
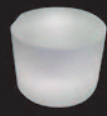

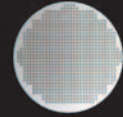
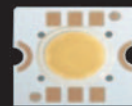



# Sapphire

## Maximizing Yields Throughout the LED Manufacturing Value Chain

### GT Advanced Technologies' Characterization of Sapphire Material Project

GT Advanced Technologies is committed to continuously pushing the boundaries of single crystal sapphire technology to drive toward higher yields of 2", 4" and 6" wafers and beyond, as well as providing material that improves downstream yields in LED manufacturing. In January of 2011, GT initiated an extensive sapphire material qualification project to determine the sapphire material "Metrics that Matter" in the manufacturing processes of HB LED devices. The project has been designed to evaluate the effects of sapphire material on yields in LED manufacturing and objectively evaluate properties and differences between different sapphire growth techniques.

<span style="color: red;">✓</span> <b>INPUTS: Measurable Fundamental Properties of Sapphire</b>					
<ul style="list-style-type: none"> <li>OHT (metrology of low angle grain boundaries, crystal structure, bubbles)</li> </ul>	<ul style="list-style-type: none"> <li>Interferometry Transmission (200-800 nm)</li> <li>GDMS (elemental analysis)</li> </ul>	<ul style="list-style-type: none"> <li>Color Analysis of Materials (color measurement)</li> <li>X-Ray (crystallographic analysis)</li> </ul>	<ul style="list-style-type: none"> <li>Laser Inspection and LED Surface Metrology (pre- and post-epi automated laser wafer inspection)</li> </ul>	<ul style="list-style-type: none"> <li>X-Ray Diffraction (crystal micro-structure)</li> <li>Physical Properties</li> </ul>	
<span style="color: red;">✓</span> <b>PROCESS: LED Process Variables and Macroscopic Interactions</b>					
 <p>Sapphire Boule</p>	 <p>Finished Core</p>	 <p>Epi-Ready Wafer</p>	 <p>LED Wafer</p>	 <p>LED Chip</p>	 <p>LED Luminaire</p>
(GT Advanced Technologies)	Wafering Study (3rd party)	MOCVD Study (3rd party)	LED Device Fab (3rd party)	LED Luminaire (3rd party)	
<ul style="list-style-type: none"> <li>Crystal Growth (yields, process)</li> <li>Finishing of Cores (process)</li> </ul>	<ul style="list-style-type: none"> <li>Wafering of Cores (process and performance)</li> <li>Epi-Wafer Analysis (wafer yields, Ra, TTV, Bow Warp)</li> <li>Wafer EPD Analysis (pits/cm<sup>2</sup>)</li> </ul>	<ul style="list-style-type: none"> <li>Epitaxial Growth (process and performance)</li> <li>Photo Luminescence (LED light metrology, wavelength, color brightness)</li> <li>Leading LED Metrology Co. (post-epi automated laser wafer inspection)</li> </ul>	<ul style="list-style-type: none"> <li>LED Fabrication (process and performance)</li> <li>Electrical Performance (forward voltage, reverse leakage, etc.)</li> <li>LED Light Performance (peak wavelength, brightness, binning)</li> </ul>	<ul style="list-style-type: none"> <li>LED Lamp (proof of concept)</li> </ul>	
<span style="color: red;">✓</span> <b>OUTPUTS: Yields, Device Performance, Economics</b>					
<ul style="list-style-type: none"> <li>LED Material Yields (mm, quality, cost)</li> </ul>	<ul style="list-style-type: none"> <li>LED Wafer Yields and Quality (wafer yields, wafer geometrics, cost per wafer)</li> </ul>	<ul style="list-style-type: none"> <li>Epitaxial Yields and Performance (epitaxial efficiency, low defects, performance)</li> </ul>	<ul style="list-style-type: none"> <li>LED Device Yields (device color binning, brightness, electrical performance)</li> </ul>	<ul style="list-style-type: none"> <li>Luminaire (esthetics, performance, brightness, life)</li> </ul>	

## GT's Characterization of Sapphire Material Project

### About GT Advanced Technologies

GT Advanced Technologies leverages its core crystalline growth and materials expertise in polysilicon, photovoltaic and sapphire to deliver sustained value to our customers. Our innovative ideas and industry experience enable the evolution and commercialization of products that elevate performance, improve quality and lower manufacturing costs.

Learn more at [www.GTAT.com](http://www.GTAT.com)

### The Project Includes Extensive Evaluatory Metrics

- Analysis and experiments for all steps in the LED manufacturing process, from crystal growth to Luminarie
- Sapphire core samples collected from four different suppliers, including GT, randomized for blind evaluations
- Third party evaluations by reputable manufacturers to obtain objective and unbiased data
- Experiment designed around material inputs, LED process, and outputs
  - Inputs: intrinsic and fundamental sapphire material properties (analysis through analytical laboratories)
  - Process: individual manufacturing steps (wafering, MOCVD, device fabrication, etc.)
  - Outputs: device performance, yields, economic impact

In September 2011, GT released the results from one phase of this project in a case study entitled "Yields Matter: The Impact of Sapphire Material Quality on the Wafering Process". The results of this phase of the study confirmed the positive observations that GT has heard from existing materials customers on the superior quality of the ASF™ grown sapphire material and its favorable impact on LED wafer yields. GT has obtained additional data and analysis results from numerous third party analytical laboratories and leading wafer and LED process metrology experts, such as data confirming the purity and superior crystal homogeneity of ASF material. GT is in the final stages of the device fabrication analysis, working with a top MOCVD OEM, as well as reputable LED device manufacturers on 2", 4", and 6" substrate processes.

► **For more information and to access the LED Wafer Yields case study, please visit: [www.gtat.com](http://www.gtat.com)**



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