Thermal Modeling of MOCVD Reactor

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Introduction: Metal-Organic Chemical Vapor Deposition (MOCVD) process is used for manufacturing Light Emitting Diode (LED) chips [1]. Multiple wafers are placed on a rotating susceptor (carrier) heated from below, with a dilute mixture of metal organic precursor gases flowing into the reactor through a showerhead (see Figure 1). Thin layers of GaN and InGaN are deposited epitaxially on the wafers [2]. The color of light emitted by the LED is known to be a strong function of the process temperature. Despite good temperature control of the susceptor, the light color is found to vary significantly for chips fabricated on the same wafer. This is a problem for LED makers who have to “bin” the chips by color in order to sell them [3].

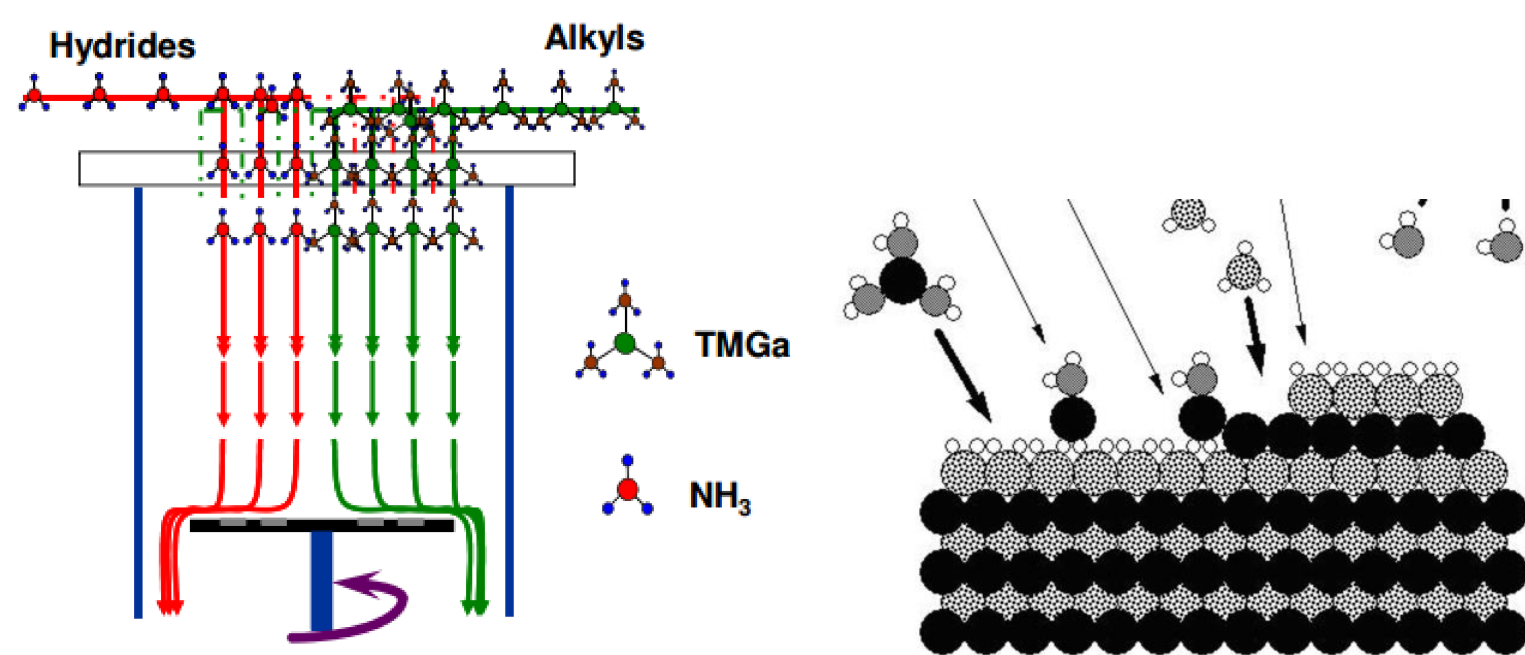

Figure 1. Left: Schematic showing precursor gases incident on rotating carrier [1]. Right: Epitaxial growth of GaN [2]

The results presented here explain the reason for the temperature non-uniformity on the wafer despite excellent susceptor temperature control. A 3D model of a Thomas Swan MOCVD reactor was developed (Figure 2, left). The 2” sapphire wafers sit on a rotating graphite susceptor heated from below by a three-zone heater.

