LED professional Review

www.led-professional.com
ISSN 1993-890X
LpR
Trends & Technologies for Future Lighting Solutions
Sep/Oct 2015 | Issue 51

Special: Zhaga's Latest Books

Tech-Talks BREGENZ: Andreas Weisl

Graphene-Based, Spectrally Tunable, Flexible LEDs

Measurement Uncertainty and Conformity

BCR linear LED driver family

Go for quality with Infineon ICs

Long term reliability and longevity of LEDs are key. BCR linear LED drivers ICs are the best choice when you need to drive LED strings supplied by a DC voltage source. Infineon BCRs are suitable for driving currents from 10 – 250 mA driving current, making the ideal solution for low and mid power LEDs. In contrast to limiting the LED driving current with a simple resistor, Infineon BCR linear regulators have the advantage that the driving current is always under control, no matter at which temperature. This contributes to longevity and reliability of your system and also allows the usage in outdoor applications. Furthermore BCR linear LED driver are suitable for PWM dimming at high dimming frequencies, allowing flicker-free light to create always the right atmosphere.

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- Architectural LED lighting
- LED strips
- LED displays and channel letters
- Automotive stop-lights and brake-lights
- Emergency lighting
- Retail lighting in fridges and freezers
- Ship, train and aircraft interior illumination

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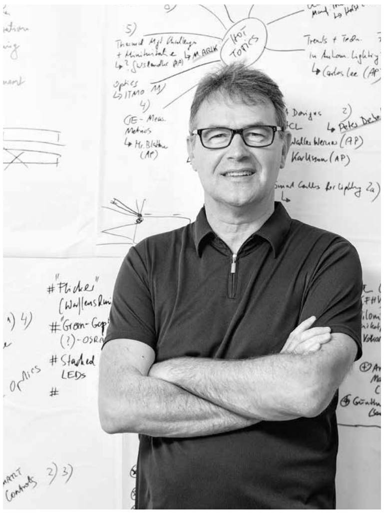


Celebration 15-5-50 & Exclusive Zhaga Papers

The numbers 15-5-50 stand for the three reasons we are celebrating this year; namely the International Year of Light 2015, the 5th anniversary of the LpS event in Bregenz and the 50th issue of the LED professional Review (LpR).

After celebrating the publication of LpR issue #50 in August, we are now looking forward to the upcoming LpS 2015 event which will take place in Bregenz on September 22-24. The focus of the 5th LpS is on the trends and technologies for future lighting solutions.

This year the program concentrates on the building blocks for smart lighting designs. A special Design-meets-Technology Day on September 22nd will bring architects, lighting designers and lighting planners together with experts from academia and industry. Closing the gap for understanding new technologies between these different groups could be essential for further progress because innovations are mainly driven from the directions of applications and technologies.

The LpS 2015 will open with the keynotes from Professor Zary Segall from the Royal Institute of Technology in Sweden, Rogier van der Heide, Design and Marketing Officer at Zumtobel Group in Austria and Jy Bhardwaj, CTO at Lumileds in the USA. About 60 presentations are grouped into the following sessions: Light Quality, Connectivity & Security, Reliability & Lifetime, Standardization, Light Sources, Smart Controls & Drivers, Thermal Management and Optics. There will be 7 workshops which are meant to augment comprehension in the fields of Light Measurement, Optics, Thermal Management, OLEDs, Smart Controls, Light Mixing and Automotive Lighting. You'll find the complete program as part of this issue.

The combination of the numbers 15-5-50 also affects our view of the synergies between international lighting collaborations, lighting events and lighting publications. This view was corroborated recently when we announced our long-term strategic partnership with the esteemed Messe Muenchen, organizer of the electronica and productronica, to further strengthen and force Solid-State-Lighting topics on an international scale. I would like to take this opportunity to thank Managing Director Mr. Senger and Dr. Lechner and his team for establishing this partnership.

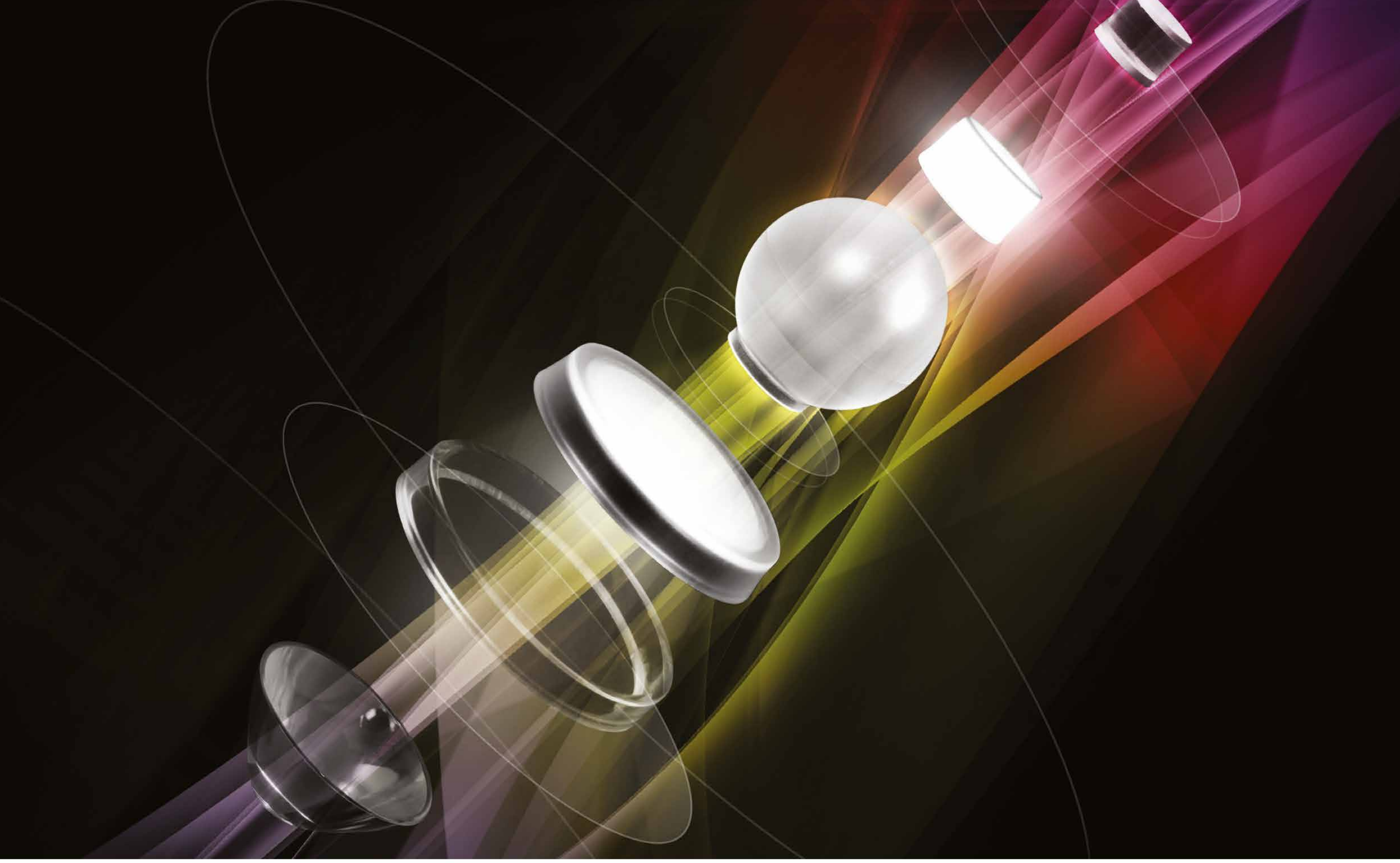
As an exclusive highlight, this issue of the LpR includes the latest technical articles from The Zhaga Consortium including the latest information and updates on COB modules, Driver and Module Interfaces, Thermal Interfaces and LES Considerations. Thank you to Musa Unmehopa and Tim Whittaker for this rewarding collaboration!

Further in this issue you'll find articles about research in phosphor materials for COB modules, photometric considerations of light measurements, graphene based LED technology, chip-array technology for SMD packages, thermal management considerations of PCB designs and noteworthy facts about light-pollution.

Have a great read.

Yours Sincerely,

Siegfried Luger
CEO, Luger Research e.U.
Publisher, LED professional
Event Director, LpS 2015

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Axel Schmid
Axel Schmid works as a designer for Ingo Maurer GmbH, a company in Munich, Germany.
They design, develop and produce lamps, light objects and interior spaces.
He studied industrial design at the Staatliche Akademie der Bildenden Kuenste in Stuttgart under Prof. Klaus Lehmann and Prof. Richard Sapper.
After his graduation he received a scholarship for Japan from the German Industrial Design association VDID. He has received various awards, one of which was the Bavarian State Award for young designers. One of his designs for Ingo Maurer is part of the permanent collection at the Museum of Modern Art in New York City.

CAN WE HAVE THAT, PLEASE? WHAT WE, AS A MANUFACTURER OF LAMPS, ARE LOOKING FOR

Many things have happened since the blue and the white LEDs were introduced to the market. It was, and still is, an exciting time for us as a manufacturer of lamps and light objects.

Of course Solid State Technologies often tries to substitute traditional light technologies (and is doing quite well in some cases), but when there are possibilities to make light broader - that's where it starts to get interesting for us. We appreciate the small form factor of LEDs and the thinness of OLEDs, for example. But often the design of structures and necessary components diminish the advantages, e.g. a heat sink, that adds volume to the back of an LED. It makes sense to find a classification and standardization so that development time is not wasted but where diversity isn't eliminated. It is compulsory in a competitive market to focus on sales figures and listen to the needs of the masses, but we need to save the niches and extremes.

In a sense this also applies to technical data, which improves continuously but still has a long way to go.

Because we generally produce light fixtures for residential spaces, we always seek a high CRI. This can be found more and more, especially with LEDs meant for ambient light output. But for lighting a room for living, you also need small and powerful spotlights with narrow beam angles and without multi shadows. This seems to be the field for flashlights, where output is the highest goal that subordinates the quality of white.

Or we want to modulate light in a certain way, not predefined or specified. Rigid systems spoil the varieties, modular set-ups help to adjust and fine-tune the outcome.

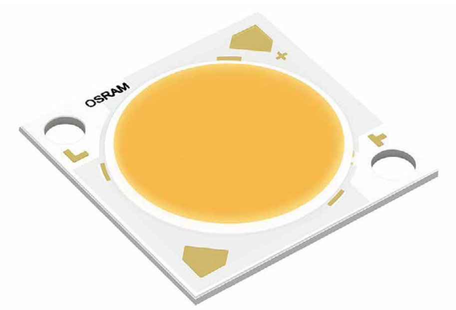
So in the end, even when the supplier market gets bigger and broader, we still have to watch what's going on at the cutting edge of SST developments, be alert and constantly willing to tinker (in its best sense) and experiment. In addition to that, we're always happy to find a supplier to team up with for development and customization (having a stake in big ideas rather than in big amounts).

And of course one is never satisfied. As soon as the next innovation is introduced, our imaginations are captured. It is indeed an exciting time for us and will continue to be so in the future. ■

A.S.

Osram Presents New Soleriq S 19 Version with Higher Efficacy

Osram Opto Semiconductors complements its Soleriq S 19 portfolio: The new "Brilliant Color" LED is especially designed for retail and shop lighting applications as it features a high color quality which is very similar to that of high intensity discharge lamps (HID). This enables rich and saturated colors and provides a high quality of white. They also launch product versions with an increased efficacy of up to 15%, depending on the type.



Optimal LED for shop lighting: The Soleriq S 19 "Brilliant Color" enables the colors of illuminated objects to look more saturated

With its new Soleriq S 19 "Brilliant Color" Osram Opto Semiconductors has managed to optimize the spectrum of the light source. The increased color gamut, together with the typical CRI of 85 ensures a good rendering of colors. This superior color quality originally is a key feature of high intensity discharge lamps (HID) and, until now, has been barely seen as a characteristic of LEDs. As the color appears more saturated, the new LED can emphasize and create an appealing appearance of commercial products. Together with its features like small size, directed light distribution, no heat radiation directly to the objects, minimal infrared and no UV radiation as well as long lifetime, it is an ideal solution for retail and shop lighting applications where products have to look as good as possible.

The three additional new versions of the Soleriq S 19 with CRIs of 70, 80 and 90 can be implemented in spot lights, professional downlights and general indoor lighting applications. With color temperatures between 2700 and 6500 Kelvin they offer warm white and cool white light for different lighting solutions. The substrate size of all versions is 24.0 x 24.0 x 1.4 mm, the operating temperature ranges between -30° C and 105° C and the junction temperature goes up to 125° C.

The launch of the "Brilliant Color" and the CRI 80 and CRI 90 versions is scheduled for mid of August 2015. The Soleriq S 19 with CRI 70 will be available by the end of the year. The certification process based on the LM-80 standard (Energy Star) is in progress. The results for 3,000 and 6,000 hours are already available; the results for 10,000 hours are expected by year-end. ■

Plessey Releases New Range of GaN-on-Si LED Dies

Plessey announced the release of its range of MaGIC™ LED die, manufactured on the company's patented GaN-on-Silicon technology. The blue die, sometimes referred to as blue pump for their ability to pump phosphor to a white color range, are the latest innovation in high brightness LED die designed for a wide range of medium to high power applications including general lighting, signage, commercial, residential and street lighting.

Plessy's new GaN-on-Silicon LED dies include a 4.5 mm high power LED die and a 1 mm die for 350mA

Plessey CTO, Dr. Keith Strickland, said, "We have developed a wide range of LED die for a number of applications and our GaN-on-Silicon technology works particularly well in higher power applications such as high bay, street lights, projector lamps, spot lamps and floodlighting. This current process technology will become the base for our application specific LEDs, the ASLED, which bridges the gap between LED component suppliers, solid state lighting fixture designers and the OEMs."

The manufacturing process produces a vertical LED structure which has the anode as bottom contact and the cathode formed in the top metal layer. The layout of the top metal layer is optimized for a particular LED size and die operating current, and includes one or more bond pads for connecting to the cathode.

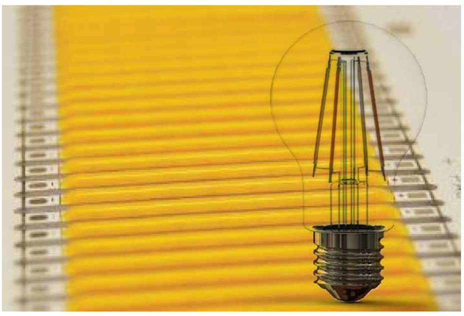
Giuliano Cassataro, Plessey's VP Global Sales, said, "We are seeing a definite move away from discrete PLCC designs, especially in the higher power applications. By having our own growth and semiconductor processing facility in Plymouth, Plessey provides the flexibility and speed of response required for a vast range of high-end applications that can use the thermal and light output from our silicon LED die."

Plessey offers its range of blue die in various wavelength options. Capable of generating over 60% light output efficiency, sometimes referred to as wall plug efficiency (WPE), the die are supplied to a standard thickness of 150 µm, whilst other thicknesses can be supplied, down to a minimum of 75 µm.

The die are supplied on a blue tape in single intensity and color bins to provide close uniformity, and are intended to be used with standard pick and place machines. Samples are available in a variety of die pack formats with blue die wavelengths ranging from 420 nm to 480 nm and from mille watts to 10 watts with the PExS4500 range having a typical optical output power of 4000 mW from a 3 A drive current. ■

Plessey Offers LED Filament Modules Using the MaGIC™ Die

Plessey announced the launch of its range of LED filaments, manufactured with the company's MaGICTM GaN-on-Silicon LEDs. The filaments are designed for the surging filament bulb market where the replacement lamps have far better performance, but still maintain the physical appearance of incandescent lamps.



Plessey's PLF series of filaments come in a variety of lengths, light output and color temperatures (CCT) from very warm 2200 K to 6500 K

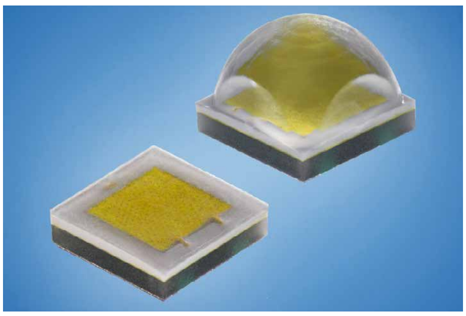
The traditional tungsten incandescent light bulb has been phased out in favor of LED technology providing the most reliable and efficient lighting solutions. Plessey's Chip-On-Board LED filaments create the same amount of light, while consuming less energy and offering longer life and utilize its patented MaGIC™ GaN-on-Silicon technology.

The LED filaments are designed with unique terminations so that they can be handled and spot welded by existing high volume fully automated glass lamp manufacturing lines. In addition to that, Plessey has incorporated a bespoke approach to controlling the current and Vf of the filaments when the filaments are driven in a bridge configuration.

