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PROGRESS IN AUTOMOBILE LIGHTING

Laboratory of Lighting Technology
September 25-26, 2001

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Development of High Brightness LED's for Automotive Applications:

Mark van den Berg , LumiLeds Lighting Netherlands

1. Introduction

In recent years the efficiency of Light Emitting Diode (LED) technology has increased dramatically making it the preferred light source in many different applications. Typical examples of applications utilizing the improvements of the LED developments are full color video signs, information signs, traffic signals and flashers.

In the automotive market LED's are the preferred solution for High Mounted Stop Lamps. Several Rear combination Lamps are using high brightness LED's, and in the United States the first Emergency Vehicles are using Light-bars on top of the car using LED's.

The reason for this large scale conversion is the fact that high brightness LED's are offering a unique set of benefits such as lower power consumption, Long operating life, compact size, increased reliability and very low maintenance requirements depending on the application.

2. History of LED Technology

The first LED's appeared during the late 1960s with typical efficiencies (Luminous watt output per electrical watt input) of 0.05 Lumens/Watt (lm/W).

It wasn't until the late 1980s with the introduction of Aluminium Gallium Arsenide (AlGaAs) technology did LED's really begin to come close to incandescent bulbs in terms of efficiency at 7Lm/W in Red.

AlGaAs technology remained the standard "High Brightness" material until the introduction of Aluminium Indium Gallium Phosphide (AlInGaP) and Indium Gallium Nitride (InGaN) in the mid 1990s with dramatically increased performance in Lumens/Watt making LED's more efficient than filtered incandescent and later even Tungsten Halogen

The AlInGaP material produces colours ranging from Amber 588 nM through to Red 630nM.

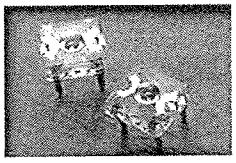
InGaN material produces colours from Blue 470nM through to Green 530nM. The InGaN material is also used for producing White LED's by taking a Blue chip and including a phosphor layer in the LED.

3. Different types of LED's

There are several types of LED's available in the market. The conventional 3mm or 5mm through hole LED's, the Surface Mount LED's (SMD) which are being produced by the billions every year.

SMD LED's are very popular for dashboard backlighting. In the late 1990s the Super Flux LED's have been introduced (Picture 1). This LED became a standard in the Automotive industry for High Mount Stop Lamps. Whereas most conventional LED's are limited in light-output , this Super Flux LED's had the capability to maintain reliable at higher currents due to improved heat management.

The Super Flux LED can be driven at 70mA. Utilizing the best available TS (Transparent Substrate) AlInGaP material this LED has set new records in light output per LED opening up a range of new application. This LED was initially available in Red and Amber but will in 2001 also become available in Blue,Green,Cyan and White



Picture 1: Super Flux LED's

The next step towards higher performance LED's was the SnapLED™ LED introduced by LumiLeds Lighting in the late 1990s. This LED could be used at current of 150mA while maintaining reliability and efficiency. This LED also enabled the reduction of the number of LED's used in specific applications which helped to reduce the overall system costs, as well as had the possibility to do stylish 3-dimensional array designs.

The trend was clearly set. In order to enable more applications inside and outside automotive a few things need to happen.

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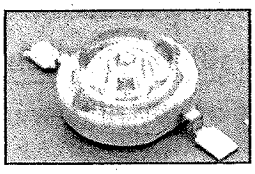
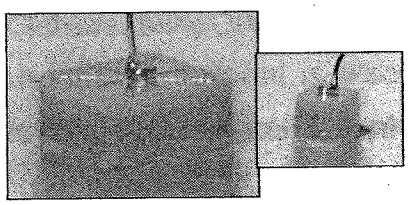
1. continue to improve the efficiency of the AlInGaP and InGaN material to enable higher Lumens/Watt values
2. Improve packaging of the chip to get the light in the correct direction as efficient as possible
3. Find a way to drive the chips harder while keeping the same reliability , same forward Voltage and same efficiency to enable higher Light-output.
4. Further reduce the number of LED's used, and reduce the overall system cost per application.