Computational Methods: The Heat Transfer with Surface-to-surface Radiation and Solid Mechanics modules were used.

Results: Figure 2 (right) shows that the lower wafer surface is 6˚C hotter than top. The differential thermal expansion of the wafer results in a concave bow (Figure 3).

The wafer bow of about 26 μm reduces heat conduction from the susceptor to the wafer through the gas which results in a radial temperature gradient (cooler at wafer edges).

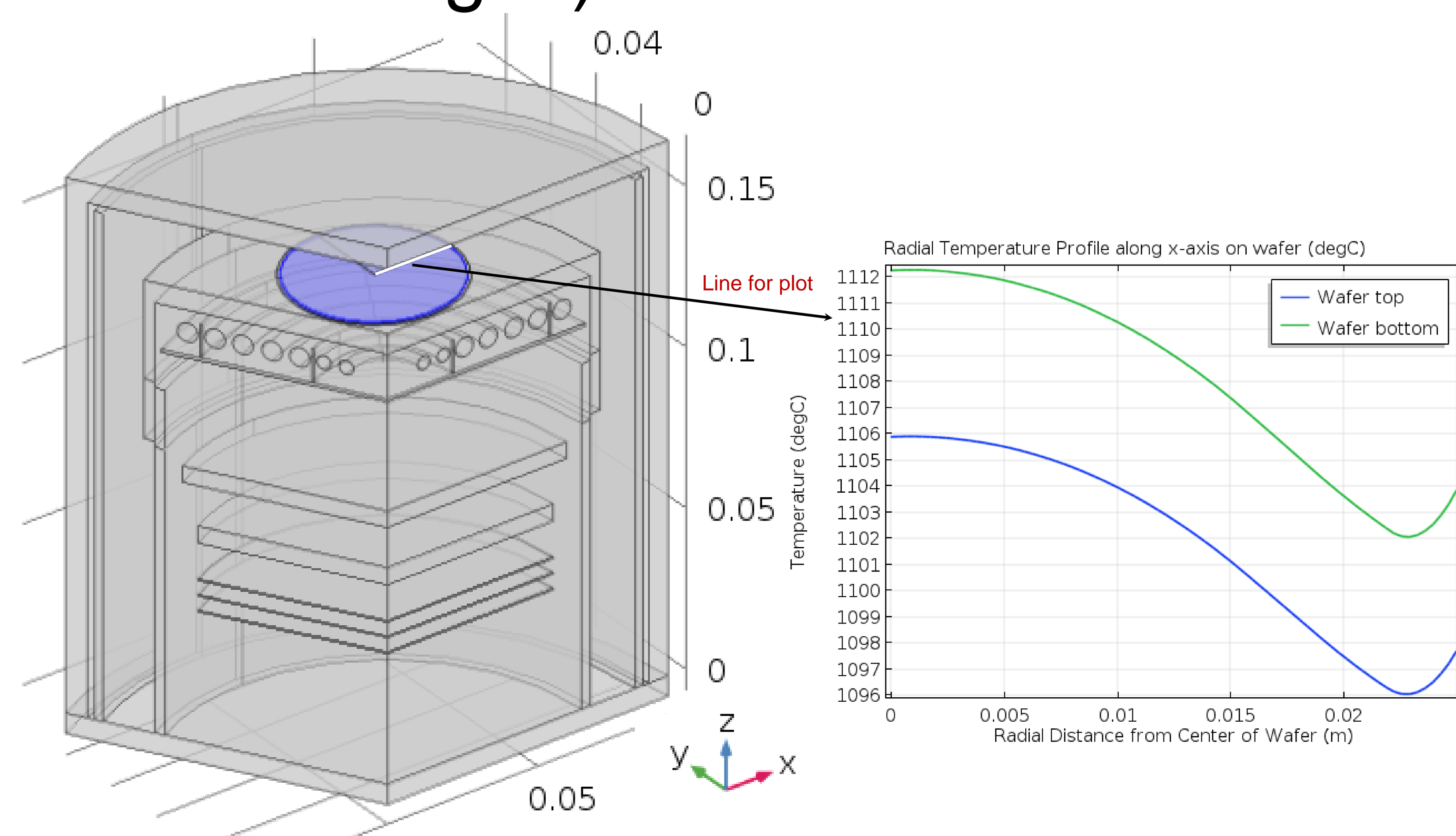

Figure 2. Left: COMSOL model of commercial MOCVD reactor. Right: Wafer temperatures along x axis.