Plessey's CTO, Dr. Keith Strickland, said, "We have taken our existing Chip-Scale-Packaging technology, also used for our dotLEDs, into a revised format for the filament. Not only do we have an improvement in terms of manufacturability with GaN-on-Silicon and enhanced the power control for filament resistors, but Plessey will also be incorporating other active and passive electronic components for Chip-On-Board and Chip-Scale-Packaging solutions in next generation of filaments. ■

Cree's new XLamp® XHP35 LEDs - The New Performance Standard for High Power LEDs

Delivering 50% more light output than the previous industry best, the XHP35 LED introduces Cree's breakthrough 12 V monolithic power die, empowering manufacturers to unleash the full capacity of extreme high power LEDs using existing drivers. Available in high density and high intensity versions the new XHP35 LED delivers up to 1,833 lumens. Offered in CRI 70, 80, and 90 and CCT from 2700 K to 8300 K with 2-step and 3-step EasyWhite® options.



Cree's new XHP35 family sets a new performance standard for high power LEDs

"We're excited that the XHP35 LED brings the performance of Cree's Extreme High Power LEDs to the XP footprint," said Jorge Fraile, CEO, Hispaled. "In addition to delivering an impressive amount of light, the XHP35 LED allows us to leverage existing drivers to achieve the full performance of Cree's high power LEDs at lower drive currents."

Unlike other existing high power LEDs, the XHP35 family of LEDs uses a new 12 V monolithic power die to deliver extreme high power performance at drive currents at or less than 1A, making the use of high power LEDs more accessible for lighting designers. This breakthrough is uniquely enabled by Cree's SC5 Technology Platform built on Cree's industry-leading silicon carbide technology and features significant advancements in epitaxial structure, chip architecture and an advanced light conversion system optimized for best thermal and optical performance.

The XHP35 LEDs are available in high density and high intensity versions that are optimized to deliver the maximum performance for specific applications. The XHP35 High Density LED delivers new levels of light output in the compact XP footprint for high lumen applications, such as outdoor and high bay lighting. The XHP35 High Intensity LED is optimized to deliver maximum candela through secondary optics to boost performance and reduce size for applications requiring high light intensity, such as stadium, torch and track lighting.

"Cree continues to redefine the performance of high power LEDs. The XHP35 LED represents a breakthrough that goes well beyond the incremental advances of other LED suppliers," said Dave Emerson, vice president and general manager for Cree LEDs. "Now, more than ever, manufacturers will be able to tap the full power of extreme high power LEDs to forge lighting designs that were previously thought to be impossible."

Samples of both XLamp XHP35 and XHP35 High Intensity LEDs are available now, and production quantities are available with standard lead times. The XHP35 LEDs are available in 70, 80 and 90 CRI and color temperatures ranging from 2700 K to 8300 K with 2-step and 3-step EasyWhite® options. ■

Edison Opto Introduces High Efficiency 2835 and 5630B Series

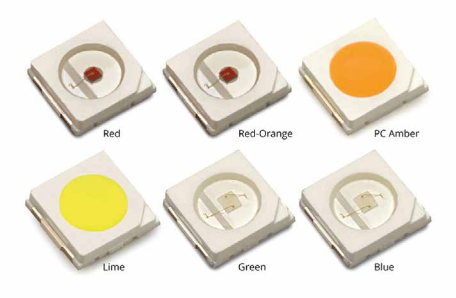
Edison Opto has been striving to introduce more high efficiency products in order to strengthen its market position. One of its new advantaged products is PLCC 2835 HE Series. It features ultra-high luminous efficacy (181 lm/W @ 4000 K) and compact package size which increase the flexibility in lamp design and expand the range of applications. With the outperforming efficiency, PLCC 2835 HE Series is optimized to be used in high-end LED markets such as boutique and luxury apparel stores.

Brighten your stores with the advanced PLCC HE Series which has higher efficiency and greater brightness; providing your customers with a better shopping environment

In addition, for the 5630 package product, Edison Opto introduces the advanced PLCC 5630B HE Series which has higher efficiency (188 lm/W @ 4000 K) and greater brightness (it reaches 34 lm @ 65 mA, 4000 K) than the previous products, providing customers with a better and brighter lighting environment. The slim size of PLCC 5630B HE series makes it flexible to be used in a variety of applications such as commercial lighting, residential lighting and hospitality lighting. ■

Lumileds Launches the LUXEON 3535L Color Line for the Perfect Color in any Situation

Lumileds launches the LUXEON 3535L Color Line, giving builders of emergency vehicle lights, signs, color tunable bulbs and architectural lamps access to high quality, single color mid power LEDs in Red, Red-Orange, Phosphor-Converted (PC) Amber, Lime, Green and Blue. "The tremendous success our customers have had with our high power color emitters convinced us that multiple markets could benefit from similar colors in the mid power performance range" said David Cosenza, Product Manager for the LUXEON 3535L Color Line.



From the PC Amber used in warm dimming lamps to the Lime used in color-changing bulbs, the LUXEON 3535L Color Line delivers high quality color in a proven, reliable package

One product from the LUXEON 3535L Color Line is the LUXEON 3535L PC Amber LED, which can replace three 2200 K LEDs in a warm dimming lamp while also delivering best-in-class flux and best-in-class hot/cold factor (flux at 85˚C relative to flux at 25˚C). The result is higher lm/W and lm/$ for creators of warm dimming bulbs.

Another standout product in the line is the LUXEON 3535L Lime LED, which makes color-changing bulbs, such as the Philips hue, much more affordable. "When mixed with Red, Lime's unique color point enables much warmer White light to be created than Off-White plus Red combinations," said Cosenza. The LUXEON 3535L Lime LED features a typical flux of 56 lumens (100 mA, 25˚C) and a stellar efficacy of 190 lm/W.

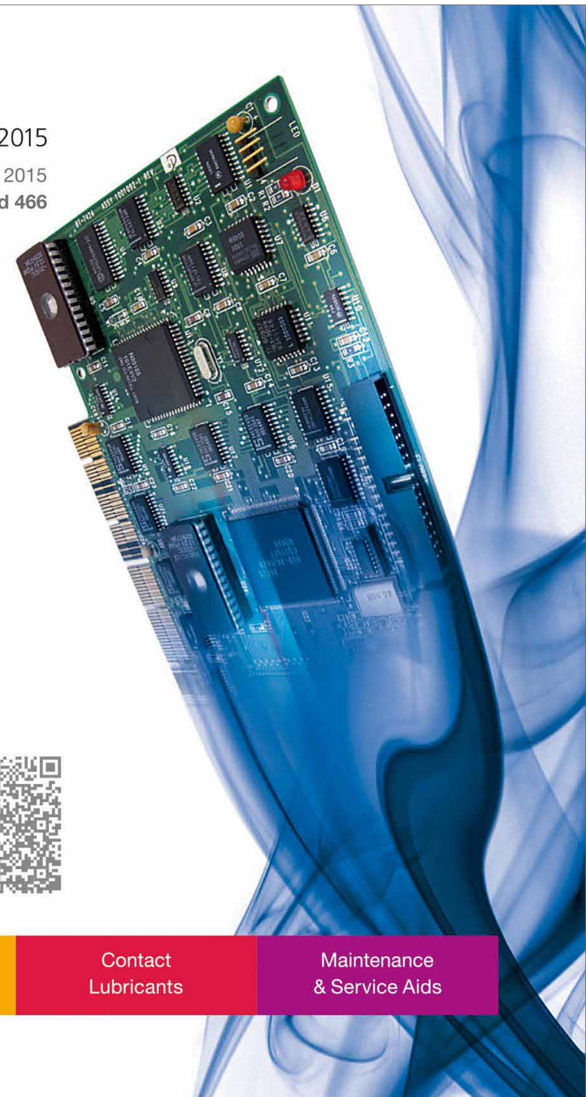
The LUXEON 3535L Color Line demonstrates the increased flexibility of the Lumileds color family through smaller lumen offerings. With the LUXEON 3535L Colors, current Lumileds customers looking to broaden their product line can realize the perfect amount of color every time, no more, no less - even using the same optics as the LUXEON Rebel Color LEDs and LUXEON Z Color emitters to quickly take their new products to market.

The addition of the LUXEON 3535L Colors to the existing LUXEON 3535L White LEDs creates the most comprehensive mid power family on the market.

Lumileds - Performance Upgrade Across the LUXEON CoB Core Range

Continuing to roll out chip-on-board (CoB) LEDs with ever higher efficacy and flux combinations, Lumileds today introduces the next generation LUXEON CoB Core Range. With the Gen 2 products, LUXEON CoB Core Range now delivers an average of 10% higher efficacy and 10% higher flux with a lower voltage and the same footprint, making it especially attractive to lighting designers.

Lumileds delivers even better options for designers of spotlights and downlights, bringing 10% higher efficacy and unmatched "punch" to its range of chip-on-board LEDs



"We are seeing tremendous demand in the retail and hospitality markets, where our award-winning* CrispWhite Technology really shines. These applications require not just the best quality of light, but the cost effectiveness that goes with an LED solution with up to 150 lm/W efficacy," said Eric Senders, LUXEON CoB Product Family Director.

For example, designers who implemented the LUXEON CoB 1208, which has a light-emitting surface (LES) of 15 mm, are upgrading lumen output from 3,600 to 4,000 lumens with a 10% higher efficiency. Alternatively, if the same output is maintained, efficacy can be boosted from 115 lm/W to 140 lm/W with the Gen 2 LEDs.

Lumileds is offering the LUXEON CoB Core Range (Gen 2) LEDs in multiple lumen packages from less than 1,000 lumens for MR16 and PAR lamps, up to 7,600 lumens for 100W CDM replacements. Color options include the popular 2,200 K for a candlelight ambiance and very efficient 90 CRI parts for high quality of light.

For ease of upgrade, the LUXEON CoB Core Range (Gen 2) products are fully compatible with Lumileds first generation of CoBs. ■

Diode Dynamics RGBW LEDs for Automotive

Diode Dynamics, has taken a major step forward in automotive lighting technology, by designing and manufacturing the first products using brand-new LED components, featuring an independent white chip in addition to multicolor functionality.

Diode Dynamics' RGBW LEDs are especially designed for automotive applications

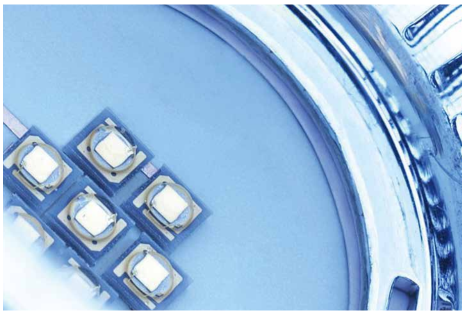
Previous generation multicolor chips feature only red, blue and green (RGB) chips, combining to create a poorly integrated white color. By adding a discrete white chip, the white color is substantially brighter and more balanced, when compared to that of old technology.

The company is now utilizing these components in a full line of LED products for automotive applications. By upgrading factory-installed LED lighting with the replacement products, vehicle owners can achieve multicolor functionality along with a crisp and pure white output.

Paul McCain, founder of Diode Dynamics, is looking to build upon his company's reputation for innovation by implementing this technology. "With the incredible versatility of these LEDs, I'm confident that they'll be standard on all vehicles within a few years. By being the first to apply this exciting new technology, we will continue being recognized as the go-to source for innovative automotive lighting products." ■

Osram Opto Improves Oslon SSL 80 and SSL 150 High-Performance LEDs

Osram Opto Semiconductors has unveiled the new generation of Oslon SSL 80 and SSL 150 with proven reliability and outstanding efficiency. These new LEDs offer improved performance and low thermal resistance, thereby extending the range of operating conditions in customer applications.



The powerful new generation of Osram Oslon SSL LEDs integrated in spotlights for professional indoor lighting

The LEDs cover a wide range of color rendering indices (CRI) and correlated color temperatures (CCT), making them ideal for various indoor and outdoor applications. They are tested under hot conditions (85° C), a temperature that is close to the operating conditions in customer applications.

Oslon SSL LEDs with a minimum CRI of 90 (2700 K to 4000 K CCT) are an ideal choice for spotlights for professional indoor lighting applications in shops or museums, for stage, accent and effect lighting as well as for retrofits and fixtures. The product versions with a CRI of 80+ (2500 K to 5000 K CCT) are suitable for applications such as high bay, low bay and PAR lamps. The minimum CRI of 70 (3000 K to 6500 K CCT) addresses the needs of industrial and outdoor lighting.

The new Oslon SSL products are 100 percent compatible with existing versions as they share the same footprint of only 3.0 x 3.0 mm. This results in high-density space-saving arrays and simplifies color mixing. Two different viewing angles of 80° (Oslon SSL 80) and 150° (Oslon SSL 150) give customers an additional choice in creating customized lighting solutions. The low thermal resistance of 4.2 K/W ensures cool running and high energy efficiency. Both new Oslon SSL types can be driven up to 1 ampere (A). Oslon SSL LEDs deliver high reliability and performance, and the high efficiency needed in professional indoor and outdoor lighting applications. ■

Universal Announces Zhaga Compliant Everline CRI 90 LED Modules

Universal Lighting Technologies announces a 90 Color Rendering Index (CRI) option for its Everline® Zhaga Hybrid (ZH) and Zhaga Hybrid Low (ZHL) Linear Modules. The 90 CRI option produces a vibrant color rendering that creates a crisp visual and better lighting solution. Everline modules are designed for use in high performance lighting fixtures with features that include high efficacy, excellent lumen maintenance and consistent color.

Everline LED modules are available in linear and round configurations for a variety of lighting fixture styles. Everline modules are offered in both indoor and outdoor LED lighting applications, and they are available in a large variety of lumen options.

In addition to Universal's current 80 CRI modules, the 90 CRI option will nearly double the available selections of Everline ZH and Everline ZHL families on the market

"We are extremely proud to be launching the 90 CRI line," said John Ronk, LED product manager at Universal Lighting Technologies. "We are confident in the quality and reliability of the product, with our long history of control manufacturing experience in North America. The continuous growth of the Everline family of LED driver and module components positions us at the forefront of LED technology and design application flexibility."

Universal has also launched new connector options for the 32 and the 56 Everline modules. These connector options are for end-to-end, series or parallel wiring. Standard, single connector models can be wired in series, while the dual connector driver can be wired at either end of the module to prevent shadowing in the middle of the fixture. ■

GlacialTech Announces 120 W LED Flood Light Heatsink Kit for High Output LED Lighting

GlacialTech, the diversified LED technology provider, announces a new 120 W heatsink kit for outdoor flood lights. The Igloo SS120 features an efficient heatsink with thermal resistance of just 0.34°C/W and includes a mounting bracket with 90 degree adjustability. A glass lens accommodates CoB LEDs and a waterproof LED cover is available for outdoor applications. Besides the default single unit kit, the Igloo SS120 also comes in double, and triple unit configurations for up to 360 W of LED illumination, allowing easy installation of high output lighting for stadiums, parking lots, and outdoor lighting applications.

GlacialTech's new Igloo SS120 heat sink can be configured to support applications with up to 360 W of LED illumination

Igloo SS120 Specifications:

- Part Number: CT-SS120000AB0001
- Dimension (mm): 370x132x60
- Weight (g): 1720
- Material: AL6063+AL1050
- Color: Black
- Surface Treatment: Black Anode
- Crafts: Stamping + Bonding
- Thermal Resistance (°C / W): 0.3417
- Surface Area (mm^2): 1047000
- Reference Design Power (watts): 120 W

Igloo SS120Features:

- Rated for 120W CoB or MPCB LEDs
- 0.34 °C/W thermal resistance
- 90° adjustable mounting bracket included
- Available in single, double, and triple unit configurations up to 360 W
- Waterproof LED cover available
- CoB LED lens available

Strong Thermal Performance for High Output LEDs:
GlacialTech's experience in thermal design allows it to create a heatsink boasting 0.34°C/W using stamping technology. The efficient thermal performance means high output CoB or MPCB LEDs up to 120 W can be accommodated.

Up to 360 W of LED Lighting for Outdoor Lighting:
The Igloo SS120 heatsink kit can be ordered in single, double or triple unit options. Up to 3 floodlights, each on its own adjustable bracket can be connected together for easy installation of high output lighting needs. With each module rated for 120 W, a total of 360 W of powerful LED flood lighting can be grouped as a triple unit array.

Complete Knock Down (CKD) Lighting Versatility:
The Igloo SS120 includes heatsink module, adjustable mounting bracket with 90-degree rotation, and optional lens or LED cover. Lighting installers can choose the appropriate LED luminaire and driver for their lighting needs and easily create high performance outdoor lighting with dependable GlacialTech thermal technology. ■

Fischer Elektronik for Cool LEDs

That the LED has already established itself as the light source of the future in many areas is sufficiently well known and hardly in doubt. Innovative heat dissipation concepts for cooling it are hence more urgently needed and sought-after than ever before to utilize its advantageous properties with true efficiency and for a particularly long service life. In this regard, Fischer is expanding its comprehensive LED cooling product range by three further active solutions.

Fischer's new LA LED 40x30, LA LED 50x20 and LA LED 50x45 active cooling series

The product series LA LED 40x30, LA LED 50x20 and LA LED 50x45 consists of a pin heat sink and a round fan motor that has been specifically conceived for active LED cooling. The fan motor has a double slide bearing and is designed for the particular requirements of LED applications in terms of noise and service life. It is screwed to the top of the pin using internally threaded distance sleeves that are provided for this purpose.

