Wavelength Control of InGaAsP Laser Structures Using In-Situ Emissivity Corrected Pyrometry Temperature Control During MOCVD Growth

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The composition, and therefore bandgap, of InGaAsP alloys is known to be a strong function of MOCVD growth temperature when using AsH_3 and PH_3 precursors. PH_3 decomposition is incomplete within the growth temperature range of 600 °C to 650 °C causing a change of As/P ration in the solid at temperature changes. Wafer temperatures differ widely from close proximity thermocouple (TC) or optical pyrometer measured wafer carrier or susceptor temperatures which are typically used to control the process. Further, accumulated deposits on wafer carriers can affect the carrier temperature and the pyrometer measurement of the carrier. A ± 1°C wafer temperature control is required to achieve reproducible control of InGaAsP bandgap to within ±5 nm wavelength. Emcore recently developed emissivity compensated pyrometry known as RealTemp for use in multi-wafer, rotating disk reactors which provides accurate measurement of the wafer surface temperature during growth. In the present work, we demonstrate wavelength control of InGaAsP MQW laser structures.

Laser structures were grown in an Emcore LDM D-180 reactor operated with precursor flows shown in Table I. Laser structures having a target wavelength of 1.55 μm were grown using two modes of growth. The first mode, TC average, employed the RealTemp system to measure and control the wafer temperature during the InP clad layer growth. During this time, the inner and outer thermocouple values were electronically recorded and averaged. These average TC values were then employed as setpoint values for thermocouple control of the inner and outer heater power supplies during the InGaAsP layers. The second mode, pyro control, used the RealTemp wafer temperature for feedback to control the inner heater power supply during the entire run. The outer heater power was driven by a difference signal between two optical pyrometers reading the wafer carrier temperature on either side of the 2" wafer pocket in the carrier radial direction. This control allowed the heating system to respond to actual wafer temperature changes.

Figure 1 shows emissivity corrected wafer temperature data recorded during an entire growth of a laser structure grown under TC average control during the active region. Figure 2 is an expanded view of the same data set in the vicinity of the active region growth. Several features were identified. A large drop in wafer temperature occurred when significant AsH_3 flow was introduced into the reactor. This initial temperature drop varied from 3 to 4.5 °C from run to run. The temperature stabilized during the InGaAsP SCH layer at a temperature lower than the temperature at which the InP buffer was grown. On entry into the MQW, the temperature dropped again due to the increased AsH_3 flow to grow the first barrier. The wafer temperature changed slightly during the growth of each well and barrier as the 43 sccm AsH_3 flow was switched between the growth of the barrier and well and increased as growth proceeded from the first barrier/well pair to the last. The wafer temperature almost instantly increased at the end of the top SCH layer upon returning to InP growth and the corresponding removal of AsH_3 from the flow.

In Figures 3 and 4 we show the wafer temperature data during the active region growth of an identical structure under RealTemp pyro control. The setpoint chosen for this pyro control mode growth was the average temperature observed during the MQW region of a previous run under thermocouple control. Different features in the RealTemp data were observed under pyro control growth of the same laser structure. The average temperature during the entire active region was identical to the average temperature in the InP layers just prior to and just after the active region growth. A large wafer temperature perturbation, due to introduction of AsH_3 flow, occurred at the beginning of the InGaAsP SCH layer. Similar perturbations occurred during the first barrier and second SCH layer. The temperature deviation during the active region was lower under pyro control and the average temperature was at the desired setpoint throughout the entire MQW growth. The resulting laser wafer wavelength average of 1557.7nm was nearly identical to the wavelength from the laser grown under TC average control, 1557.8 nm.

To further demonstrate the benefit of RealTemp pyro control, two additional structures were grown with two different target wavelengths, 1530nm and 1520 nm. The only change to achieve the wavelength reduction from 1530 to 1522 was to increase the pyro control RealTemp setpoint from 606 °C to 608 °C. Figures 5 and 6 show the RealTemp data along with the peak wavelength for each wafer averaged over the six wafers in each run.

Conclusions

Observation and control of wafer surface temperature was achieved during the growth of InGaAsP 1.55 μm laser structures. Wafer temperature decreased (increased) during the InGaAsP active region growth as AsH_3 flows were increased (decreased) in the chamber. Under thermocouple control, the initial wafer temperature drop was observed to vary from 3 to 4.5 °C which contributed to wavelength variation from run to run under TC average control of growth temperature. Emissivity corrected pyrometry was shown to control the temperature, and thus composition, during InGaAsP MQW growth. RealTemp pyro control improved control of InGaAsP based laser wavelength from run to run.