LumiLeds Lighting introduced in 1998 a high flux emitter (Luxeon ™) (Picture 1) with even higher current capabilities. The main characteristics of the LED are the large LED Chip (Picture 3), excellent thermal characteristics and an optimized light extraction making it possible to drive the AlInGaP LED's at 250mA and the InGaN LED's at 350mA.
The LED's show a dramatic increase in light output per device and per unit area when compared to other LED's. There is no sacrifice in reliability caused by the increase in total device current since the current per unit area in unchanged. (Larger Chip). The LED chip itself is mounted on a slug that serves as a heatsink to dissipate the heat from the chip and to transfer this heat to a secondary heat sink . The slug is fixed in a body that support the cathode- and anode lead. On the topside a plastic lens covers the LED chip. The body and the plastic lens can accommodate a high expansion and shrinkage due to the temperature differences, and the chip is surrounded by a low stress opto-coupling gel. Both lens and gel are highly resistant to UV radiation (from outside) to ensure high lumen maintenance.



Picture 2: Luxeon ™ High Flux Emitter



Picture 3: Large AlInGaP Chip vs. small chip

The Luxeon LED is available in 2 different radiation pattern. A Batwing radiation pattern with a peak intensity near 40 degrees with a steep drop-off of intensity outside this angles. This pattern has been designed to provide uniform incidence to a planar secondary optic.
The second radiation pattern is a Lambertian "point source" pattern.

Good thermal system design is critical to achieve the best efficiency and reliability of the Luxeon™ LED's. AlInGaP LED's (Red and Amber) experience a temporary loss in light output as the temperature increases. The lower the die or the junction temperature is kept, the better the luminoue efficiency of the product.

In 2001 LumiLeds released the Lambertian LED in Red, Red-Orange and Amber with capabilities to use at current of 385mA, achieving records in light output performance of typical 44 lumens per LED in Red. The Lambertian LED is using a new type of special shaped chip which maximized the light output efficiencies.
Also the Batwing Luxeon™ has been qualified at 350mA for all colors.

Table of Power development:

Type of LED	SMD	5mm	Super Flux	SnapLED	Luxeon Batwing	Luxeon Lambertian
DC Forward current	20mA	20mA	70mA	150mA	350mA	385mA
Typical light output (red)	0.5 lm	1 lm	3 lm	6 lm	25 lm	44 lm

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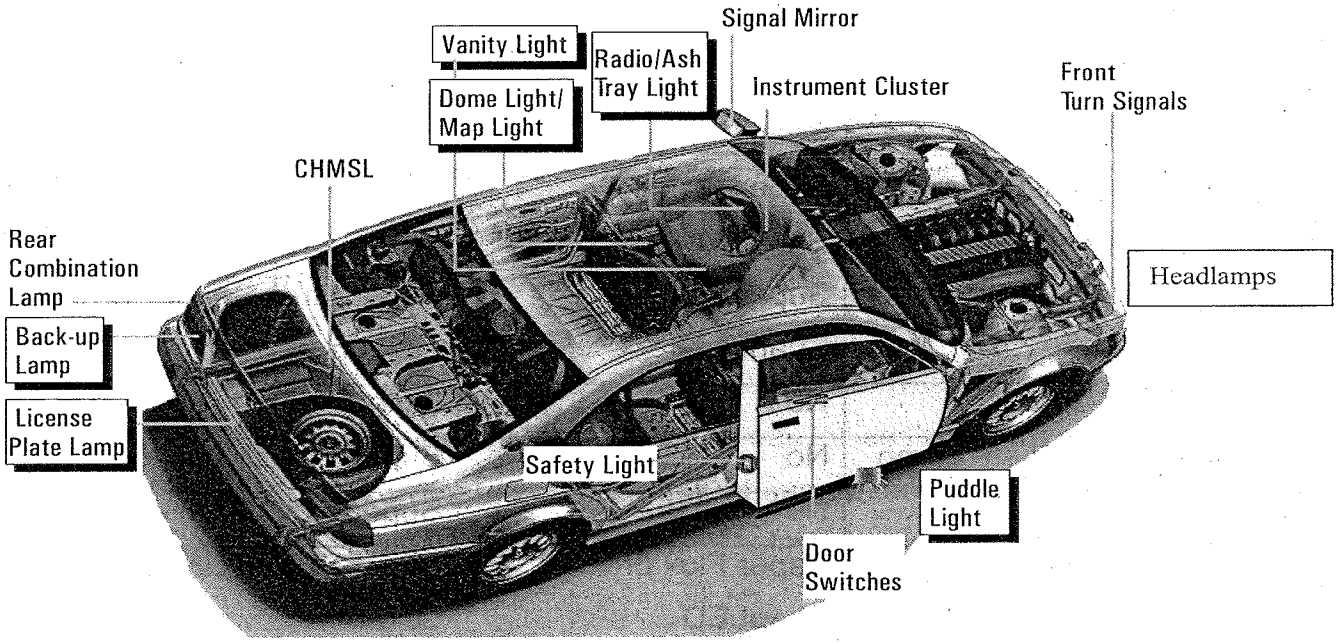
4. Potential Applications for LED's in Automotive

