Optical Monitoring of MBE Growth of AlN/GaN using Single-Wavelength Laser Interferometry - A Simple Method of Tracking real-time changes in Growth-Rate

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Introduction:

Single wavelength laser reflectometry can offer a simple and robust method of determining both growth-rate and optical constants (n,k) in real-time as growth progresses. The technique has been demonstrated on a Veeco GEN200™ MBE reactor system with intermittent optical access. Data acquisition can be synchronised with the opening of the view-port shutter, resulting in successful fitting (via R-Fit v2.0 ORS proprietary software) for a shutter cycle of only 1 second in 6. Changes in growth-rate during deposition could readily be monitored, whether such changes were due to initial establishment of steady growth, or changes in the temperature of the Ga Knudsen cell. This demonstrates the value of the technique for process monitoring as it has the ability to yield system diagnostic information (e.g. evidence of flux drift) as well as growth data.

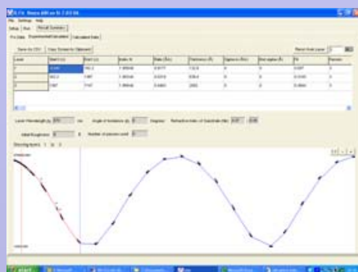
Experimental:

An AlN/GaN structure was grown on a Ga template on Si(111), in a Veeco GEN200™ MBE reactor system. Growth was monitored using an ORS Ltd. EpiEYE1000 laser interferometer (wavelength 670 nm) at normal incidence. The existing standard Varian 2¾-inch optical port was used, with an effective optical access of 1 inch, due to the presence of a heated sapphire plate to minimise material condensation. The window itself (7065 glass vacuum window) was at 5° off-angle, thus reducing the effect of thermal fringes.

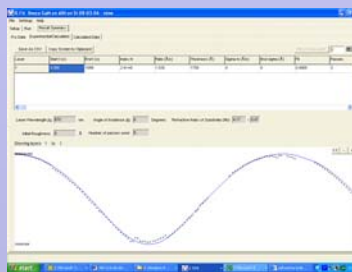
The degree of substrate wobble was measured prior to growth using a laser reflection onto a printed grid , and was found to be approximately ±1° from the centre.

A shutter reduced the amount of time the window was exposed to the contents of the growth chamber. Data can be collected continuously, (but only when the shutter is open), or alternatively the EpiEYE system can be configured to operate in a mode where data is recorded a specific time after receiving a TTL pulse. If the TTL pulse is received once per rotation from the motor driving the sample rotation, the opening of the shutter can be synchronised with data acquisition and the wafer reflectance sampled once per rotation. Rotation speed was 10 rpm.

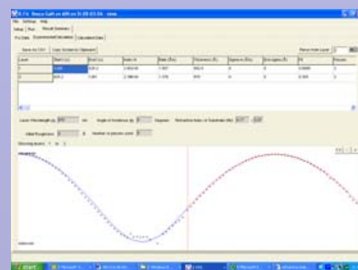
Results and Discussion:



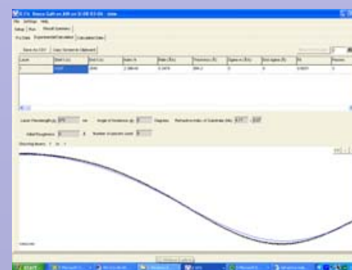
***1.** Growth of AlN on Ga template on Si(111) at 850°C*



***3.** Ga growth with Knudsen cell temperature reduced to 910°C*



***2.** Growth of GaN on AlN buffer layer at 923°C*



***4.** Ga growth with Knudsen cell temperature reduced to 862°C*

An Arrhenius plot of ln(Growth-rate) vs 1000/T for the Ga cell can yield a value for the enthalpy of desorption for Ga desorbing from the cell:

$$\text{Slope} = -E_a/(k_b \cdot 1000)$$

The value obtained, E_a = 2.64 eV is in excellent agreement with the values typically observed using a standard beam flux monitor (ion gauge).

1. Changes in growth rate due to growth mode changes and the catalytic nature of ammonia decomposition on AlN, are shown by fitting to 3 separate layers or regions (vertical dotted lines on diagram). Growth stabilised at 0.45 Å/s after the AlN layer reached a thickness of 770Å.

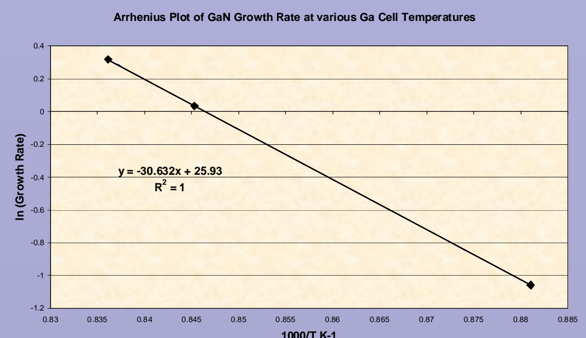
Fitting results in refractive index value of between 0.96 and 2.0, in good agreement with the literature for AlN

2. Data acquired in synchronisation with opening of shutter. 2-layer fitting again shows an initial reduction in growth-rate from 1.5Å/s to just under 1.4Å/s.

Fitting results in refractive index value of 2.4, in good agreement with the literature for GaN

3. Change in growth-rate of GaN due to reduction of Ga cell temperature

4. Further change in growth-rate due to further reduction of Ga cell temperature



Conclusions:

- Both growth-rate and optical constants can be determined and tracked in real-time as growth progresses.
- Information normally provided by beam flux monitor (ion gauge) can also be obtained.
- Data acquisition can be configured to conform to shuttering requirements.