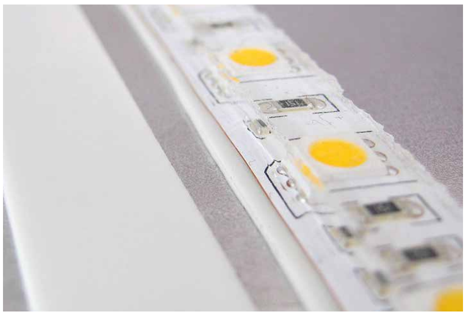
With their special arrangement and high number of pins, the compact pin heat sinks are designed for optimal air throughput. Thanks to the properties of their materials, their geometry and structure, these pin heat sinks are extremely efficient coolers for electronic components in free convection, but particularly also in forced convection.

The aluminum alloy used (Al99.5) has very good heat conductivity. In addition, the manufacturing process serves to create a homogenous material arrangement and microstructure that follows the direction of the heat flow - all of which ensures fast and even heat distribution in the heat sink bottom and fins.

The LEDs can be fastened to the pin heat sink with thermally conductive adhesive, double-sided thermally conductive foil, or screws. Mechanical treatments, custom designs and surface finishes can also be provided for your specific application.

Techsil - New Heat Transfer Tapes for Thermal Management in Electronic Systems

Heat is often the enemy of performance n today's intricate electronic systems, Techsil's new thermally conductive, pressure sensitive adhesive tapes provide a cooling solution by efficiently transmitting heat away from sensitive components. These double-sided tapes are designed for bonding heat sinks on PCBs, LED strips and IC packages, mounting of ICs, GPUs, heat pipes and for heat sink assembly.



Techsil's two new thermally conductive tapes consist of an acrylic adhesive which contains thermally conductive ceramic particles. This guarantees excellent thermal coupling for the tape that also provide a trustworthy bond

Benefits of Tapes as TIM:

- Clean: No mixing, dispensing or cleaning
- Fast: The strip and stick solution will increase output and minimize waste, it is easy to apply. As tape is a completely dry system there is no waiting around for it to cure, saving time
- Safe: Your Health & Safety department will be thrilled; there is no risk of spill, no mess and no hazardous nasties within the product composition to deal with
- Reliable: The length, width and thickness will result in a controlled thermal path
- Cost Effective: Can replace mechanical fixtures
- These gap filling foam tapes also come with the added benefit of providing vibration insulation and restricting any unwanted movement or slippage

Techsil are excited to introduce two new thermally conductive tapes (Stokvis 202331 and 202332) which not only allow heat to transfer easily and dissipate quickly but also provide a trustworthy bond. They consist of an acrylic adhesive which contains thermally conductive ceramic particles which transmit heat away from sensitive components.

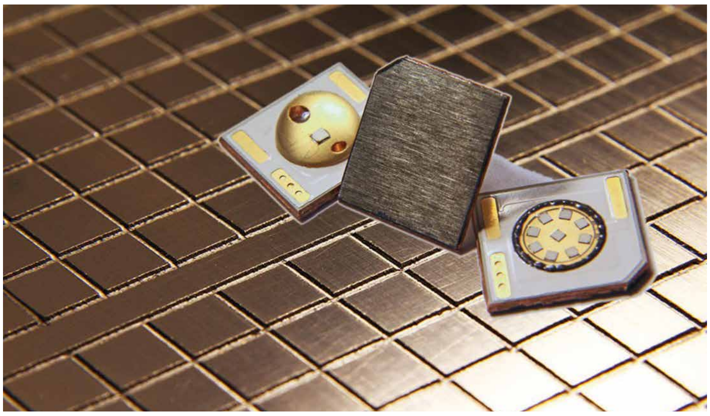
Providing excellent thermal coupling between components and heat sinks - their foam-like, compliant interface means that they fill any air gaps, thereby reducing the thermal resistance at the interface and can accommodate materials of different coefficients of thermal expansion. These double-sided tapes can be used in place of mechanical fasteners and are designed for bonding heat sinks on PCBs, LED strips and IC packages, mounting of ICs, GPUs, heat pipes and heat sink assembly.

Along with high thermal conductivity, Stokvis 202331 and 202332 also offer good heat resistance, age resistance and weatherability. These white, flame retardant acrylic foam tapes are halogen free and perform at intermittent temperatures of up to 150°C, with a continuous service temperature range of -40°C and +105°C - which means that electronic components can perform at the upper limits of their operating range for longer periods of time.

Here's the Technical bit:
The thermal conductivity offered by Stokvis 202331 is 2 W/mK, with a breakdown voltage of 35 kV/mm. It offers high adhesion on stainless steel and a static shear (@ 23°C) of 1 kg/625mm^2. This grade comes in a 0.5 mm thickness as standard, however if you're looking for a thicker alternative try Stokvis 202332 which is 0.8 mm thick. It still offers a high thermal conductivity of 1.2 W/mK, with a higher adhesion to steel.

Litecool Black X™ - New Dielectric Material for Thermal Management

Litecool has produced LED packages using a new dielectric material that has a thermal conductivity of 1000 W/mK - 3 times higher than copper and 30 times better than alumina ceramic. Dielectrics are used within LED packages to isolate electrical tracks but they hinder the thermal path causing the LED to overheat. Mid-lower, low cost LED packages use plastic as the main dielectric material. High-power, high cost LED packages use ceramics such as alumina as the dielectric.



Litecool claims Black X™ to have a thermal conductivity 3 times higher than copper and 30 times better than alumina ceramic

Litecool has successfully prototyped and tested LED packages using Black X™, offering a thermal conductivity 30 times higher than alumina, as the dielectric. The LED packages have a thermal resistance of between 0.2 °C/W and 0.5 °C/W depending on the construction. This is up to 6 times lower than the closest competitor which means the LED can be powered with 6 times more current without overheating.

"It is an incredible material. We have always assumed dielectric materials will hinder the thermal performance of our LED packages but this material actually improves it. The thermal resistances of the LED packages we have made are so low we had trouble measuring it. We had to use 9 high power LEDs in one package to give enough power density to record any difference in temperature," says Robert Corbin, Project Engineer at Litecool.

"This is a step change in the performance of an LED package. We will be able to hit new lumen density thresholds without the need for costly heat sinks, heat pipes or fans. We see this material initially being used in spot light applications for pin-point light sources but we also intend to incorporate it into our Lumen Block for the wider LED lighting market," Litecool's CEO James Reeves is convinced.

Mean Well Introduces New Price-Effective High Voltage, High Power LED Power Supply Series

Mean Well has been involved in the LED power supply field for years. Many models, such as CLG, HLG and HLG-C series, with the supreme product specification and high reliability, have been extensively exploited in various kinds of outdoor or indoor luminaire applications. In order to cope with the intense competition in the LED lighting market, Mean Well is now introducing the ELG family, the optimal price-performance ratio model with highly competitive pricing.

Mean Well's ELG family comprises 75 W through 240 W LED power supplies with high performance at reasonable cost

Main Features:

- 180-295 VAC input
- Constant Current (C.C.) output
- Built-in active PFC function
- High efficiency up to 92%
- Working temperature: -40~+70°C
- Protections: Short circuit / Over current / Over voltage / Over temperature
- Comply with harmonic current limit per EN61000-3-2 Class C (@50% load)
- Meet 6kV surge immunity level (EN61000-4-5)
- Approvals: UL / CUL / ENEC / CB / CE
- Type "HL" for use in class I, Division 2 hazardous (Classified) location luminaires
- Metal case, dimension (L x W x H): 280 x 144 x 48.5 mm
- 5 years warranty

The ELG family comprises the wattage from 75 W through 240 W. All of the models operate for the input range 180-295VAC. ELG-150-C is the first series that is announced - a 150 W power supply with constant current and high voltage output. This series adopts a fanless design; with the high working efficiency greater than 91%, it can work between the ambient temperature -40~+70°C under free air convection. ELG-150-C offers multiple function options, dimming functions and IP protection levels that can perfectly satisfy the design flexibility for lighting fixture designers (please refer to the table under Order Information).

ELG-150-C fits all kinds of LED luminaire applications, such as LED street lighting, LED harbor lighting, LED bay lighting, LED greenhouse lighting, etc. It is expected to be an extremely popular power supply product once launched into the market. ■

Thomas Research Products Introduces New PLED60W High-Performance LED Driver

Thomas Research Products has added the new PLED60W to the PLED series of high-performance LED Drivers. And with it, the entire PLED line is now UL Type HL rated for use in hazardous locations. Thomas Research Products manufactures complete SSL power solutions.

TRP's new PLED60W LED driver offers similar features and better performance than its predecessor while being 25% smaller

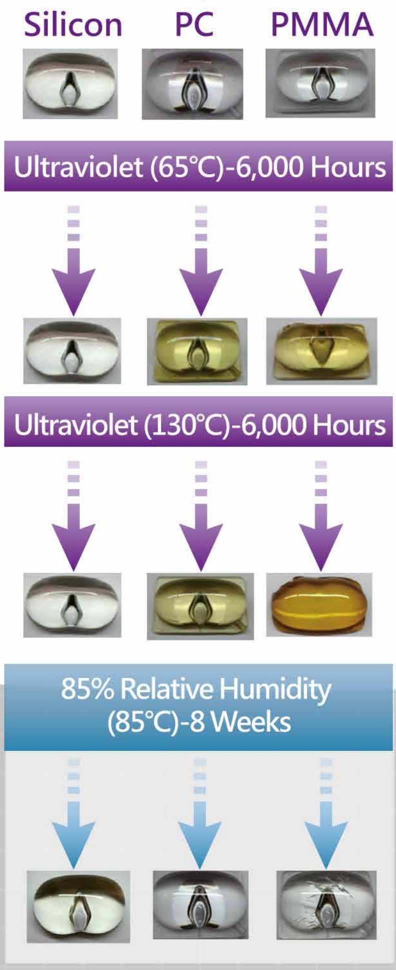
All PLED series drivers, including the PLED60W, now feature Type HL rating by UL. The design is robust enough for use in Class I Div 2 Hazardous Location luminaires. Even though not all applications require this rating, it provides OEMs assurance that these drivers will perform in a variety of environments.

TRP's PLED series drivers offer the features for which the company is known, including Black Magic Thermal Advantage™

Silicone Lens

High heat-resistance (150℃~200℃)
Apply to the High-Wattage and Heat-Concentrating product, e.g. street lamps, automobile lamps, stage lamps.

High Stability:
Ultraviolet endurance is better than PC and PMMA materials.



· Reliable Efficiency

- ✓ High purity.
- ✓ Maintain optical and mechanical stability when temperature reaches to 150℃.
- ✓ High optical transmittance.
- ✓ It doesn't yellowing easily.

Variety design via mold processing.

· Design Flexibly and Process Easily

- ✓ Lighter than glass and plastics.
- ✓ Precision molding (micro-size).
- ✓ Complex shapes (e.g. bottom routing, minus draft angle)
- ✓ Injection molding.

Equipment

Ledlink invested the silicon equipment and start to produce some single lens by our own. We also have another subcontractor to support our capacity.

aluminum enclosures. To keep luminaires performing, they offer over-voltage, over-current and short circuit protection with automatic recovery. They are also IP66 rated for dry and damp locations, and come with a 5 year warranty. ■

ROAL's New MESO 50W Offers RFID Wireless Programming

ROAL Electronics SpA announces the release of its newest programmable LED driver series, MESO 50, featuring the wireless programmability. This new RFID technology offers measurable benefits by enabling simultaneous feature set programming of multiple devices without the need to turn on the unit, or to remove the product from its packaging.

The only "all-in-one" 50W driver platform available with compact size, WW Input, Multi-Unit Wireless Programmability and Multiple Dimming - Suitable for indoor, outdoor and architectural applications

Providing 50 watts of power in a very compact size (105 x 73 x 27 mm / 4.13 x 2.87 x 1.06 in), with worldwide AC input voltage range (120/230/277 VAC) or optional DC power input and the industry's first multi-unit wireless programmability feature, MESO 50 reduces design time, lead time, and part numbers to stock while increasing designer flexibility.

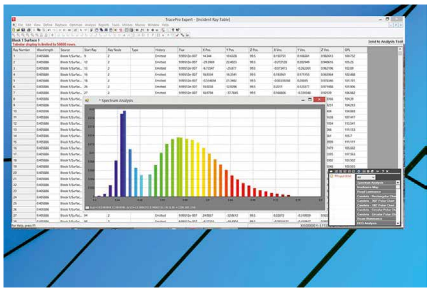
This flexibility is demonstrated by MESO 50's unique multiple dimming options, including Analog 0 - 10V, Digital control via either DALI or PWM, and Push Dimming.

MESO 50 ensures universal adaptability and delivers many advanced features such as lower THD <20%, PF > 0.9 at any nominal input voltage and 5kV Surge Protection. It is also suitable for harsh environments up to 90°C case temperature.

This new LED driver demonstrates ROAL's continued commitment to bring value to the lighting industry. Seven years ago ROAL introduced the most compact LED drivers in the market, enabling lighting designers to create smaller and more elegant fixtures. Now the lighting market benefits with the industry's first multi-unit RFID programmable platform. ■

Lambda Research Releases TracePro® Version 7.6 Update

Lambda Research Corporation, a leading designer and publisher of illumination and optical design software, announces the current release of the latest version of its flagship TracePro software.



Lambda Research's latest version of TracePro® has implemented several new features and material catalogues

The latest release, TracePro v7.6, includes the capability to create repetitive features on curved surfaces, new diffuser catalogs, new macro editor and a simplified menu structure that broadens the program's capabilities. The BrightView, Bayer Makrolon®, and Luminit diffuser sheet catalogs are now available as surface property catalogs in the TracePro v7.6 optical properties database. TracePro's Source Editor has been expanded to operate on Grid and File sources. The incident ray table now includes Optical Path Length information for each ray. The solar utility has been enhanced to add multiple solar tracking solutions and to calculate turbidity over a period.

TracePro's revised texture utility creates any type of repetitive geometry feature and textures on curved surfaces. This new feature is perfect for modeling curved displays especially ones using scattering features. The solid geometry created is fully customizable allowing optimization by the utility to create uniform displays. Users can specify spacing, feature type and cell layout using the utility to texture any curved or planar object.

A new Scheme macro editor has been added, Notepad++© to provide users with a powerful editing component. This new editor provides Scheme macro syntax highlighting, multi-document support, auto-completion, and macro launch directly from the editor.

Additionally, TracePro's menu structure has been simplified to create a more logical workflow by moving utilities into the correct menu placements. Menus have been kept one level deep to create a simple menu structure creating the easiest to use optical product on the market today.

TracePro offers the most powerful and sophisticated illumination design software available for LED implementation into lamps and luminaires. TracePro streamlines the prototype-to-manufacturing process by combining an intuitive 3D CAD interface, superior ray-tracing performance, advanced utilities, and seamless interoperability with other mechanical design programs. ■

Konica Minolta - New Compact, Easy to Use CRI Illuminance Meter

The CRI Illuminance meter CL-70F is a compact, lightweight, handheld entry-level instrument for measuring the color and illuminance of light sources (including new LED and EL light sources). Measurement data is displayed in terms of CRI, tristimulus values, illuminance, chromaticity, dominant wavelength, excitation purity, correlated color temperature, and difference values from a target.

Konica Minolta's new CL-70F CRI Illuminance Meter provides easy measurement and display of CRI, CCT, chromaticity, spectral information and gives a quick overview of all relevant values

Main Features:
- Spectral sensor with a measuring range of 380 nm - 780 nm
- Measure Color Rendering Index (CRI) with a comprehensive color bar graph
- Compact, easy to carry and battery operated
- Color touch screen for graphical and numerical display of measurements

The sleek instrument is designed for a variety of common lighting tasks including lighting design and ongoing maintenance. Providing spectral information and CRI measurement the CL-70F provides entry level access to cutting edge light measurement features. Combining the instrument with a flash sync cable enables spectral measurements of flash light making the CL-70F a powerful tool for professional imaging and entertainment markets.

CRI measurement:
The CL-70F provides easy access to CRI measurement data. The display shows the Ra value including all individual indices (R1 to R15) in a simple bar graph.

Easy measurement of correlated color temperature (Tcp):
The CL-70F can measure correlated color temperature and the difference from the blackbody locus Δuv, values which are often used to describe the color of light sources. The color temperature of light is defined as the absolute temperature (in Kelvin) at which a blackbody would emit that particular color of light. The colors of light emitted by a blackbody at various temperatures can be plotted on a curve which is called the "blackbody locus". Since the output of many light sources do not lie directly on the blackbody locus, "correlated color temperature" is used to describe their colors.

Easy Zero-adjustment without a receptor cap:
Slide the ring on the diffusor counterclockwise to perform dark calibration.

Additional features provided by included Utility software CL-SU1w:
With the software CL-SU1w which is included as a standard accessory, you can modify instrument settings, store & group data and make further analysis of the measured data.

The CRI Illuminance Meter perfectly fits into the range of compact handheld Light Measuring instruments between the colorimeter model CL-200A and the high precision spectrometer CL-500A.

