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GaN uniformity control on multiple 3 inch wafer grown in planetary reactors®

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We report on recent results obtained using an AIX 2400G3HT production type Planetary Reactor® in the 5×3 inch configuration for growth of typical group-III nitride layer structures consisting of GaN, InGaN and AlGaN. The optimum reactor geometry has been found by extensive modeling of the reactor design. Increased thermal management allows maximum reactor temperatures above 1400°C. The temperature uniformity could be improved to less than 1°C over the satellite and from satellite to satellite. As a consequence of extensive reactor modeling, the process transfer from 6×2 inch to 5×3 inch configuration was carried out by simple scaling of the corresponding process parameters of the 6×2 inch configuration. The scaling factor is calculated with respect to the changed reactor geometry. We used optical reflectrometry for in-situ growth control during this process development and could confirm the theoretical scaling requirements for obtaining identical growth conditions as compared to the 6×2 inch reactor configuration. This is verified by the generation of identical reflectance spectrum features, leading to identical growth results as shown in Fig. 1. This important issue of in-situ control will be discussed in detail. The TMGa efficiency could be kept at about 17%. Switching to the 8×3 inch configuration the efficiency increases up to about 27%, which is an improvement of 63% as compared to the 6×2 inch configuration.

The obtained thickness uniformity on three inch wafers is around 1% standard deviation without rim exclusion. Typical photoluminescence emission wavelengths of 480 nm with 6 nm standard deviation could be achieved as shown in Fig. 2. For these results a run to run reproducibility of less than 1% standard deviation was proven by growth of several identical consecutive runs. The full width at half maximum (FWHM) of the 300 K emission is in the range of 35 nm at 475 nm as depicted in Fig. 3. We also report on doping uniformity data of single layer growth. The n-doping uniformity is better than 5% standard deviation on 3 inch. Electroluminescence test structures with emission wavelengths of 480 nm show average forward voltages of less than 4 V at 20 mA operation current indicating a uniform and highly conductive p-type cap layer.

Additionally we present results of AlGaN bulk layers. The growth rate of AlGaN has been reduced to about 1 μm/h to obtain good layer quality with mirror like surfaces. The Al distribution uniformity is in the rage of about 1% without rim exclusion for 10% Al content. The full width at half maximum (FWHM) of 300 K photoluminescence is about 5 nm at 340 nm emission wavelength. To maintain the low cycle time the successful etch back of the AlGaN residuals at 1400°C using our standard HCl etching procedure is an important step.

All of these results demonstrate that the up-scaling of the high temperature production reactor to larger wafer diameter applications is just a question of scaling the corresponding process parameters.

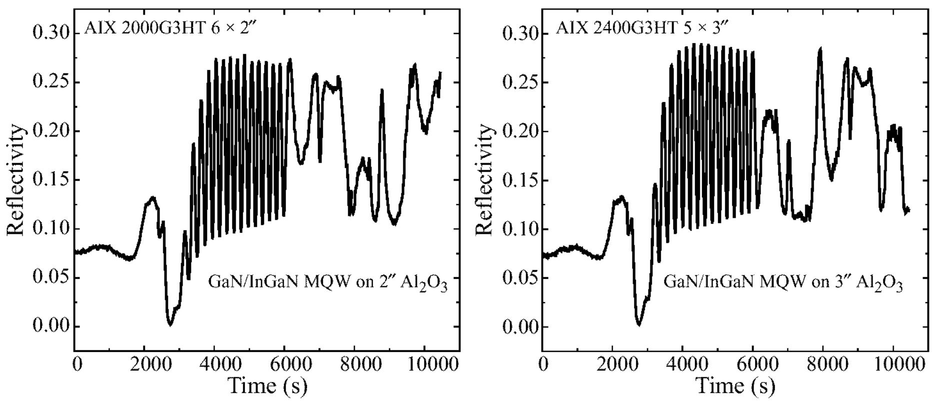

Fig. 1. Comparison of reflectance spectra of 5 period InGaN/GaN MQW structures grown in 6×2″ and 5×3″ planetary reactor configuration, respectively.

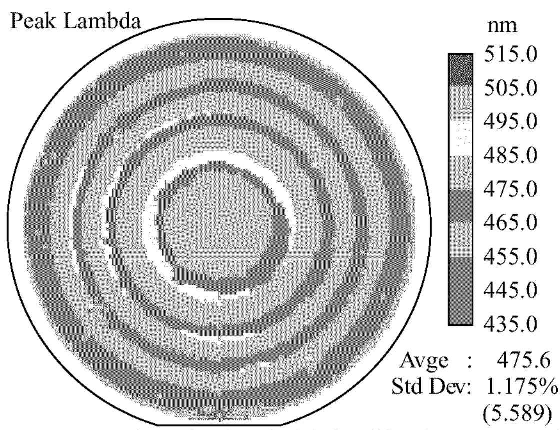

Fig. 2. Photoluminescence mapping of a 5 period InGaN/GaN quantum well structure grown on 3 inch sapphire. Standard deviation of wavelength using 3 mm rim exclusion is 5.6 nm which is 1.2%.

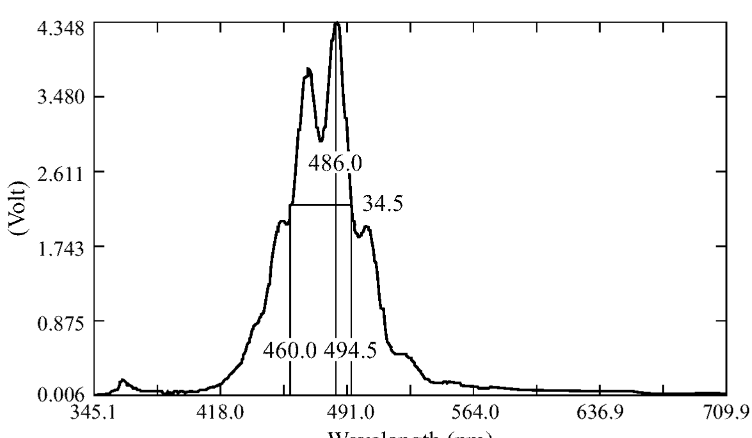

Fig. 3. Typical photoluminescence spectrum of a 5 period InGaN/GaN MQW structure. Wavelength is 480 nm, full width of half maximum (FWHM) is about 35 nm.