, the MO inlet being sandwiched between two hydride inlets above and below. Momentum balancing between all three inlets is well matched, with all gas flows redirected before entering into the process chamber, and gas flow fully axis-symmetric and parallel to substrate surface. This insures a higher level of stability of the system against mechanical mis-adjustment. Experimental and simulated processes indicate better utilisation of NH_3 via delivery (in part) through the top inlet. The water cooled injector ensures a cold gas inlet zone, with a more abrupt transition to process ambient. This minimises the risk of gas phase pre-reactions and adduct formation, and also provides better growth conditions for high Al content layers.

To determine the temperature uniformity of the setup pyrometric temperature measurements with radial and azimuthal resolution were performed on the susceptor surface. At the crucial temperature for InGaN growth of 800°C a temperature uniformity of $\Delta T = \pm 0.5°C$ was measured across the 3x2 inch satellites.

All structures reported in this abstract consist of a 5 period InGaN/GaN stack grown onto a ~2 µm thick GaN:Si$^{(-)}$ buffer layer. TMGa, TEGa, TMIn, SiH_4 and NH_3 were used as precursors. H_2 and N_2 were used as carrier gases for the high-temperature GaN and InGaN/GaN stack growths, respectively. To enhance the structural quality of the GaN buffer, we used c-plane sapphire with an off-orientation of 0.3° towards the m-plane.

One crucial aspect for the development and production of optoelectronic devices is the capability of independent tuning of parameters such as wavelength and uniformity. Therefore, the tool must allow maximum flexibility. For instance, it is well known that the tuning of the total flow Q_{tot} is the easiest way to adjust the on-wafer wavelength and thickness uniformity in the Planetary Reactor®. As can be seen from Fig. 2 the tuning of Q_{tot} also affects the photoluminescence (PL) wavelength of the structures. The new injector design offers additional free parameters of process tuning to counter such effects, e.g. the ratio of the group-V flows in the upper and lower inlet and the amount of pusher flow at the group-III inlet (see Fig. 3 and Fig. 4).

After optimizing the growth conditions, we achieved a standard deviation of the PL wavelength of less than 1 nm at a mean wavelength of 464 nm with 2 mm edge exclusion (see Figure 5). The full width at half maximum (FWHM) of the peak was on the order of 20 nm across the wafer indicating excellent quality of the quantum well stack.

Additional information on run to run and wafer to wafer results will be given with a special focus on the stability of the system in a production environment. This includes the effects of a newly designed RF-coil for heating and an optimized sandwich susceptor, that guarantees a more uniform heating of the susceptor body, thus, increasing the longevity of these parts.

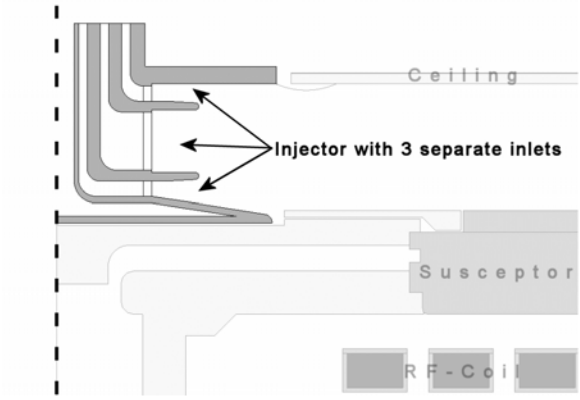

Figure 1: Schematic of the inlet area of the reactor; dashed line is the symmetry axis.

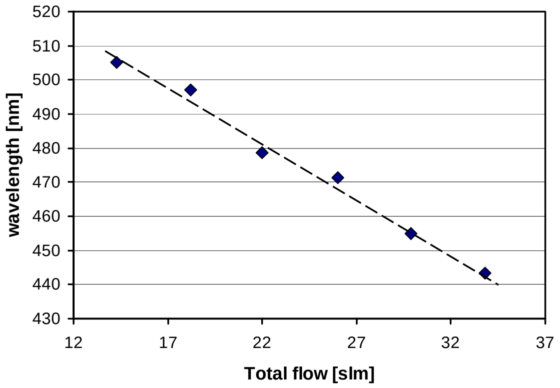

Figure 2: PL wavelength as a function of total flow Q_{tot} in the reactor. The dashed line serves as a guide to the eye.

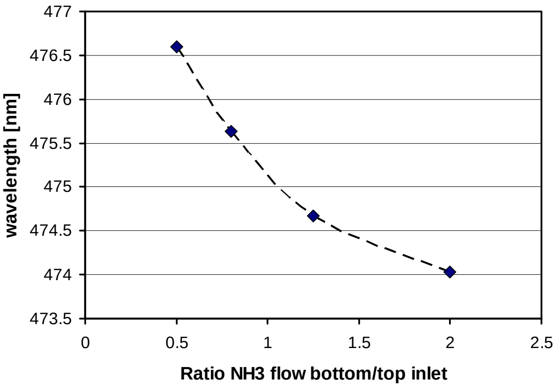

Figure 3: PL wavelength as a function of the ratio of the NH_3 flow between the lower and upper group-V inlet. The dashed line serves as a guide to the eye.

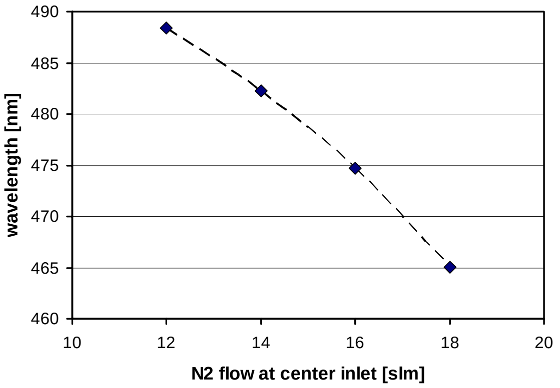

Figure 4: PL wavelength as a function of the N2 push flow at the center group-III inlet. The dashed line serves as a guide to the eye.

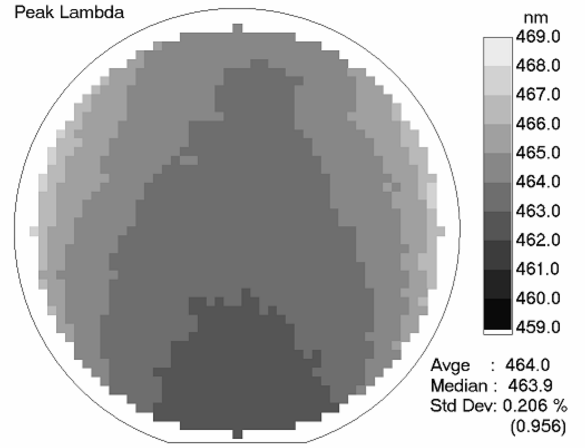

Figure 5: Photoluminescence mapping of an optimized structure. A wavelength standard deviation of $\sigma < 1$ nm was achieved for a mean wavelength of $\lambda = 464$ nm (2 mm edge exclusion).