MTCS-C3 Colorimeter for LED Quality Control, Color Measurement

The new MTCS-C3 product family enables users to implement their own True Color Colorimeter into lighting, backlight, LED tests, color selection or other applications. The MTCS-C3 is ideal to measure color coordinates (XYZ), CCT or brightness levels.

MAZeT's OEM Sensor Board MTCS-C3 with USB interface for color measurements based on CIE1931 can be used as stand-alone USB color sensor

CIE1931 XYZ Colorimeter board for color testing applications
The sensor system is based on the JENCOLOR® standard components MTCSiCF (True Color sensor) and MCDC04 (Signal converter). The sensor is based on the CIE1931 XYZ color standard, while the signal converter allows an output at 16/20 bit at a dynamic range of 1-to-1,000,000.
The Evaluation Kit is prepared for specific customer calibrations.

The JENCOLOR® True Color sensors and signal ICs are an ideal solution for stabilization of LED light in regards of aging, binning and temperature shifts. Additionally used in industrial color measurement tasks, medial applications and for metrology solutions.

True Color measurement made simple
The sensor system is based on the JENCOLOR® standard components MTCSiCF (True Color sensor) and MCDC04 (Signal converter). Therefore displays can be measured at very low brightness levels and at high accuracy - even dimmable high brightness power LEDs at high temperatures (>100°C) and brightness levels can be measured close to the target.

The colorimeter has a micro USB interface and can be directly controlled via Windows software. The software includes ADC parameters such as gain, integration time, offset correction, and divider options.
The values can be individually calibrated to the application and have several output options (color spaces, export functions, etc.) The MTCS-C3 is an ideal solution for LED

tests in manufacturing or incoming goods inspection and is a cost-efficient solution to be utilized at multiple measurement points. A simple user calibration can be performed to the existing LED selection and as soon as color or brightness deviations occur, actions can be taken.

Even special features like flicker detection for displays are implemented. For customer-applications, an adaptation of the software is offered or they can use the DLL libraries to develop and integrate their own software solution.

The MTCS-C3 is available in 4 versions. As an OEM-Board with and without metal casing or as a Development Kit including software with or without metal casing. Only one software license is required to use it for multiple sensors. ■

Molex TermiMate™ Connector Minimizes LED Shadowing

Molex Incorporated introduces the new TermiMate™ one-circuit terminal-style connector system. Designed to minimize the shadowing effect in LED lights and TV backlighting applications, the ultra-low profile TermiMate coplanar board-to-board and wire-to-board connector reduces component and assembly costs for manufacturers.

Molex TermiMate™, the sleek new connectors for LED lighting, help to save space and money

"In LED applications, standard higher profile components are prone to create unwanted shadowing that negatively impacts the light quality," said Goji Tanabe, regional product manager, Molex. TermiMate connectors provide the lowest profile possible to most effectively prevent shadowing, coupled with space savings to address downsizing trends in LED lighting designs.

Delivering a 3.0 A rated current, the 1.20 mm height TermiMate connector system provides an economical alternative to higher profile two-piece style LED housing components. A simple plug and receptacle terminal makes TermiMate connectors ideal for wire-to-board and coplanar board-to-board LED lighting configurations. The TermiMate system requires no direct wire soldering, which reduces assembly cost and eliminates risks associated with weak solder joints that can cause problems in LED performance.

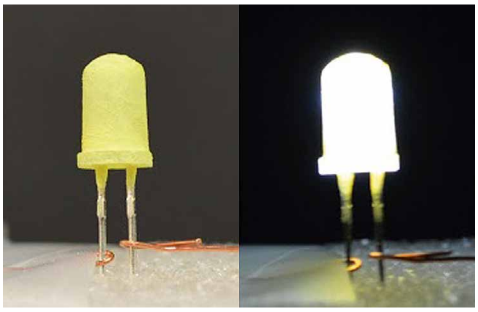
Unlike soldered components, the TermiMate connector allows for easy mating and unmating. Designed with built-in floating tolerances, the TermiMate board-to-board connection supports proper insertion to help prevent terminal damage during assembly and maintenance. The wire-to-board receptacle mates with the PCB crimp facing to reduce risk of signal conductors making contact with board circuitry. A friction lock assures secure mating and connectivity.

"The brilliance of eliminating the housing means Molex customers gain design flexibility, improve LED reliability, and save money with new TermiMate connectors when compared with a traditional two-piece connector housing," adds Tanabe.

By combining best-in-class electrical, thermal and optical expertise with in-house design and manufacturing capabilities, Molex creates LED light modules and connectivity solutions designed to overcome challenges unique to LED lighting. ■

Researchers Propose New Technology without Rare Earth Metals for LED Lighting

At the 250th meeting of the American Chemical Society a novel approach to generate white light without using rare earth metals was presented. The researchers claim that this approach will lead to cheaper warm white LEDs than the currently used technologies. A press conference on this topic was held on August19, at 9 a.m. Eastern time in the Boston Convention & Exhibition Center.



An LED coated with a yellow "phosphor" is shown turned off (left) and then turned on (right). This "green" LED is inexpensive and provides warm white light (Credit: Zhichao Hu, Ph.D.)

Highly efficient, light-emitting diodes (LEDs) could slash the world's electricity consumption. They are already sold in stores, but more widespread adoption of the technology has been hindered by high costs due to limited availability of raw materials and difficulties in achieving acceptable light quality. But researchers will report today that they have overcome these obstacles and have developed a less expensive, more sustainable white LED.

"If more people in the U.S. used LEDs in their homes and businesses, the country's electricity consumption could be cut in half," says Zhichao Hu, Ph.D., a member of the Rutgers University team that performed the research under the direction of Jing Li, Ph.D. At that time, he was a graduate student. He is now a postdoc at Rutgers and is studying the recovery of rare-earth elements there. Zhichao adds that studies show substituting one LED light for a common incandescent light bulb in every American household could save the nation $700 million annually in energy costs.

To achieve the common, soft white light that consumers expect, current LED technologies typically use a single semiconductor chip to produce light, usually blue, and then rely on a yellow-emitting "phosphor" coating to shift the color to white. That's because LEDs do not emit a white light. The phosphor is made from materials, such as cerium-doped yttrium aluminum garnet, that are composed of rare-earth elements. These elements are expensive and in limited supply, since they are primarily available only from mining operations outside the U.S. Additionally, the light output of these phosphors tends to be harsh, "cold" colors.

Li's team is developing hybrid phosphor-based technologies that are much more sustainable, efficient and low-cost. They combine common, earth-abundant metals with organic luminescent molecules to produce phosphors that emit a controllable white light from LEDs. By varying the metal and organic components, the researchers can systematically tune the color of the phosphors to regions of the visible light spectrum that are most acceptable to the human eye, Hu and Li note. The team is continuing to experiment and develop other rare-earth-free LED phosphors based on different metals and organic compounds.

Many material combinations are possible, so they use a computational approach to initially sort through the possibilities and to predict what color of light the various metals and organics combinations will emit. They then test the best combinations experimentally.

Their approach allows a systematic fine tuning of band gaps and optical emissions that cover the entire visible range, including yellow and white colors. As a result, their LEDs can be fine-tuned to create a warmer white light, similar to cheaper but inefficient incandescent lights. Their approach shows significant promise for use in general lighting applications.

“One of the challenges we had to overcome was to figure out the right conditions to synthesize the compound,” Hu notes. “Like cooking, the synthesis requires a ‘recipe’. It’s often not the case that one can simply mix the starting materials together and get the desired product. We optimized the reaction conditions - temperature and the addition of a solvent - and developed an easy procedure to make the compound with high yield.”

Experiments with some materials have shown that the team’s technology can cut LED costs by as much as 90 percent from current methods that rely on rare-earth elements. They have several granted and pending U.S. patents and are exploring manufacturing possibilities.

Funding for this research was provided by the National Science Foundation and Rutgers University. Hu is currently funded by the Department of Energy’s Critical Materials Institute.

The American Chemical Society is a nonprofit organization chartered by the U.S. Congress. With more than 158,000 members, ACS is the world’s largest scientific society and a global leader in providing access to chemistry-related research through its multiple databases, peer-reviewed journals and scientific conferences. Its main offices are in Washington, D.C., and Columbus, Ohio.

Quantum Dot Technology may Help Light the Future

Advances at Oregon State University in manufacturing technology for quantum dots may soon lead to a new generation of LED lighting that produces a more user-friendly white light, while using less toxic materials and low-cost manufacturing processes that take advantage of simple microwave heating.

The orange color in the letters “OSU” is produced from “quantum dots” viewed under a microscope, as they absorb blue light and emit the light as orange - an illustration of some of the potential of new technology being developed at Oregon State University (Image courtesy of Oregon State University)

The cost, environmental, and performance improvements could finally produce solid state lighting systems that consumers really like and help the lighting bill almost in half, researchers say, compared to the cost of incandescent and fluorescent lighting.

A key to the advances is the use of both a "continuous flow" chemical reactor, and microwave heating technology that's conceptually similar to the ovens that are part of almost every modern kitchen.

The continuous flow system is fast, cheap, energy efficient and will cut manufacturing costs. And the microwave heating technology will address a problem that so far has held back wider use of these systems, which is precise control of heat needed during the process. The microwave approach will translate into development of nanoparticles that are exactly the right size, shape and composition.

"There are a variety of products and technologies that quantum dots can be applied to, but for mass consumer use, possibly the most important is improved LED lighting," said Greg Herman, an associate professor and chemical engineer in the OSU College of Engineering.

"We may finally be able to produce low cost, energy efficient LED lighting with the soft quality of white light that people really want," Herman said. "At the same time, this technology will use nontoxic materials and dramatically reduce the waste of the materials that are used, which translates to lower cost and environmental protection."

Some of the best existing LED lighting now being produced at industrial levels, Herman said, uses cadmium, which is highly toxic. The system currently being tested and developed at OSU is based on copper-indium-diselenide, a much more benign material with high energy conversion efficiency.

Quantum dots are nanoparticles that can be used to emit light, and by precisely controlling the size of the particle, the color of the light can be controlled. They've been used for some time but can be expensive and lack optimal color control. The manufacturing techniques being developed at OSU, which should be able to scale up to large volumes for low-cost commercial applications, will provide new ways to offer the precision needed for better color control.

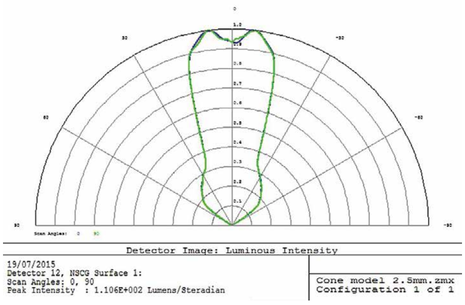
Some past systems to create nanoparticles for uses in optics, electronics or even biomedicine have been slow, expensive, sometimes toxic and often wasteful.

Other applications of these systems are also possible. Cell phones and portable electronic devices might use less power. Compounds with specific infrared or visible light emissions, could be used for precise and instant identification of e.g. counterfeit bills or products.

OSU is already working with the private sector to help develop some uses of this technology, and more may evolve. The research has been supported by Oregon BEST and the National Science Foundation Center for Sustainable Materials Chemistry.

Litecool Demonstrates that Narrow Beam LED Packages are Possible

Litecool has been working on various LED package designs to give luminaire manufacturers an LED package that doesn't need any further lensing or reflectors to give the desired beam patterns for lighting applications. Litecool is well known for their innovative approaches to thermal management but this is their first real development in optical technology and it looks like it could be pretty useful for lighting manufacturers.



Litecool have shown promising results for new LED package design that gives focused light beams with no secondary optics or reflectors

Nearly all LED packages come with a near Lambertian emission leaving the luminaire manufacturers to work out how to shift that into something useful for their application. This gives both an efficiency and financial cost which Litecool believes they can eliminate with their packages.

Litecool designs and develops LED COBs and packages from scratch. That means they can change the optical surfaces within the package allowing for different emission patterns. A recent project completed by Litecool has shown that with minor changes to these surfaces they have been able to produce a 36-degree spot with efficiency above 90%. The project is set to continue and will look to bring the beam angles down to levels suitable for the majority of lighting applications including spotlights. It is expected that Litecool will incorporate this technology within the Lumen Block product range due out next year.

"This is the first iteration and it looks promising. We will be able to reduce beam angles down to around 20 degrees with about 90% efficiency. It doesn't cost much to make a few design tweak in our packages so it looks like we are going to be able to offer specific beam patterns directly from our LED packages with greater efficiency and lower system costs than what can be achieved at the moment," says James Reeves, CEO of Litecool.

Non-Glare Hybrid Optics with Defined Beam Angles by Auer Lighting

Auer Lighting presents new hybrid glass optics. The Jupiter product line is designed for advanced LED luminaires featuring the lighting designer's desire: no glare and defined beam angles.

The Jupiter is a combination of a lens and a reflector, merging two optical concepts in only one product. The lens in the center greatly reduces the amount of direct emission from the LED that typically leads to unwanted light spill.

The reflector directs the light via its facetted free-form surface into a defined angular cone forming nicely shaped Lambertian distributions. The durable dichroic coating, using Auer's patented PICVD technology, results in a reflectivity >95%.

Pressed-in SNAP IT® features enable an easy mounting as well as a user-friendly exchange to other beam angles in the luminaire.

The optic is made from durable SUPRAX® glass that easily withstands temperatures up to 450 °C. It lasts even under harsh conditions. No yellowing effect is seen, nor any degradation over time.

The surface of the glass and even the coating is easy to clean, scratch-resistant and guarantees longest life times.

The Jupiter optic is now available as 50 mm diameter version with narrow, medium and flood beam angles, best for LEDs with 6 mm LES or below. The same beam angles are available for the slightly larger 70 mm version, which is optimized for LEDs with a LES of 9 mm and below.

Dow Corning® EI-1184 Clear Encapsulant

Material description

Dow Corning® EI-1184 Encapsulant is a clear, two-part silicone product designed to offer reliable Electronics protection for lamps and luminaire components in interior and outdoor applications.

Featuring high transparency and weatherability, the two-part silicone encapsulant delivers reliable, long-lasting protection of sensitive LED electronics in environments containing moisture, ultraviolet (UV) light, thermal cycling and extreme temperatures for both indoor and outdoor lamp and luminaire applications.

Key features of this advanced material include:

- Protects against harsh outdoor environment
- UL 94-V1, UL 746C (f1)
- High transparency and less yellowing
- Two-part, 1:1 mix ratio
- Rapid and versatile cure processing controlled by temperature

Dow Corning® EI-1184 Clear Encapsulant is suitable for:

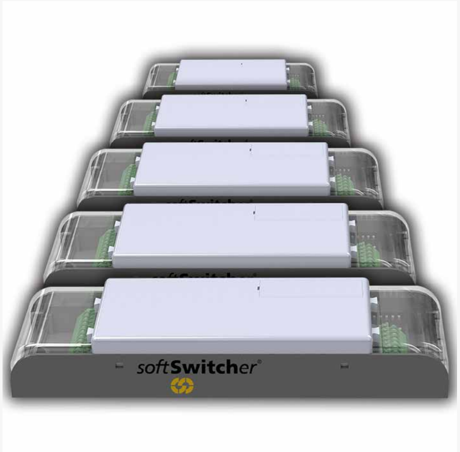
- Encapsulating rigid and flexible circuit boards indoor and outdoor LED Lighting applications

GL TEC Control System

Today, the realm of light measurement is expanding beyond classic optical measurement and investigating phenomena like thermal conditions, current or power levels. Requirements placed on luminaire developers and manufacturers either by updated standards or the market directly go beyond the classic sphere-based system and for example, call for stable and reliable ambient temperature conditions. The need has therefore arisen to stabilize the temperature of LED fixtures during measurements or simulate different LED performance temperatures. In fact, the latest test method standards, like CIE S 025/E:2015, are demanding that lighting developers and manufacturers look at the issues of thermal control more closely.

To this end, GL Optic has taken the step to develop and now offer a complete solution to meet the new thermal control demands. The GL TEC Control System includes our top-of-the-line Spectis 6.0 laboratory grade spectrometer, coupled with a state-of-the-art TEC controller and mount, along with a programmable power supply and the GL OPTI SPHERE 500. With detailed control from the temperature controller, the module can create the optimal stable conditions for measurements, or simulate nearly any temperature conditions. The hardware is integrated with GL AUTOMATION, a powerful module of the GL SPECTROSOFT software solution, which essentially lets you control the entire set of peripheral devices and plan, launch and monitor any required automated testing scenario.

Softswitcher SSW60Q from SwitchTech AB



The all new LED driver SSW60Q (V-36060SSWQ) is available in drive powers of up to 60 W on two independent output channels. At the same time all 60 W can be utilized on a single channel or any other combination. It is suitable for large indoor installations such as office, retail, hotel or conference rooms and special applications. It is also ideally suited for demanding lighting needs in all locations. Its drive capabilities, extreme flexibility and small size makes it a perfect driver solution.

