

PROCEEDINGS OF SPIE

# ***Gallium Nitride Materials and Devices IX***

**Jen-Inn Chyi  
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*Editors*

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## Introduction

GaN based electronic and optoelectronic devices, particularly light emitting diodes and exploration of semi-polar orientations now that the truly bulk GaN substrates are available, albeit to a small group of researchers, continue to develop rapidly as reflected by the advances reported at the conference. Having penetrated the automobiles, traffic lights, moving signs, outdoor displays and lighting, handheld electronics, and background lighting in many consumer electronics gadgets including flat panel televisions, the GaN based LEDs are at the cusp of becoming the dominant technology in general lighting. The most challenging of all, the indoor lighting with LEDs, is on its way as high efficiency warm-white LED light sources are also being made available by an increasing number of vendors, including an attractive approach of integrating GaN based white LEDs, operating near the maximum efficiency at low current, with conventional red LEDs in the high voltage configuration.

Particulars of the efficiency retention issue (rather the loss of it) at high injection levels continued to receive a good deal of attention again due to its impact on efficiency of indoor lighting by LEDs. This time around direct observation of Auger process generated hot electron flyover reported in a vacuum electron emission spectroscopy experiment along with theories of efficiency loss based on this mechanism together with other contributions provided intense discussions. As if oblivious to it all, the LED industry has been moving along with a two-prong approach. In one, dubbed the "high voltage LED", a series of LEDs (most likely configured in the form of a full-wave bridge rectifier) operating at low currents where the efficiency is at its maximum are used with the added benefit of much reduced power supply complexity and weight. The other is the continual improvement of layer quality and optimum active layer design, taking technological parameters into consideration, which would lead one to ponder whether there is a killer inherent efficiency limiting process. Luminous and wall plug efficiencies are now about 260 lm/W and over 60%, respectively, at high currents, which is astonishing.

To reduce the cost of LEDs, 200 mm Si substrates are being implemented with the added advantage of using abandoned Si fabrication lines for LED production. The attendees heard that GaN based LEDs on 200 mm Si substrates exhibit 63% wall-plug efficiency at an injection current of 350 mA, which translates to approximately 75% efficiency once the voltage (~90%), and phosphor conversion (~90) efficiencies are accounted for. Assuming the same extraction and external quantum efficiencies, one gets about 86% for each. It would not be an exaggeration to conclude that mid 90% internal quantum efficiency is probably in play here, which means that the purported inherent problems dominating the discussion seemed to have been reduced to an academic exercise as predicted by some already. Eventually, the real limiting factors are the extent of hole supply

(can be mitigated by increased hole concentration) and thermal wall (can be mitigated by increased efficiency and efficient heat removal).

Both HVPE and ammono-thermally-grown GaN are being positioned for niche markets. Bow free templates produced by HVPE are successfully used by certain segments of the industry to produce LEDs with high yield. Availability of high quality true GaN substrates is making it possible to delve deeper into GaN based lasers and also RF power devices. Ammono-thermally grown GaN substrates with novel semi-polar orientations is allowing a glimpse of some interesting properties along with potential benefits and challenges in terms of growth and also device performance. With the advent of truly bulk GaN substrates, researchers are now able to delve deeper into the lasers unearthing their unique properties which forked into vertical cavity lasers as well as photonic crystals with attractive fabrication processes.

The SPIE conference on GaN Materials and Devices is annually organized to disseminate the latest developments and provide an opportunity for researchers from around the world to engage in far reaching and probing discussions. Many world-renowned invited speakers from Asia, Europe and United States set the stage with wide ranging formal discussions. Not to be underestimated is the fact that the meeting served the purpose of getting experts and newcomers together for friendship and informal discussions of issues relevant to GaN and related materials and devices, and also to develop collaborations. Such exchanges will undoubtedly play an invaluable role in propelling the field forward in general and in particular addressing pivotal issues such as determination and improvement of internal and external quantum efficiencies of LEDs as well as realizing the full potential of GaN power devices for energy efficiency products.

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