As stated earlier, several applications are today using LED technology as the preferred solution. Main applications on the road today are dashboard backlighting, indicators, Air-conditioning – and Radio backlighting as well as High Mount Stop Lamps and Rear Combination Lamps in Automotive exterior.

As the LED's are getting brighter and brighter more applications in Automotive can start to make use of the benefits of LED's.

In the next year we will see the first cars on the road using Amber LED's for Turn Signals. White LED's for puddle lamps or position lamps , as well as Red,Green,Blue LED's for Navigation systems.



Inside the car High Flux LED's are being considered for mood-lighting, ambient lighting and reading lamps.

In addition to all these potentials, the probably biggest potential for LED's in Automotive is in Headlamps. As LED's are achieving a brightness of 150 – 200 Lumen in White it will be possible to achieve the needed brightness levels.

Application	LED used today	LED for the future
Interior :		
Dashboard-backlighting	SMD	SMD or Luxeon (Edge-lighting)
Buttons	SMD	SMD
AC / Radio	SMD	SMD or Luxeon
Navigationsystem	No	Luxeon
Mood Lighting	No	Luxeon
Ambient Lighting	No	Luxeon
Reading Lamps	No	Luxeon
Exterior :		
Rear Combination Lamp	Super Flux or SnapLED	Super Flux, SnapLED or Luxeon
High Mount Stop Lamp	Super Flux or SnapLED	Super Flux or SnapLED
Front Trun Signal	Super Flux or SnapLED	Super Flux, SnapLED or Luxeon
Back-up Lamp	No	Luxeon
License Plate Lamp	No	Super Flux or Luxeon
Puddle Light	No	Super Flux or Luxeon
Signal Mirror	Super Flux or SnapLED	Super Flux, SnapLED or Luxeon
Side Repeater	Super Flux or SnapLED	Super Flux, SnapLED or Luxeon
Position Lamps	No	Luxeon
Headlamps	No	Luxeon

Table of LED / Application

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5. Summary and Outlook

High Flux LED's will play a big role in the future of Lighting. More and more applications in general illumination will start to use LED's. In the Automotive market there is a big potential to use the High flux LED's in a lot of different applications , giving both the end-user as well as the car-maker benefits.

The Luxeon™ LED's will allow further reduction in LED's and in specific applications reduce the overall system costs.

Important is to use the LED's in the right way in order to achieve the maximum result and benefits.

The future of the LED is bright. Enclosed a flux per LED roadmap for the next years for the main colors in Automotive Red,Amber and White

Colour	2001	2002	mid 2003	mid 2004
Red	12	44*	48	50
Amber	12	36*	40	44
White	18	40	75	120

Typical performance of LED in Lumens/LED. Chip size or current density might change

* new special shaped chip @385mA

All values are subject to change, and are best on expectations.