The new digital design implies several advantage for digital LED drivers due to characteristics of the Softswitcher platform:

- Driver design for less weight and smaller size
- Highe efficiency (up to 90%) over the entire output range means increased energy savings
- Power factor up to 0,98
- Synchronized and dynamic adjustment of switching patterns to reducte EMI
- Impressive life time of 100 khs
- Intelligent software using microcontrollers means limitless control options including 0/1-10 V, DALI, DMX, phase-cut control, Wifi, Zigbee, Bluetooth etc..
- Scalable technology with customizable features means short time to market
- Custom drivers in low volumes due to reprogramming using software tool

PLEXIGLAS® WH Simplifies Manufacture of Slim Edge-Lit Panel Lights

A new product from Evonik Performance Materials, PLEXIGLAS® WH, not only simplifies manufacturing of slim edge-lit panel lights, but also enables new design options.

PLEXIGLAS® WH combines several centerpieces of an edge-lit light guide panel in a single product: a PLEXIGLAS® PMMA light guide sheet, a light extraction pattern optimized for homogeneity and efficiency, and a high performance light reflector layer. Small volumes for validation are available immediately upon request. The length of the panel is variable and can be trimmed to its required size by typical processing methods suitable for PLEXIGLAS® (e.g. CNC mill, circular saw, laser). Costly optical simulations for optimization of the light extraction patterns, as well as screen printing or laser etching of the extraction pattern are no longer necessary for edge-lit luminaire manufacturing with this product.

In addition to standard flat light guide applications much more complex shapes are possible with this product by thermo- or vacuum forming processes, literally opening up a new dimension of design options for edge-lit LED luminaires.

Energy Harvesting Ambient Sensor for Tunable White Control

Light quality is a very important factor in human wellbeing. In addition to lighting intensity, Correlated Colour Temperature (CCT) also has a fundamental influence on our mood and performance. Furthermore, we live in an era of smart of environmentally responsible technologies.

To facilitate control, iLumTech has developed BlueBridge, and interface between Bluetooth Smart and standard DALI buses. BlueBridge is powered from directly from the DALI bus and so does not need any power source. Using BlueBridge allows for complete control via a DALI installation, even of type 8 devices (colour control). The GUI is an app that runs on Android devices that support Bluetooth Smart. The control features of BlueBridge can be used generally for any type of DALI installation where the range of Bluetooth Smart is sufficient (up to 50 m without obstacles). Furthermore, BlueBridge is fully compatible with the EHA Sensor. Using the app, users can configure a simple regulation loop that reads data from an EHA Sensor and control Tunable White luminaires (defined by group addresses) using BlueBridge as an interface with the DALI bus.

The EHA Sensor is a pocket-sized solution for accurate and realistic measurement of ambient lighting intensity and CCT values at task areas in offices and homes. In combination with BlueBridge and compatibility with Bluetooth Smart, it allows for comfortable date presentation and wireless control of DALI installations (exclusive of the wiring of the luminaires).

Dow Corning® CI-2001 White Reflective Coating

Material description:

The Jupiter optic is now available as 50 mm diameter version with narrow, medium and flood beam angles, best for LEDs with 6 mm LES or below. The same beam angles are available for the slightly larger 70 mm version, which is optimized for LEDs with a LES of 9 mm and below.

Uses:

Dow Corning® CI-2001 White Reflective Coating is used as a bright-white reflective coating to enhance light output and efficiency for light reflectors, mixing chambers, backlightunits, light engine units, printed circuit boards and aluminum surfaces used in assembly of LED lamps and luminaires.

Key features of this advanced material include:

- 96% reflectance at 5-mil coating thickness and 94% reflectance at 3-mil coating thickness
- One-component formulation offers simple room-temperature cure that can be accelerated with heat for higher productivity
- Applies easily by spraying, dipping, brushing or flowing
- After cure, forms a tough, resilient coating with a nontacky surface
- Reliable, long-lasting performance between -45 and 200°C (-49 and 392°F)
- Less than 50 g/l of nonexempt VOC content
- UL flammability rating UL-V0

Gaggione LLC66N7 - Silicone Narrow Beam Collimator

Gaggione expanded its LEDnLIGHT® family to address the latest performance demands for solid-state lighting with the patented new collimator LLC66N7 in optical grade silicone with a narrow beam angle down to 6° based upon LES.

The unique design of Gaggione's LLC66N7 with an internal concave cylinder shape, a negative counter draft angle, permits the use of larger, brighter COB light sources with optimal light output ratios up to 23 mm LES. Our patent pending designe erases stray light detracting from the output of LED light sources. Gaggione's proprietary output micro texture contributes to an incomparable homogeneous light distribution.

The use of optical silicone delivers reliable mechanical and optical performance despite exposure to high lumen densities, outdoor ultraviolet (UV) light or external temperatures cycling between -40°C and 150°C and minimizes the injection channel to less than 2 mm.

Features:

Dimensions:	d = 67.2 mm, h = 36.0 mm
Material:	MS-1002 moldable Silicone Material Dow Corning 80 Shore, UL listed
Tolerances:	Comply with NFT47001 category M1

ISD-100-HFT - A New Integrating Sphere from Gigahertz-Optik

LED lamps are highly effective. Even so, when they are in use the electronic control gear produces heat. For LEDs as a semiconductor, this causes changes in the luminous flux, spectrum and color and can result in a reduction of the life span. Therefore the heat must be dissipated effectively. The orientation of the lamp, with the socket facing downwards, upwards or horizontal, can have an effect on the thermal management. Therefore it is important to take the intended operating position into account when evaluating the lighting technology.

The new Integrating Sphere ISD-100-HFT from Gigahertz-Optik GmbH has a circumference of one meter and makes it possible to measure various light parameters like light flux, spectrum and color. The sphere can be opened and makes it possible to install lamps with various sockets with its adjustable sample holder. The optional four pole measuring sockets allow precise measurements of the electric operation parameters of the lamp. The integrating sphere is easy to turn and lock on its horizontal axis. This makes it easy to qualify lamps in various operation positions.

The BiTec-Lightsensor Spectroradiometers from Gigahertz-Optik GmbH are ideal for use with the sphere. Their construction concept avoids the use of light conductors and their disadvantages.

OUT OF BOUNDS DESIGN CONTEST

STUDENTS EXPLORING COMPLETE FREEDOM IN LIGHTING DESIGN

Seventeen innovative prototypes are the outcome of a four-month long journey taken by students from the Department of Design at the University of Applied Sciences in Munich, Germany. In collaboration with Seoul Semiconductors they got to experiment with AC-LED modules as light sources and discover lighting design without the traditional barriers of LEDs. The prototypes will be exhibited at the LED professional Symposium +Expo 2015 in Bregenz, Austria.

Who better to explore complete freedom in lighting design than those with fresh eyes and minds, namely design students? This idea laid the foundation for Out of Bounds Design Contest, which awarded the most imaginative, forward-thinking designs. "By engaging with young and creative students, who have no limits and could work unreservedly with this technology, we wanted to provide a platform to demonstrate what great solutions can be realized with the design freedom enabled by Acrich. By doing so, it was our goal to show established lighting manufacturers what excellent designs can be achieved with new technologies like AC-LED technology, and that in reality the barriers are not as high as the perception today", said Andreas Weisl, Vice President Europe, Seoul Semiconductor.

Award Ceremony at the LpS 2015

On July 9th the prototypes were presented to a jury comprising of Prof. Peter Naumann from the University of Applied Science in Munich, the internationally well-known industrial designer Ingo Maurer, Andreas Weisl from Seoul Semiconductor, Stefan Eckstein - President of the federation of German lighting designers, Markus Helle - Chief Editor at the Highlight Magazine and Siegfried Luger - Founder of LED professional. According to the jury it was extremely difficult to choose a winner, as all prototypes were so different in their designs and application. Finally they agreed not to award any of the projects but to highlight three prototypes, which were most interesting from a technical point of view: A construction lamp from Lena Gillitzer, a hanging lamp from Julian Lang and another hanging lamp from Christopher Gros. "I am very proud of the fantastic results. The seventeen luminairies couldn't have been more diverse. This diversity highlights the quality and creativity of the young designers.", stated Prof. Naumann, who guided the group of students through the project. The award ceremony will take place on Sept. 22nd at the LpS 2015 as a part of the "Design meets Technology" program. All seventeen prototypes will be exhibited during the three-day LpS event in Bregenz, the meeting point for the international lighting industry.

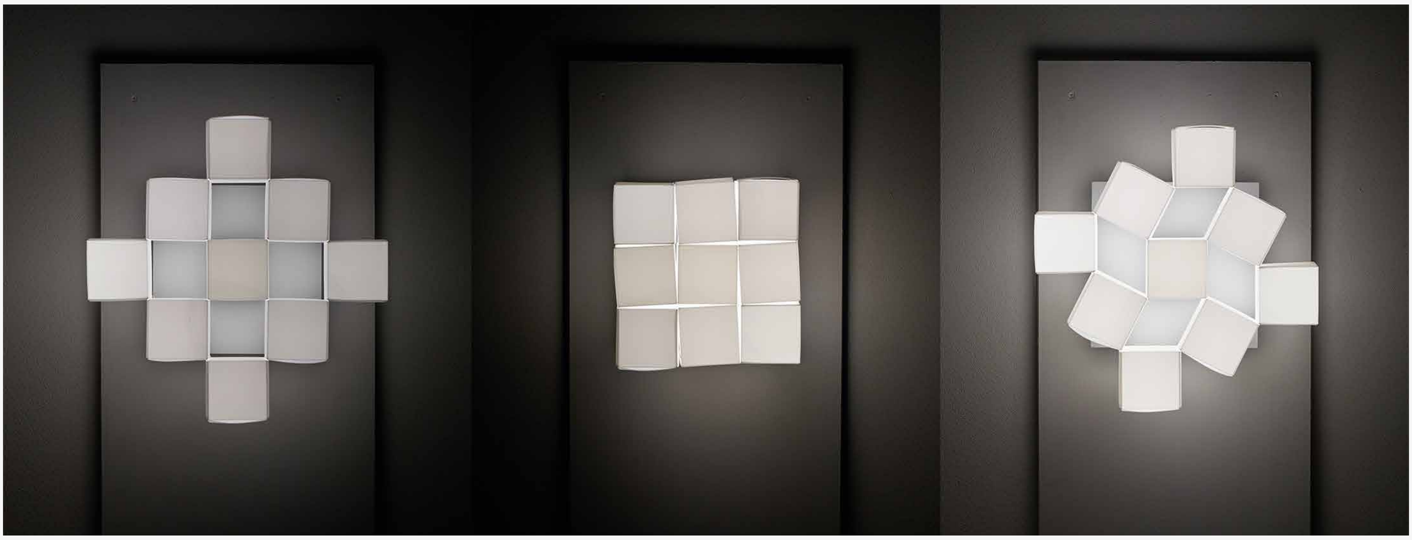
A student describes her journey

Magdalena Gillitzer created an innovative construction lamp, consisting of two foldable light panels. The panels can be turned and twisted for creating different light directions and different impressions. She described the Acrich3 technology as very useful and important for her lamp as the lamp stays flat in the design without any electronic ballast. This makes it easier to carry the lamp and change locations.

Ms. Gillitzer has a passion for light and technology and she has taken part in other lighting projects before. "Seoul Semiconductor's technology is something very functional, in my opinion. So it was clear to me from the beginning that I would design something useful and functional where the technology makes sense", explained Ms. Gillitzer. In the research phase of her project she realized that most of the existing construction lights are very functional in their aesthetics and shape and therefore often not attractive. She decided to design something different: a functional lamp which is highly aesthetic at the same time. The most difficult part was for her to deal with high power LEDs, which produce a lot of heat and therefore need a certain sized cooling body and distance to the diffusor. "So in the end, the light effect had to take a back seat", said Ms. Gillitzer. She focused on the body of the lamp, which is the cooling body at the same time.

In a next step she plans to give the 3D-Data of her construction lamp called "Trinity" to a professional miller. According to her it will be possible to optimize the cooling body in order to have an even better cooling effect through thinner cooling ribs. She also plans to optimize the light effects. After asking her about her future plans she said "It would be great to use the Acriche 3 Technology one day to have a dimmable light".

LpS Event Website: www.LpS2015.com



The IAU as a partner of IYL is working towards raising awareness of light pollution and providing solutions. For the IAU's Cosmic Light Working Group, the IYL is a big chance - via the "Cosmic Light" Cornerstone - to build on the success of the "International Year of Astronomy" - 2009. Furthermore, the IYL is providing the IAU with another welcome opportunity to reach out to other communities and particularly to LED manufacturers and users.

IYL 2015 - AN ASTRONOMY'S PERCEPTION OF THE WISE USE OF LEDS TO MINIMIZE LIGHT POLLUTION

by Malcolm Smith, IAU

Several articles in January's LpR (Issue 47) already show an understanding that it is important that the various professional communities involved in lighting our planet continue to improve communication with each other. It is via the IYL that some astronomers are getting to know more about "Trends and Technologies for Future Lighting Solutions" - which is why this contact with the LpR is especially welcome. The IAU Focus Meeting on Light Pollution in August also included a session on "Advances in LED technology and options for spectral management".

Light pollution is useless artificial light. Huge amounts of such stray light are still needlessly being sent upwards - all night. Substantial amounts of this wasted light are then scattered and/or refracted back to earth. This creates a luminous glow in the sky that competes with the faint light being studied by optical astronomers. Appropriately designed LED fixtures currently being installed in many cities can help avoid this waste. Of course, communities have to decide what to do about the downward-directed light that is necessary, in moderation, yet will be reflected upwards and will affect astronomers and others wishing to see the natural night sky. In recent decades, the response of astronomers has been to move away from population centers, locating their observatories far from cities and encouraging local economies to benefit from astronomy-friendly activities such as astro-tourism. However, the planet is now running out of such places.

Currently more than half the human population lives in cities. The entire world is now imaged each night at 750-meter resolution by the Visible Infrared Imaging Radiometer Suite Day-Night Band on board the Suomi weather satellite. It is now becoming clear that the way that cities use light varies between regions and countries. For example, according to recent remote sensing research (by Chris Kyba et al.) German cities emit several times less light per capita than comparably sized cities in the US - and the gap increases with increasing city size.

Until recently, astronomers have been able to observe blue light from the cosmos without much interference from the artificial light from humans, thanks mainly to the widespread use of (yellow) sodium lamps. With the introduction of LED lights, the amount of blue light increases. The increasing interference from this blue LED light is particularly unwelcome to astronomers. Since about 2012, therefore, astronomers at several of the major optical observatories have begun working directly with LED manufacturers to help in the development of astronomy-friendly lighting systems, which shine their light below the horizontal and keep the amount of blue light in their output spectrum below about 15% of the light energy in the rest of the optical spectrum between 420 nm and 690 nm. Demand for such limited-spectrum lighting has appeared in the Canary Islands, Hawaii and Chile, where the astronomy industry now has significant economic impact. The first Amber LEDs with an emission between 540 nm and 630 nm were installed in La Palma in 2012.

In the "International Year of Astronomy", 2009, IAU has had special success in the area of outreach and education, with thousands of schools around the world showing interest and ingenuity in responding to the educational needs of humanity, which had almost unconsciously been shutting itself inside a ball of light on a tiny planet. Humanity has the right to continue to learn from what the sky can tell us. It also has the skill to develop competitive, astronomy-friendly, LED lighting - as well as showing increasing interest in this option. IAU aims to continue this successful work in the IYL 2015. ■

M.S.