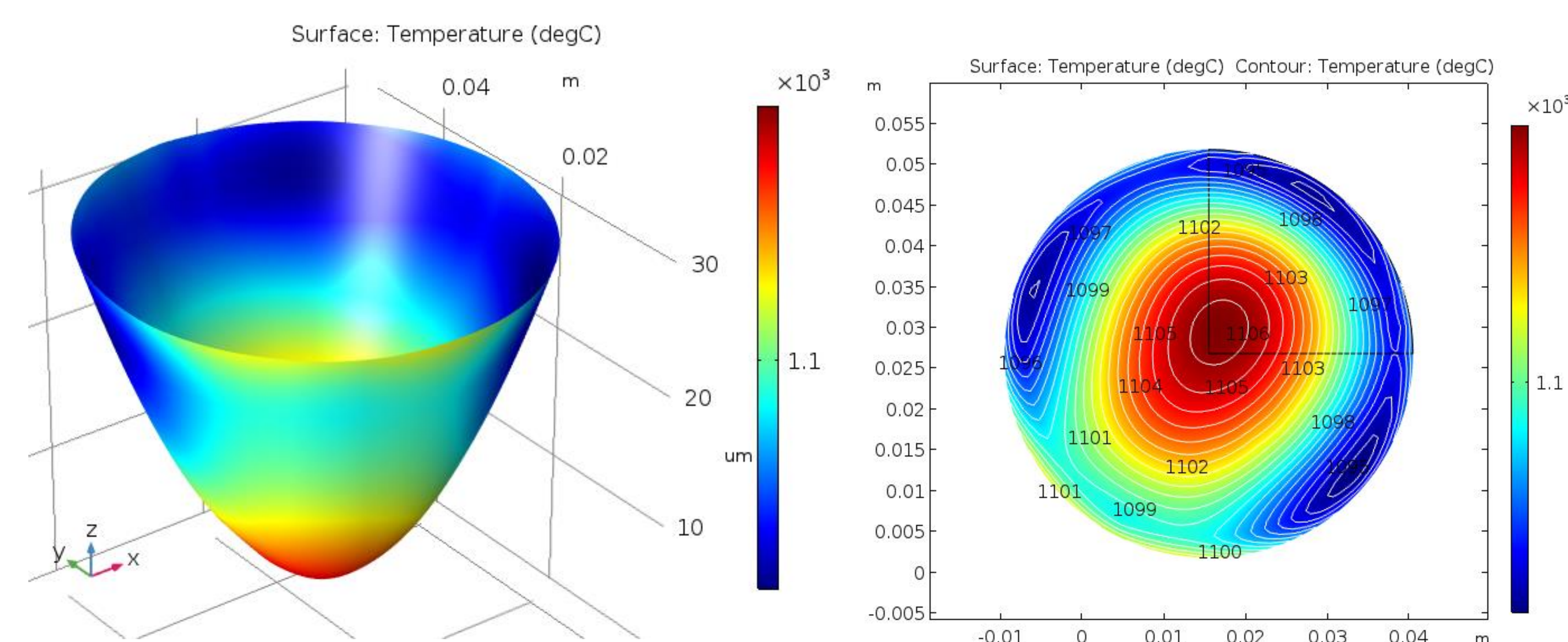

Figure 3. Wafer curvature.

Figure 4. Temperature non-uniformity on top surface.

Conclusions: Simulation results from the COMSOL model reveal that the bowing of the wafer due to thermal expansion has a significant effect on the within-wafer temperature non-uniformity, which, in turn, is the primary root cause of the “binning” problem in the LED industry.

References:

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2. C. J. Pinzone, in *Metalorganic Vapour Phase Epitaxy*,
3. E. Armour, *et. al.*, "LED Growth Compatibility between 2", 4", and 6" wafers," *Semiconductor Today*, p. 82, April/May 2009.

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