How GaN-on-Si could disrupt the current equilibrium of the booming LED industry

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Introduction

As the old semiconductor industry saying goes "if it can be made on silicon it will be made on silicon". Will this prediction turn true for the solid state lighting industry as well? For many years, LED-on-Si has been touted as "the next big thing" in LED manufacturing. However, efforts have so far failed to come to fruition and transform the industry. But in the last 18 months, many established LED manufacturers and startup companies alike have announced impressive results showing that mass manufacturing of LEDs on 6" or 8" silicon substrates might finally be around the corner.

Managing TEC and light absorption

The main challenges for the use of Si substrates to manufacture LED stem from the lattice and Thermal Expansion Coefficient (TEC) mismatch with GaN, which are much higher than with SiC and Sapphire substrates. Lattice mismatch results in higher defect densities that are detrimental to performance, and TEC mismatch and high level of mechanical stress in the epitaxial layers causing the wafer to bow during growth and furthermore increasing the potential for reduced yield due to breakage during processing steps to follow. This prevents from growing the thick (>5 um) layers needed for LED.

In addition, Silicon strongly absorbs light at the typical emission wavelength of GaN LEDs (Blue, Green), thereby suppressing about 50% of the light emitted by the active layers (corresponding to the emission toward the substrate).

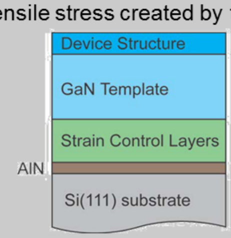
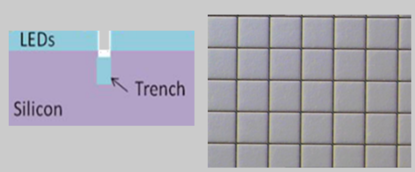
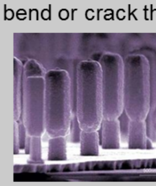
	Stress Management layers	Patterned Substrates	Nano-Column GaN structure
Overview	Include intermediate layers generating compressive stress to compensate for the tensile stress created by the GaN. 	Create deep trenches in the Si substrate in order to promote isolated GaN growth on silicon island and avoid accumulation of tensile stress on the entire wafer. 	Grow vertical nano scale and discontinuous LED structures. The strain is localized at the base of the nanowires, and thus doesn't bend or crack the wafer. 
Benefits	•The full surface of the wafer is available •Can be grown in situ in the MOCVD reactor	•Good reproductibility.	•Possibly compatible with any wafer size
Drawbacks	•Difficult to control, reproducibility	•Reduces useable wafer area •Requires additional lithography/masking and etching pre-processing of the wafer.	•LED Processing (contacts, electrodes, etc.) might differ significantly from standard process
Comments	Typical stress release structures comprise multilayers of GaN / Low temperature AlN layers	This techniques is often combined with stress management layers	Still in development, processing and performance not proven yet
Example	Azzurro, Lattice Power, Bridgelux, Samsung, Lumileds, Sanken, Translucent, Rose street Lab, IMEC	Lattice Power, Photonics Technology Center (Hong Kong)	GloAB, HelioDEL.

Figure 1: Main solutions to grow LED on Si substrate

Most of these issues have now been solved, and significant improvements in manufacturability and performance have triggered renewed interest in LED on Si.

The main incentive for making LED-on-Si is cost, not performance

The potential advantage of LED on Si is cost, not performance. The key conditions for LED on Si to succeed are:

1. Must equal LED on Sapphire performance
2. Must reach similar manufacturing yields
3. Must be compatible with CMOS, ideally on 200 mm

The major incentive for a transition to Si wafers for LED manufacturing is the possibility to process the epiwafers in 150 mm or 200 mm fully depreciated and highly automated (efficient) CMOS fabs.

If technology hurdles are cleared, LED on Si will be adopted by some LED manufacturers, but will not necessarily become the standard. A single large CMOS fab could supply worldwide LED demand for years to come. As a result, massive adoption of LED on Si would dramatically change the landscape of the front-end LED industry. It would facilitate the emergence of new or smaller players who currently don't have access to the capital needed to become major players in the industry, and could also entice vertically integrated LED makers to abandon in-house chip manufacturing because of higher production costs.

All major LED companies are investigating LED on Si, but only two (Bridgelux and Lattice Power) have so far committed to the transition and Osram has just announced the building of a pilot line.

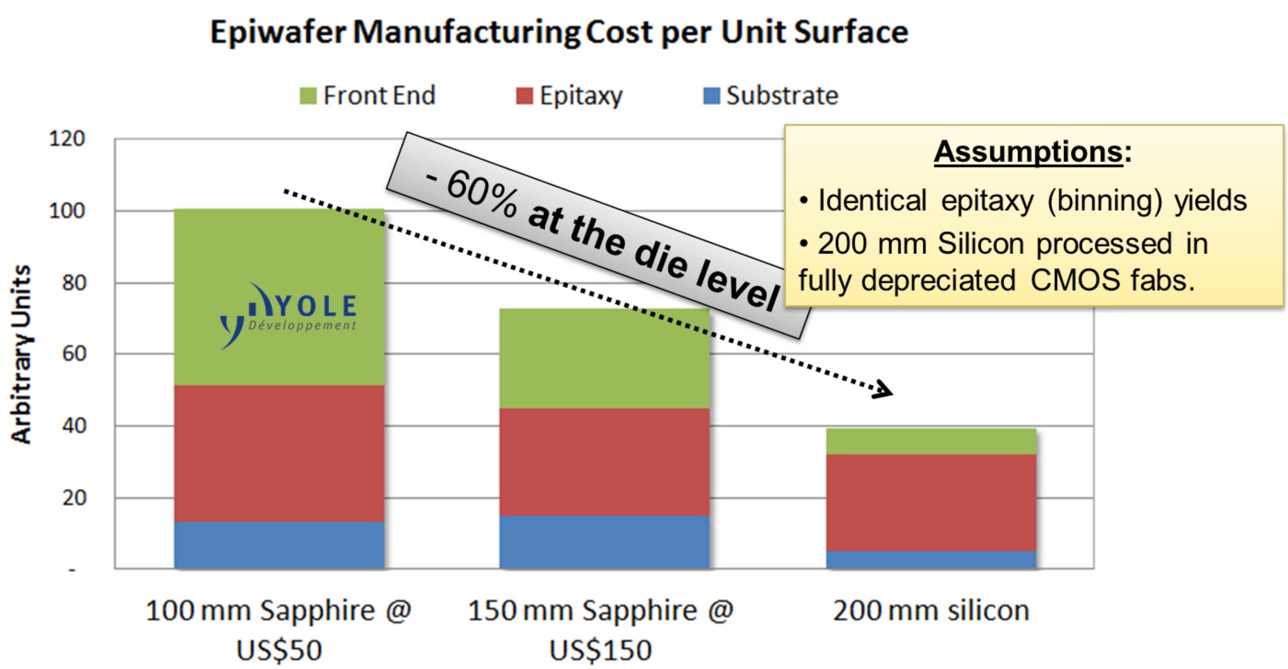


Figure 1: LED-on-Silicon: Potential Cost Benefits