LpS 2015 - PROGRAM

EVENT OVERVIEW

DAY 1

SEPT. 22ND TUESDAY

Opening

10.00 - 10.30	**Opening & Scientific Award Ceremony** | Grosser Saal
10.30 - 12.00	**Keynotes** | Grosser Saal

Parallel Sessions

13.30 - 18.00	**Light Quality** | Seestudio
13.30 - 15.30	**Connectivity & Security** | Seefoyer
16.30 - 18.00	**Reliability & Lifetime** | Seefoyer
13.30 - 15.30	**Standardization** | Propter Homines
16.30 - 18.00	**Workshop Light Measurement** *by GL Optics* | Propter Homines
10.00 - 20.00	**Design meets Technology Day** | Grosser Saal, Foyer & Expo

Evening Events

18.00 - 20.00	**Poster Session** | Foyer
18.00 - 20.00	**Exhibition Reception & Oktoberfest** | Werkstattbühne & Seitenbühnen

DAY 2

SEPT. 23RD WEDNESDAY

Parallel Sessions

08.30 - 15.30	**Light Sources** | Seestudio
08.30 - 15.30	**Smart Controls & Drivers** | Seefoyer
08.30 - 12.30	**Thermal Management** | Propter Homines
13.30 - 15.30	**Optics** | Propter Homines
16.30 - 18.00	**Workshop OLEDs** *by LG Chem* | Saal Bodensee
16.30 - 18.00	**Workshop Optics** *by Lambda Research* | Saal Bodensee
16.30 - 18.00	**Workshop Thermal Management** *by ams* | Saal Bodensee

Evening Events

17.00 - 18.00	**Press Conference** | Parkstudio
18.30 - 23.00	**Get-Together Event** | Boat Trip on Lake Constance

DAY 3

SEPT. 24TH THURSDAY

Parallel Sessions

09.00 - 10.30	**Lighting Systems** | Seestudio
09.00 - 10.30	**Optics** | Propter Homines
09.00 - 12.30	**Measurement and Production** | Seefoyer
11.30 - 12.30	**Workshop Smart Controls** *by Luger Research* | Propter Homines
11.30 - 12.30	**Workshop Light Mixing** *by LightCube/Uni Padua* | Seestudio
09.00 - 12.30	**Workshop Automotive Lighting** *by EPIC* | Saal Bodensee

Plenum Sessions

13.30 - 14.30	**Tech-Panel: Key Trends & Technologies** | Seestudio
14.30	**Closing** | Seestudio

DAY 1 - SEPTEMBER 22ND - TUESDAY

Time	Opening, Keynotes & Light Quality	Connectivity, Security, Reliability & Lifetime	Standardization & Light Measurement	Design meets Technology Day
10.00	Grosser Saal **Opening & Scientific Award Ceremony**			DMT Day | Grosser Saal **Opening**
10.30	KEYNOTE | Grosser Saal **Semantic Light** *Prof. Zary Segall, Royal Institute of Technology, Sweden*			DMT Day | Grosser Saal **Keynote**
11.00	KEYNOTE | Grosser Saal **The Second Wave of Lighting Innovation - Towards Lighting Beyond Illumination** *Rogier van der Heide, Chief Design & Marketing Officier at Zumtobel Group, Austria*			DMT Day | Grosser Saal **Keynote**
11.30	KEYNOTE | Grosser Saal **Trends and Challenges for System Integration** *Dr. Jy Bhardwaj, CTO at Lumileds, USA*			DMT Day | Grosser Saal **Keynote**
BREAK				
13.30	LIGHT QUALITY | Seestudio **Human Centric Lighting - What We Know and What is Needed** *DI Peter Dehoff, Zumtobel Group & LightingEurope, Austria, The Netherlands*	CONNECTIVITY & SECURITY | Seefoyer **Why We Need Smarter Smart Lighting** *Dr. Walter Werner, CEO at Werner Mgt. Consulting, Austria*	STANDARDIZATION | Propter Homines **OpenAIS - Innovation Towards an Open Architecture for Intelligent Solid-State Lighting** *Dr. Christian Moormann, Head of Global Technology, Tridonic, Austria*	DMT Day | Foyer, Expo **Exhibition Walkthrough**
14.00	LIGHT QUALITY | Seestudio **CIE Test Method for LED Lamps, LED Luminaires and LED Modules** *Dr. Peter Blattner, Head of Optics Laboratory at METAS, Switzerland*	CONNECTIVITY & SECURITY | Seefoyer **Lighting Systems and Cyber Security** *Ken Modeste, Principal Engineer at Underwriter Laboratories (UL), USA*	STANDARDIZATION | Propter Homines **Zhaga Standardization of LED Light Engines, Modules and Drivers Helps to Simplify LED Luminaire Design** *Musa Unmehopa, Secretary General at Zhaga Consortium, The Netherlands*	DMT Day | Foyer, Expo **Exhibition Walkthrough**
14.30	LIGHT QUALITY | Seestudio **Concepts of Intelligent Lighting and LED Luminaires Taking Color Quality and Human Centric Lighting into Account** *Prof. Tran Quoc Khanh, TU Darmstadt, Germany*	CONNECTIVITY & SECURITY | Seefoyer **Intelligent Methods to Secure Connected Lighting and Smart City Installations** *Dr. Geoff Archenhold, Serenity Lighting, UK*	STANDARDIZATION | Propter Homines **An Introduction to DALI 2** *Steve Roberts, CTO at Recom, Austria*	DMT Day | Foyer, Expo **Exhibition Walkthrough**
15.00	LIGHT QUALITY | Seestudio **The Degrees of Freedom Provided by Modern Methods to Tune CCT and LED Wavelengths** *Wojtek Cieplik, LEDengin*		STANDARDIZATION | Propter Homines **Challenges and Solutions of Photobiological Safety Assessment for Lighting Products** *Prof. Jiangen Pan, CEO at Everfine, China*	DMT Day | Expo **Luminary Design Prize**
BREAK				
16.30	LIGHT QUALITY | Seestudio **Quality of LED Lamps for Residential in European Market and Associated Health Issues** *Prof. Georges Zissis, Toulouse 3 University, France*	RELIABILITY & LIFETIME | Seefoyer **Reliability of High Power LEDs: From Gradual to Catastrophic Failure** *Prof. Matteo Meneghini, University of Padua, Italy*	Propter Homines **WORKSHOP LIGHT MEASUREMENT** *by GL Optic, Germany*	DMT Day | Expo **Exhibition**
17.00	LIGHT QUALITY | Seestudio **SSL Solutions for Human Centric Lighting** *Dr. Nicola Trivellin, LightCube, Italy*	RELIABILITY & LIFETIME | Seefoyer **LED Tunnel Lamp - A Reality Check: 50,000 Hours Field Data and Lifetime** *Alexander Wilm, SSL Expert, OSRAM Opto Semiconductors, Germany*	Propter Homines **WORKSHOP LIGHT MEASUREMENT** *by GL Optic, Germany*	DMT Day | Expo **Exhibition**
17.30	LIGHT QUALITY | Seestudio **Sky Luminance and Radiance Distribution Patterns: Empirical Assessment and Computational Models** *Prof. Ardeshir Mahdavi, Technical University Vienna, Austria*	RELIABILITY & LIFETIME | Seefoyer **Statistical Analysis and Prediction of LED Lifetimes** *Dr. Wolfgang Scheuerpflug, Diehl Aerospace, Germany*	Propter Homines **WORKSHOP LIGHT MEASUREMENT** *by GL Optic, Germany*	DMT Day | Expo **Exhibition**
18.00 | 20.00	Werkstattbühne & Seitenbühnen **OKTOBERFEST**	Foyer **POSTER SESSION**	Werkstattbühne & Seitenbühnen **EXHIBITION RECEPTION**	DMT Day | Expo **Networking**

DAY 2 - SEPTEMBER 23RD - WEDNESDAY

Time	LED & OLED Light Sources	Smart Controls, Drivers & Optics	Thermal Management & Optics
08.30	LIGHT SOURCES | Seestudio **Solid-State Light Products Design Breakthrough** *Mauro Ceresa, Field Application Engineer, Cree, Italy*	SMART CONTROLS & DRIVERS | Seefoyer **Energy and Light Quality Results of EnLight Lighting Solutions Applied to a Hospitality Environment** *Dr. Herbert Weiß, Project Manager Corp. Technology at OSRAM, Germany*	THERMAL MANAGEMENT | Propter Homines **The Effect of Dynamic Thermal Management for Smart Controlled Solid State Lighting Systems** *Dr. Mehmet Arik, Ozyegin University, Turkey*
09.00	LIGHT SOURCES | Seestudio **Progress in Single Crystal Luminophores for High Power LEDs and LDs** *Dr. Jan Kubat, Head of Materials and Precision Optics at Crytur, Czech Republic*	SMART CONTROLS & DRIVERS | Seefoyer **Human-Focused Outdoor Illumination: A Trade-off Between Pleasing Color and Circadian Action** *Dr. Prancisskus Vitta, Vilnius University, Lituanica*	THERMAL MANAGEMENT | Propter Homines **A Case Study: Opto-Thermal Modelling of a Mid-Power LED** *Dr. V.D. Hildenbrand, Researcher at Philips Lighting Solutions, The Netherlands*
09.30	LIGHT SOURCES | Seestudio **An Iterative Optical and Thermal Simulation Method for Proper Simulations of Phosphor Converted LEDs** *Dr. Wolfgang Nemitz, Researcher at Joanneum Research, Austria*	SMART CONTROLS & DRIVERS | Seefoyer **A New Software Approach/Architecture for Scalable Distributed Lighting Control** *Prof. Peter Niebert, CTO LED's CHAT, France*	THERMAL MANAGEMENT | Propter Homines **Reliability of Interconnects in LED Lighting Assemblies Utilizing Metal Clad Printed Circuit Boards** *Justin Kolbe, Principal Engineer at The Bergquist Company, USA*
BREAK			
11.00	LIGHT SOURCES | Seestudio **LED Lighting for Visual Merchandising** *Dr. Daniel Doxsee, Deputy Managing Director of Nichia Europe, Germany*	SMART CONTROLS & DRIVERS | Seefoyer **Wireless Mesh Networks Demystification** *Vladimir Sulc, CEO at MICRORISC, Czech Republic*	THERMAL MANAGEMENT | Propter Homines **Thermal Impedance Analysis of LED Modules** *Dr. Stefan Defregger, Program-Manager at Material Center Leoben, Austria*
11.30	LIGHT SOURCES | Seestudio **Trends in SMD LED Packages for General Lighting** *Dr. Christopher Keusch, Everlight Electronics, Germany*	SMART CONTROLS & DRIVERS | Seefoyer **Quality Characteristics of LED Power Supplies and Drivers** *DI Stephan Wegstein, CEO at sysLED, Germany*	THERMAL MANAGEMENT | Propter Homines **Nanoceramic Substrates for Thermal Manage-ment of High Brightness LEDs** *Dr. Giles Humpston, FAE at Cambridge Nanotherm, UK*
12.00	LIGHT SOURCES | Seestudio **Leveraging Chip Scale Package Technology to Deliver a Robust and Future-Proof Platform** *Ingolf Sischka, Technical Solution Manager at Lumileds, Germany*	SMART CONTROLS & DRIVERS | Seefoyer **Reliable and Cost Effective LED Drivers Impro-ving Perception Artefacts and Grid Compatibility** *Prof. Eberhard Waffenschmidt, Cologne University, Germany*	THERMAL MANAGEMENT | Propter Homines **Advantages of Using Thermally Conductive Polymers for Heat Sinks** *Dr. Klaus S. Reinartz, Marketing Manager at Bayer Material Science, Germany*
BREAK			
13.30	LIGHT SOURCES | Seestudio **Luminescent Glasses and Glass Ceramics for White Light Emitting Diodes** *DI Franziska Steudel, Research at Fraunhofer, Germany*	SMART CONTROLS & DRIVERS | Seefoyer **Advantages and Challenges of Modern Software Based Digital SMPS LED Drivers** *Mikael Pettersson, R&D Manager at SwitchTech, Sweden*	OPTICS | Propter Homines **Why Moldable Silicone is Driving Innovation in En-gineering of LED Optics for Professional Lighting?** *Dr. Francois De Buyl, Dow Corning, Belgium*
14.00	LIGHT SOURCES | Seestudio **Spectrally Tuneable SSL Solutions and Appli-cations** *Dr. Josep Carreras, Head of the Lighting Group at IREC, Spain*	SMART CONTROLS & DRIVERS | Seefoyer **How to Combine Smart Lighting with a Driver-less, AC-Driven Solution** *Lorenz Bauer, Field Application Engineer at Seoul Semicon-ductor, Germany*	OPTICS | Propter Homines **Sensitivity of the Optical Performance of LED Illu-mination Systems to Manufacturing Tolerances** *Dr. Christian Paßlick, Engineer at Auer Lighting, Germany*
14.30	LIGHT SOURCES | Seestudio **Human Centric Lighting: The Future of the Lighting Industry** *Prof. Guenther Leising, Lumitech, Austria*	SMART CONTROLS & DRIVERS | Seefoyer **PFC Flyback with Software Controlled Digital Driver** *Ulrich vom Bauer, Infineon, Germany*	OPTICS | Propter Homines **Styrenics for LED lighting - How Specialty Styre-nics Open New Possibilities in LED Lighting** *Dr. Eike Jahnke, Technical Product Manager at Styrolution, Germany*
15.00	LIGHT SOURCES | Seestudio **What is the Future of OLED for Lighting?** *Pars Mukish, Analyst at Yole Developpement, France*		OPTICS | Propter Homines **Thin-Film Light Management System for Intelli-gent Large-Area LED Luminaires** *Dr. Oscar Fernandez, CSEM, Switzerland*
BREAK			
16.30 | 18.00	Saal Bodensee **WORKSHOP** **OLEDs** *by LG Chem, Korea*	Saal Bodensee **WORKSHOP** **OPTICS** *by Lambda Research, USA*	Saal Bodensee **WORKSHOP** **THERMAL MANAGEMENT** *by ams, Germany*
17.30	Parkstudio **PRESS-CONFERENCE**		
18.30 | 23.00	Boat trip on Lake Constance **GET TOGETHER EVENING**		

DAY 3 - SEPTEMBER 24TH - THURSDAY

Time	Lighting Systems, Light Mixing & Tech-Panel	Measurement & Production	Optics & Smart Controls	Automotive Lighting
09.00	LIGHTING SYSTEMS | Seestudio **The Paradigm Shift of Residential Lighting from Retrofit Lamps to Fully Integrated Fixtures** *Jeremy Ludyjan, Director of Innovation at Bulbrite Industries, USA*	MEASUREMENT & PRODUCTION | Seefoyer **New Standards for the Photometry of LED Based Light Sources - A Challenge for the Laboratories** *Dr. Udo Krüger, Head of Photometry, TechnoTeam, Germany*	OPTICS | Propter Homines **Better Light Through Optical Design for Manufacturing** *Dr. Angelika Hofmann, Optical Design Manager at kdg Opticomp, Austria*	Saal Bodensee **WORKSHOP AUTOMOTIVE LIGHTING** *by EPIC*
09.30	LIGHTING SYSTEMS | Seestudio **Six-Channel LED-Luminaire for Retail Lighting** *Prof. Meike Barfuss, FH Suedwestfalen, Germany*	MEASUREMENT & PRODUCTION | Seefoyer **Impact of New SSL Standards on Goniospectroradiometric Measurements** *Dr. Denan Konjhodzic, Application Engineer at Instrument Systems, Germany*	OPTICS | Propter Homines **Diffusion Panels - The Way Out of the Glaring Inhomogeneous LED Misery** *Dr. Dieker Henning, R&D Designer at VS Lighting, Germany*	Saal Bodensee **WORKSHOP AUTOMOTIVE LIGHTING** *by EPIC*
10.00	LIGHTING SYSTEMS | Seestudio **High-Temperature Reliability of Retrofit LED Bulbs** *Dr. Matteo Dal Lago, Researcher at LightCube, Italy*	MEASUREMENT & PRODUCTION | Seefoyer **Effect of Thermal Management for LED Based Street Lighting Systems** *Gokhan Hasan, Engineer at Bosch & Siemens Home Appliance Group, Turkey*	OPTICS | Propter Homines **24/7 Custom Optics: Improved Capabilities Increase Manufacturing Speed and Flexibility Significantly** *Bram Mueleblok, LUXeXceL, The Netherlands*	Saal Bodensee **WORKSHOP AUTOMOTIVE LIGHTING** *by EPIC*
BREAK				
11.30	Seestudio **WORKSHOP LIGHT MIXING** *by LightCube & University of Padua, Italy*	MEASUREMENT & PRODUCTION | Seefoyer **Adhesive Developments for Low Cost Flip-Chip and High Precision Bonding in LED Lighting Applications** *Andreas Kraft, Business Development Manager at DELO, Germany*	Propter Homines **WORKSHOP SMART CONTROLS** *by Luger Research, Austria*	Saal Bodensee **WORKSHOP AUTOMOTIVE LIGHTING** *by EPIC*
12.00	Seestudio **WORKSHOP LIGHT MIXING** *by LightCube & University of Padua, Italy*	MEASUREMENT & PRODUCTION | Seefoyer **New High Speed Assembly Technology "Reel to Reel Flip Chip LED"** *Franz Brandl, Head of R&D at Mühlbauer, Germany*	Propter Homines **WORKSHOP SMART CONTROLS** *by Luger Research, Austria*	Saal Bodensee **WORKSHOP AUTOMOTIVE LIGHTING** *by EPIC*
BREAK				
13.30 | 14.30	Seestudio **TECH PANEL KEY TRENDS & TECHNOLOGIES**			
14.30	**CLOSING**			

Tech-Talks BREGENZ - Andreas Weisl, SSC Europe, Vice-President

Andreas Weisl

Andreas Weisl is Vice-President of Seoul Semiconductor Europe GmbH, which he joined in November 2010. Prior to joining Seoul Semiconductor he spent 5 years with OSRAM Opto Semiconductors GmbH in various roles in Account and Distribution Management. Andreas studied Industrial Engineering and Information Technology at Munich University of Applied Sciences and joined a European Business & Management Program at the Brunel University of London. His thesis was titled “Development and Realization of sales and marketing concept for the new wireless technology ZigBee™”.

Seoul Semiconductor has more than 20 years of experience in semiconductor manufacturing and invests more than 10% of its annual revenue in LED research and development. On average, Seoul Semiconductor applies for more than 600 patents every year. Currently, the company holds more than 10,000 LED patents, including patents in core LED technologies such as Acrich, Acrich MJT, nPola, TV Direct Backlight Technology, UV, and many more. Seoul Semiconductor's extensive patent portfolio in LED technology includes epitaxial growth, fabrication, packaging, and system application of LED technology. LED professional talked with Andreas Weisl, Vice-President of Seoul Semiconductor Europe GmbH about their business, technologies and solutions.

