In-Situ Measurement of GaN Surface Temperature, Effects of Changes in Carrier Gas and Satellite Rotation Speed on Temperature Profiles

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In MOCVD growth of Nitride compound semiconductor layers, the temperature at the growing surface determines adatom surface mobility, growth rate and multinary layer composition. Specifically in GaN LED production, surface temperature uniformity directly translates into emission wavelength uniformity. The control of wafer-to-wafer and on-wafer temperature uniformity, hence, critically defines total process yield. During an LED growth sequence, process conditions such as temperature level and pressure are changed frequently and carrier gases are switched between hydrogen and nitrogen. In MOCVD reactors featuring gas borne rotation disks (Gas Foil Rotation\(^\circ\)), flow rate and gas properties of the rotation gas are another factor of the thermal management. The control of temperature profiles is further complicated by the fact that wafers are subject to more or less pronounced bow that may be thermally induced or related to strain of the deposited layer stack (see Fig. 1). The resulting wafer curvature gives rise to a thermal gap between pocket floor and wafer. Temperature profiles on the curved wafer are affected by the wafer pocket itself but also by the thickness and shape of this thin gap and thermal properties of the gas that fills the gap. This properties also and change during the growth process based on the different process conditions in different recipe steps. Fig. 2 shows some typical temperature profiles, as measured during GaN LED structures on sapphire.

Infrared (IR) pyrometers can only measure the temperature of IR absorbing and emitting materials. Thus, for GaN epitaxy on sapphire, only the pocket temperature of the susceptor under the wafer is accessible to IR pyrometry. Due to the strained growth and the evolving wafer curvature, the true radial wafer surface temperature profile usually deviates significantly from the pocket temperature profile. In this contribution, non-invasive measurement techniques will be presented in order to acquire temperature profiles on Nitride deposited sapphire wafers and wafer pockets independently. Using a newly developed UV pyrometer to detect thermal radiation of GaN at the wavelength of 400 nm, we were able to measure directly the surface temperature of GaN layers on a sapphire in production scale MOCVD systems. The effects of carrier and rotation gas changes were studied on 2” and 3” wafers. True wafer surface temperature, pocket temperature and wafer curvature were measured and are qualitatively discussed by analyzing the heat transfer phenomena between wafer pocket, wafer itself and chamber ambient in a production scale MOCVD reactor (Fig. 3a and b). All parameters were measured at various positions across the wafers’ diameter, allowing for spatially resolved results on temperature and wafer curvature distribution. We will show that several key effects on the true GaN surface temperature are invisible to the conventional infrared pyrometer.

Fig. 1: Comparison of susceptor pocket temperature profile (red curve, left schematic) and real wafer temperature profile (blue curve, right schematic) as measured during GaN buffer growth. The wafer temperature profile shows a much stronger variation across the wafer as a result of wafer bowing.
Fig. 2: In-situ measured wafer temperatures profiles during a GaN LED growth run. Due to different growth conditions (such as temperature, mixture of carrier gas and reactor pressure) the temperature profiles change significantly during the run, as illustrated by six representative wafer temperature profiles (1 to 6).

note: all diagrams have same 10K T-scale