LED professional: Thank you very much for visiting Bregenz for this Tech-Talk. Even though Seoul Semiconductor (SSC) is a well known company in the field of SSL, could you please share a few important milestones of the company?

Mr. Weisl: SSC's history can be divided into roughly three phases since our CEO, Mr. Lee, assumed office. The years 1992 to 2001 were the years spent establishing the company in the Korean marketplace. By the end of this period, SSC had reached the number 1 LED manufacturer position in Korea. The years between 2002 and 2013 saw SSC developing towards becoming a global player in the lighting field. The current phase, from 2014 to 2019, is, and will be dominated by the goal of becoming the world market leader as an LED component manufacturer and supplier.

Currently, SSC is number 6 in the global LED manufacturers' ranking with a revenue of USD 940M last year. If we exclude the captive market revenues from the top 5 LED suppliers, SSC is #2 for white LED products. With more than 10,000 listed patents and cross license agreements with global key players, in the areas of design, material and manufacturing methods, SSC was the only LED component manufacturer to be selected in the 2012 and 2013 Semiconductor Manufacturing Patent Power Ranking by the Institute of Electrical and Electronics Engineers (IEEE). The cooperations with the Solid State Lighting and Energy Center (SSLEC) of the University of California, Santa Barbara (UCSB) and with SETI, a company working in the field of UV LEDs and which our subsidiary Seoul Viosys has recently secured the executive management share from, are important strategic partnerships for future developments. Prof. Nakamura from the UCSB and SSC have been engaged in joint R&D for over 10 years.

LED professional: Your total production packaging capacity is 1.8B pieces per month which is a huge number but a necessity for the economy of scale. On the other hand the price reductions over the past years have been tremendous as well, haven't they?

Mr. Weisl: Due to market shifts there are overcapacities available in production. But the massive price-reduction was not expected in such huge dimensions. A main driver for the price degradations is caused by governmental subsidies in Asia. We are well prepared for the upcoming market consolidation. Factors such as cost optimization, a lean organization and especially new competitive technologies will help us to overcome these tough times. For the further development of the company our goal is to at least double our market share from today's 6-8% to 15% within the next years.

LED professional: Heavy investments are necessary in production to reach the market goals. On the other hand, you're confronted with declining prices. Are there other instruments that can help the industry and SSC in this situation?

Mr. Weisl: The IP portfolio is an important factor for further growth. More and more we see that LED chip producers - tier 1 manufacturers - are approaching module or lamp manufacturers when they use LEDs which are not free-to-operate from the patent point of view. For example, a leading US LED manufacturer went to court against a big US luminary manufacturer last year due to a patent infringement of their Asian LED supplier. We also filed a patent infringement lawsuit against a U.S. manufacturer one year ago. In July, the court finally issued the judgment in favor of Seoul Semiconductor. So, in fact, the companies who invested huge amounts of money in the development of LEDs are now starting to protect themselves by approaching tier 3 manufacturers, for example. IP-safety is a key topic for the years to come and a strong IP portfolio is getting more and more important. SSC invests around 10% of the annual revenue into global R&D activities.

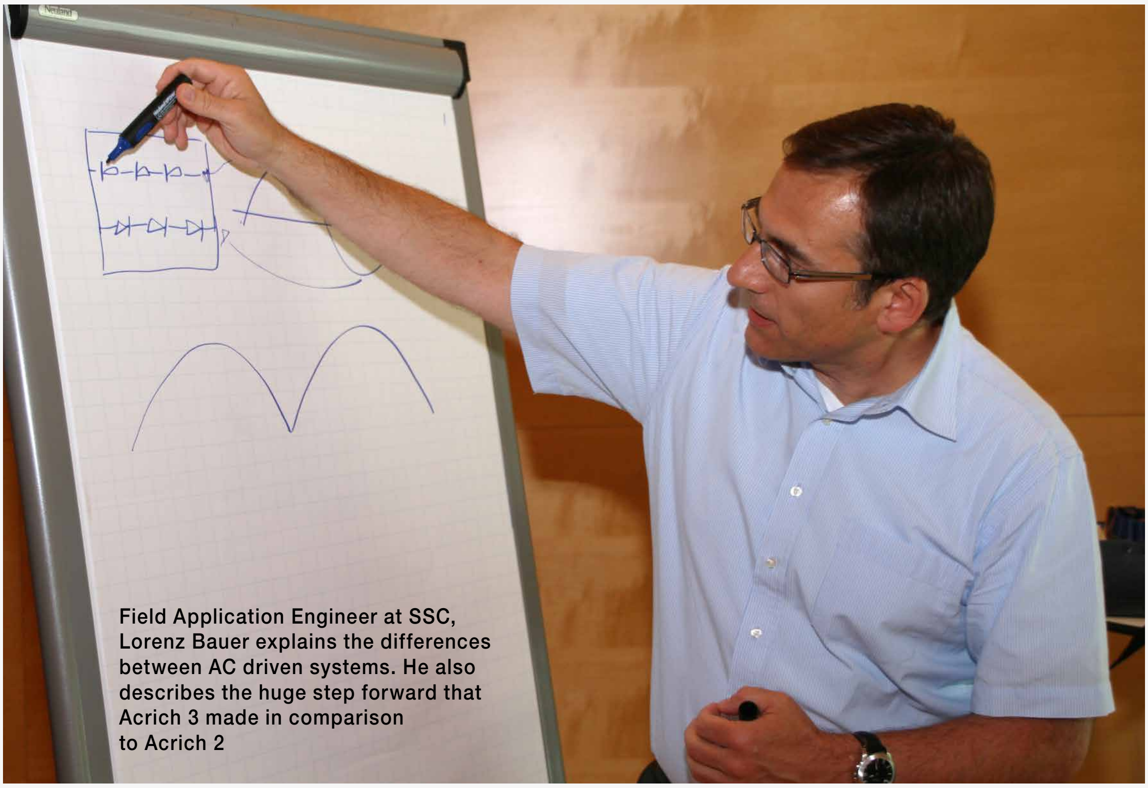
LED professional: One technology which is always a topic of discussion is GaN-on-GaN technology or nPola technology as SSC calls it. What can you tell us about the nPola technology?

Mr. Weisl: The key point is that this technology can increase the light output by a factor of 5-10 using the same chip size as for conventional LEDs and still keep the high efficacy. In other words, we could reduce the chip size by a factor of 5-10 and generate the same light output as from conventional LEDs. At the moment the substrate is still expensive and that's why we didn't launch a product for mass applications yet. The technology shows much better droop behaviour and is ideally applicable for higher currents. Applications for spotlighting, wave-guides or automotive lighting would gain a lot from it. In general, the manufacturing costs will have to come down. The nPola technology is a future trend, especially for high-performance light sources, and that's why SSC is also doing research in this area.

LED professional: But that's not for mass production, is it?

Mr. Weisl: We do see three different strategic options for further developments in Solid-State-Lighting. Option 1 is the cost strategy, option 2 the elimination of additional drivers and option 3 the quality strategy. The nPola technology fits into option 3 for higher CRIs and "better white colors". But also for combined technologies for UV light sources. In a second step it will also fit to option 1 because 5-10 times more light output with the same chip size as conventional LEDs will

THE MOST RECENT DOE FINDINGS ABOUT HV AC LEDS



Field Application Engineer at SSC, Lorenz Bauer explains the differences between AC driven systems. He also describes the huge step forward that Acrich 3 made in comparison to Acrich 2

The US Department of Energy (DOE) has forecasted in its annual SSL R&D plan for 2015 that by 2030 approximately 80% of all lighting fixtures in the US will be LED lighting - which would result in an annual energy savings of up to 395 TWh, a 60% reduction in electricity consumption, which at a commercial price of $0.10/kWh would correspond to an annual savings of $40 billion.

While much progress has already been made over the years in improving the efficiency of LED lighting systems to reach their full energy savings potential, further advances need to be made in the total luminaire efficiency. The driver losses alone in a luminaire could be 10% or greater and failure rate of the drivers are as high as 52%. The report mentions AC LED packages, such as Seoul Semiconductor's Acrich technology, that are designed to run directly off the AC line power and High-voltage LEDs, such as Seoul Semiconductor's proprietary MJT (Multi Junction Technology) LEDs, operating closer to the line voltage as possible options to help luminaire designers to reduce their fixture costs and further improve on the efficiency of the luminaire.

The US Department of Energy in its annual reporting continues to project direct AC LED technology and High-voltage LEDs as promising technologies in the continued adoption of LED lighting. For instance, in the study conducted by the DOE in 2010 Seoul Semiconductor's direct AC LED technology, Acrich MJT, had energy savings of up to 86% as compared to traditional lighting. In the 2015 report, DOE has again mentioned direct AC LED technology and High-Voltage LEDs as the next generation of light sources.

result in cost reductions as soon as substrate costs decrease.

LED professional: How does SSC strategically position itself in the value chain?

Mr. Weisl: We are a producer of chips, packaged LEDs and LED modules. We don't sell light engines but mainly customized modules. Our customers still have to look after the right optical solution and the thermal design by themselves. We are decidedly not making moves towards integration for retrofits and luminaires and competing with our clients. SSC is one of only two LED manufacturers who are sticking to the pure component and module business. We see this as a necessity in order to make our clients successful by supporting them on an engineering level. This was especially needed with our Acrich product line.

LED professional: How does this support work?

Mr. Weisl: We have built up so-called small R&D labs in Munich, Shanghai, Tokyo and Atlanta. These labs support application and design - especially for custom-specific product designs. They are equipped with modern measurement, design and layout tools which can be used for Acrich or DC system developments. Originally these labs where driven by the support demand of the Acrich product segment.

LED professional: Let's look at the market portfolio. What are the different market segments that SSC delivers its products to?

Mr. Weisl: We have a strong presence in three major segments; namely Lighting, BLU & Mobile, and Automotive. Actually, the BLU & Mobile part covers roughly 50% of our business while Lighting and Automotive are the strong growing areas. In Europe only the Lighting and Automotive segments are relevant markets. The lighting portfolio covers high and mid-power, COBs, high voltage and AC technologies. The AC business has been growing significantly and already represents one fourth of our lighting business.

In the automotive market, we also focus on white LEDs and offer products specially developed for automotive applications. Although our automotive business is still second to the lighting business in terms of revenue distribution, we see high potential in this segment. Currently in Europe, automotive accounts for 20% of our revenue with a strong indication that its share will increase in the future. Nevertheless, the main part of our business will still be dedicated to general lighting, which is forecasted to have the biggest growth rate. Globally, LED based luminaires count for about 5% and are expected to have very high growth rates that will increase them to 70% within the next few years.

The global automotive lighting market is about 1.6B USD and the exterior lighting segment is about 1B USD. It has surpassed the interior part since 2013. The daytime running lights and the headlamps will count for about 50% of the exterior part during the next years. That's exactly the domain on which SSC is focusing. An interesting trend is the fact that LEDs for automotive lighting applications are more and more differentiated from the general lighting products. So very specific automotive LED solutions are necessary to fulfill the requirements of the automotive market.

LED professional: What are the core technologies at SSC now?

Mr. Weisl: Latest key technologies are our Acrich technology for AC & DC solutions and the NewGen, which is our package-less LED technology, as well as the module business including smart lighting capabilities.

LED professional: If we take a closer look at the Acrich technology, what are the latest developments?

Mr. Weisl: The Acrich3 IC solution is based on a four-step bank switch technology which increases the forward voltage in steps, allowing for a quicker turn-on time and a better match of the current to the voltage wave form. The base-technology are MJT chips but combined with an intelligent driving-IC for those 4 channels. This solution generates non-noticeable flicker and is suitable for most general lighting applications, even for street lighting. For very sensitive applications, parallel capacitors can smooth out the flickering even more. For dimming applications, the Acrich3 driver IC has an additional 0-2 V analog dimming input and an additional power source for external sensors.

With this approach, systems from 4 to 200 watts can be realized, reaching power-factor values of over 0.97, which also stays nearly constant over the full dimming range. The system's performance ranges up to 130 lm/W on a lighting system level. But taking into consideration that the driver electronics is responsible for about 50% of all light source failures, the Acrich3 system is very reliable since it has no driver at all. Acrich3 was introduced to the market at the end of last year but developments are continuing for AC LED technologies. A DoE report especially highlighted the necessity of going in these directions when looking at future trends.

LED professional: What about Acrich3 and smart lighting technologies?

Mr. Weisl: For Bluetooth, ZigBee and WiFi, there are special interface modules for Acrich3, including sensors, available. The problem is that there is no standard dominating the field yet but we're offering networking solutions for all major controls. Our design support helps to develop and create so-called reference designs and then it's up to the client if he's going to produce and source the module himself or if SSC delivers the module through one of our certified production suppliers, guaranteeing SSC quality performance. For the smart lighting technologies, as well as the production partners, we can access a high-quality standard process line and partners.

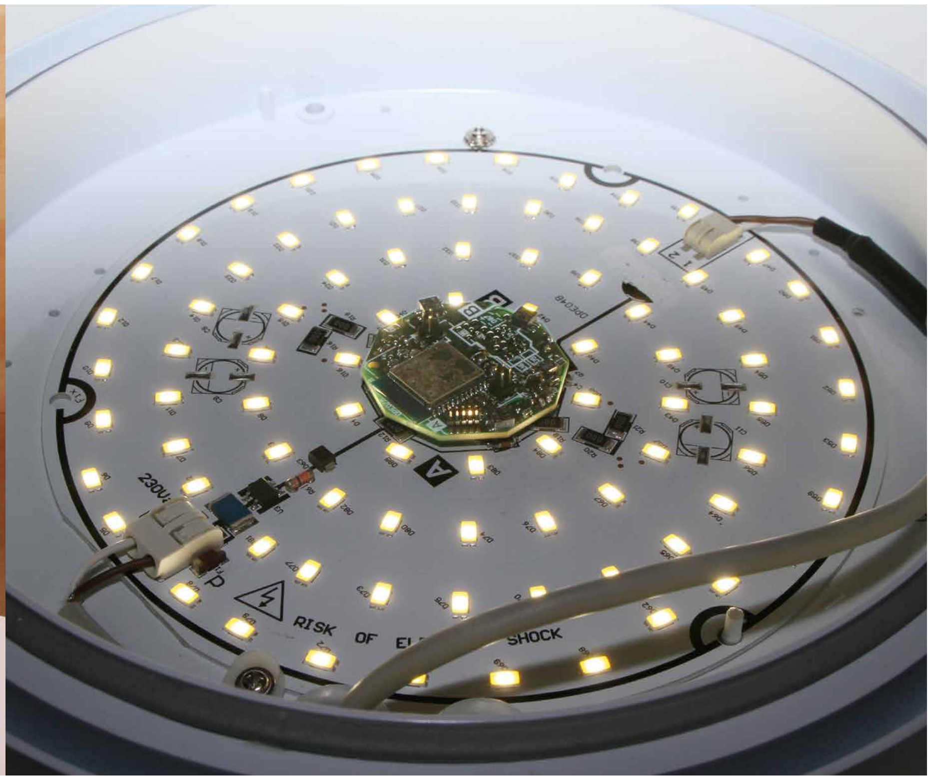
LED professional: Is this a kind of a new business approach for the lighting industry?

Mr. Weisl: Price degradations, shorter development cycles, short time-to-market periods and high flexibility does make the business quite difficult. The luminary companies have built up SSL knowledge in-house but they are trying to focus on their core-competences. Solid partners, such as SSC have to ensure IP-save, high-quality and reliable solutions for the OEMs.

LED professional: SSC is exhibiting at the LpS 2015. What can visitors to Bregenz expect to see from your portfolio?

Mr. Weisl: This year we will have a double role. First of all, we'll have a booth in the exhibition area, and secondly we will be presenting the Acrich-based luminaires from our "Out of Bounds Design Contest" in the entry area. In this case our focus will positively be on Acrich.

At our booth, besides showing the Acrich products for indoor and outdoor lighting, we will also be presenting the smart lighting



Andreas Weisl presents an experimental sample demonstrator luminaire. The luminaire by Lucibel was adapted with an Acrich solution in connection with various smart lighting modules. The system will be exhibited at the LpS 2015

capabilities of this technology. In addition to that, we will be showing components for outdoor lighting and a preview of products that will be launched soon. Products like the NewGen, our package-less LED. In the foyer visitors will be able to see what is possible with Acrich when they look at the 17 luminaire prototypes designed by students of the University of Applied Sciences Munich. In a four month long study project, the goal was to develop luminaires that clearly show the advantages of Acrich technology. The project was a complete success and the variety of high quality lighting designs was extremely impressive. As part of the exhibition, we are also taking part in the "Design meets Technology" day. The official award presentation ceremony will also be a part of the program as will be viewing the exhibits. Visitors will have a chance to talk directly with the students about their creations and our staff will be on-hand to explain the technical details.

LED professional: What was your motivation to initiate the Design Contest with Prof. Peter Naumann and the University of Applied Sciences Munich?

Mr. Weisl: Some customers are still sceptical of AC driven LED solutions and overlook the potential benefits that this new technology can offer them. They often do not realize that this technology has been further developed over the past one to two years and that a lot of progress has been made. After many years of development and optimization, AC LED solutions are ready for general lighting both from a technical point of view as well as a design point of view. The decisive advantage is the absence of a converter. Complete new design possibilities open up because the converter no longer has to be considered during the design process. There have also been a lot of improvements on the technical side.

By engaging with young, creative students who have no limits and could work unreservedly with this technology, we wanted to provide a platform to demonstrate what great solutions can be realized with the design freedom enabled by Acrich. By doing so, it was our goal to show established lighting manufacturers what excellent designs can be achieved with new technologies like AC-LED technology, and that in reality the barriers are not as high as the perception today.

Al_2O_3 Coated Europium-Activated Aluminum Silicon Nitride for COB LED Technology

Eu^{2+} activated nitride phosphors have drawn much interest for solid state lighting because of their interesting photoluminescence. While they show excellent optical properties, they are hygroscopic and have the potential of being degraded by atmospheric moisture and high temperatures. A coating layer on the surface is an effective method to improve stability against moisture and oxidation. For use in chip on board technology, Nika Mahne, master student at the Institute of Inorganic Chemistry, A. Reichmann, B. Bitschnau, R. Fischer, from the Graz University of Technology, and F. Schrank from Tridonic Jennersdorf propose an approach where a $CaAlSiN_3:Eu^{2+}$ [1, 2, 3] phosphor was coated with Al_2O_3, obtained via a Brønsted precipitation reaction based on a solution-coating process from a mixture of aluminum halide with a base after annealing at a temperature of 400°C.

Eu^{2+} activated nitride phosphors like $CaAlSiN_3:Eu^{2+}$ offer interesting photoluminescence properties [1]. Among Eu^{2+} doped red nitride phosphors used in solid state lighting, $CaAlSiN_3:Eu^{2+}$ was found to show excellent optical properties because of adequate thermal stability, lack of environmental hazard, non-toxicity, high emission efficiency and high quenching temperature [2]. However, these materials are hygroscopic and have the potential to be degraded by atmospheric moisture and high temperatures under operation [3]. One of the effective methods to improve its stability is to create a coating layer on the surface of the phosphor particles [4]. The coating should be optically transparent, and a precise quantity of coating must homogeneously cover the surface of the individual phosphor particle [5]. Therefore, inorganic materials such as Al_2O_3 are usually chosen to act as a coating layer on the surface of phosphors [5].

Experimental

1 g of uncoated phosphor material (europium-activated calcium aluminum silicon nitride phosphor [1, 2, 3]) and 80 ml isopropyl alcohol were sonicated while being stirred vigorously for 20 minutes. The aqueous educts solutions were prepared according to table 1. 5 ml of the $Al(NO_3)_3 \cdot 9H_2O$ (aq) solution were added dropwise via an automatic syringe pump to the suspension. After 20 ml of $Al(NO_3)_3 \cdot 9H_2O$ (aq) and 20 ml of $NaHCO_3$ (aq) were simultaneously added dropwise to the suspension and stirred for additional 30 minutes, to form $Al(OH)_3$ on phosphor particles. The coated particles were filtered via vacuum, rinsed twice with 20 ml H_2O (D.I.), twice with 20 ml isopropyl alcohol, dried at 100°C and annealed at 400°C in a tubular furnace under constant N_2 flow to obtain a homogeneous coating of Al_2O_3 according to figure 1. After annealing at 400°C the observed colour of the coated unexcited phosphor particles changed from orange to brighter turbid orange. In order to obtain thick Al_2O_3 layers this procedure was repeated three times with the same coated particles.

Characterization

To look at the morphology of particles and to examine the efficiency of Al_2O_3 coating on the phosphor SEM investigations were recorded. For that reason the

Table 1: Preparation of aqueous solutions for the coating experiments

Name of experiment	$Al(NO_3)_3 \cdot 9H_2O$ [mol/l]	$NaHCO_3$ [mol/l]	Reaction time [h:min]
Coated phosphor material 1	0.09	0.03	1:35
Coated phosphor material 2	0.35	0.12	6:50

Figure 1: Chemical equation

$$Al(NO_3)_3 \cdot 9H_2O + NaHCO_3 \rightarrow 2\ AL(OH)_3 + \text{side products} \xrightarrow{400°C} Al_2O_3 + 3\ H_2O$$

sample had to be coated with a thin electrically conductive layer using gold for the topography images and carbon for the chemical analysis. The SEM measurements were carried out in a Tescan Performance Nanospace (topography images of the particles) and in an Ultra 55 from Zeiss equipped with a silicon drift detector (SDD) from EDAX for energy dispersive X-ray spectroscopy. For the examination of the Al_2O_3 coating and the chemical analysis a cross section was prepared. Therefore the powder was embedded in epoxy resin, afterwards the sample was ground on silica carbide paper finishing with 4000 grit and was polished using a 0.25 µm diamond paste. ATR-IR spectra were recorded on a Bruker spectrometer (Alpha-P) in a range of of 4000-375 cm^{-1} with mid-wavelength infrared radiation. The phase compositions of uncoated and coated phosphor materials were analyzed by powder diffraction using CuKα radiation (Bruker, D8 Advance, LYNXEYE Detector, Bragg Brentano Geometry). The phase purity before treatment and after treatment was evaluated by Rietveld refinement of the XRD patterns using the program X-PertHighScorePlus (PANalytical). The photoluminescence properties of uncoated and coated phosphor material particles were determined using a spectrofluorometer (Horiba Scientific Jobin Yvon Fluorolog-3) at room temperature equipped with a 450 W xenon CW lamp.

Excitation spectra and emission spectra were measured in a range of 350-600 nm and 500-800 nm with an excitation wavelength of 465 nm. The samples were made from a slurry-mixture consisting of 200 mg phosphor, 200 mg polystyrene in 1000 mg chloroform, which was stirred for 1 h. The slurry was knife-coated on a PET-foil with a wet film thickness of 25 µm. Quantum efficiencies were measured with an extra modular integrating sphere unit (Quanta-ϕ) using a filter in non-reflecting PTFE sample holders. The used reference material ZrO_2 (Merck), possesses a similar refraction index, shows a similar particle size distribution and no emission after excitation with visible light as compared to the phosphor. Quantum effieciency and CIE color coordinates were calculated with the program FluorEssence.

Results

According to the material safety data sheet, the chemical content of the fine powdery orange coloured starting material, contains Ca_3N_2 30-40%, AlN 25-35% and Si_3N_4 30-40% doped with 0-5% Eu_2O_3. However, due to its water, acid and moisture sensitivity, it may generate ammonia gas by contact with moisture. Figure 2 shows the result of the Rietveld refinement of powder X-ray data of coated nitride phosphor before annealing. The material is pure phase europium-activated calcium aluminum silicon nitride with the chemical formula $CaAlSiN_3$. The corresponding sharp peaks are in good agreement (ICSD 161796 $CaAl_{0.54}Si_{1.38}N_3$). It has an orthorhombic crystal system with the space group Cmc21.

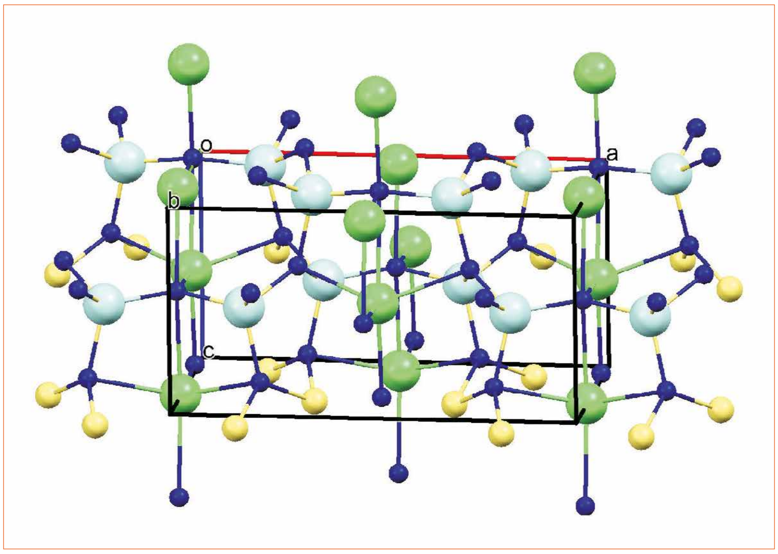


Figure 2:
Crystal structure of nitride phosphor Ca (green), N (blue), Si (yellow), Al (light blue)

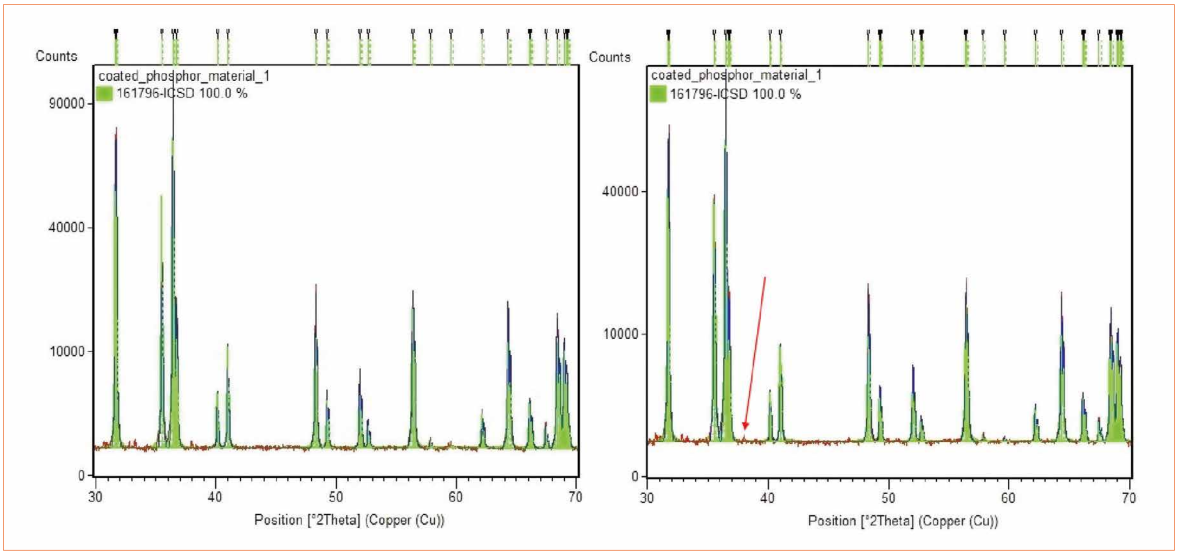


Figure 3:
Powder diffractograms of coated nitride phosphor 1 before annealing process (left) and of coated phosphor material 1 from (right)

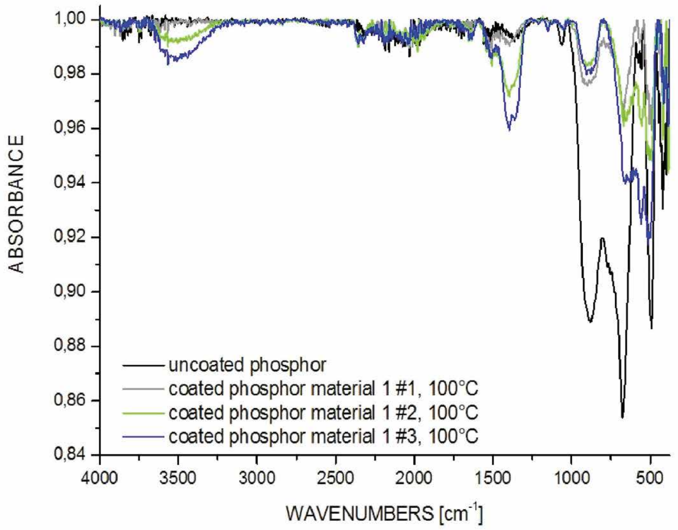


Figure 4: ATR-IR spectra of coated phosphor material 1 annealed at 100°C

Table 2: Lattice parameters of uncoated phosphor material 1 before and after annealing

	Uncoated nitride phosphor	Uncoated phosphor material 1
Space group	Cmc21	Cmc21
a [Å]	9,7917(1)	9,7927(1)
b [Å]	5,6461(1)	5,6465(1)
c [Å]	5,0579(1)	5,0588(1)
V [Å³]	279,621	279,726
α = β = γ	90°	90°

The lattice parameters of the doped crystal (Figure 2) are as follows:

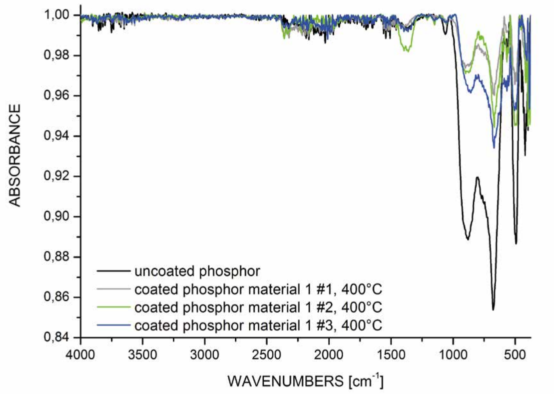
- a = 9.7917(1) Å
- b = 5.6461(1) Å
- c = 5.0579(1) Å and
- a unit cell volume of 279.621 Å³

The XRD pattern of coated phosphor material 1 annealed at 400°C (Figure 3, right) shows no significant peak changes compared to coated phosphor material 1 dried at 100°C in Figure 3 (left). Lattice parameters did not change in general (Table 2). Therefore it can be said that the coating process did not change the host lattice and so educts react with each other, but not with the phosphor.

The XRD pattern shows no proof for the complete formation of crystalline Al_2O_3 from $Al(OH)_3$ after the annealing process (Figure 3). Only a very small peak at 38° 2θ indicates the presence of less than 0.5% crystalline Al_2O_3 (ICSD 75479). Therefore it can be concluded that the obtained coating layer is of amorphous nature. Also an increased background indicates amorphous parts, which was undergone a background correction.

Figure 4 shows the ATR-IR spectra of uncoated phosphor and coated phosphor material 1. The spectrum of europium-activated calcium aluminum silicon nitride shows several sharp peaks in the finger print area from 800 cm^{-1} to 400 cm^{-1}. Since the peaks cannot be ascribed to defined absorption peaks, the uncoated phosphor spectrum should function as a reference spectrum. Figure 4 shows spectra of uncoated phosphor and coated phosphor material 1 after coating process number 1, 2 and 3 after drying at 100°C. The broad absorption peak at 3400 cm^{-1} can be assigned to the symmetric and asymmetric stretch modes of water and 1640 cm^{-1} to the stretching and bending mode of water respectively [6]. The absorption peak at 1400 cm^{-1} can be dedicated to the bending vibration of the v[O—H] bond in $Al(OH)_3$, not to residual moisture [6].

Figure 5 shows spectra of the uncoated phosphor and coated phosphor material 1 after coating process 1, 2 and 3 after annealing at 400°C. The formation of Al_2O_3 from $Al(OH)_3$ can be confirmed due to the lack of signal in the area around 3400 cm^{-1} and new signals at around 1330 cm^{-1}, 1200 cm^{-1} and 1150 cm^{-1} [6]. By comparing the weight of coated phosphor material 1 after drying at 100°C and 400°C a loss of weight of around 13% was observed. This loss of weight can be ascribed to the formation of H_2O besides Al_2O_3. One trend can be observed: compared to the uncoated phosphor the intensities are decreasing due to the hydrolysis of uncoated phosphor through water and the formation of hydrolysis products during the coating process. The inorganic segment of the v[Al—O—Al] band is observed at 800-400 cm^{-1} and its



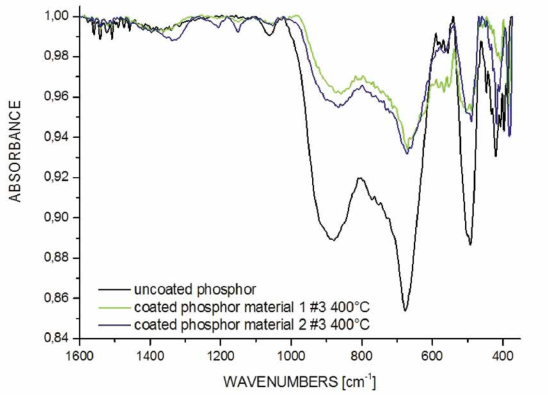


Figure 5 (left): ATR-IR spectra of coated phosphor material 1 annealed at 400°C

Figure 6 (right): ATR-IR spectra of uncoated phosphor material, coated phosphor material 1 and 2 after annealing at 400°C in the range of 1600-375 cm^{-1}

Philips Advance Xitanium

40W Linear 120-277V 0.1-1.1A SR Indoor LED Driver

The Xitanium SR LED driver reduces complexity and cost of light fixtures used in wireless connected lighting systems. It features a standard digital interface to enable direct connection to any suitable RF sensor on the market. Functionality is integrated into the SR driver that ordinarily would require additional auxiliary components. The result is a simpler, less expensive light fixture that can enable every fixture to become a wireless node.

Features

- Standard digital interface based on DALI 2.0
- Auxiliary power for sensors
- Occupancy and accurate energy reporting
- Dim-to-off capability
- Drive current setting via SimpleSet wireless programming or Rset2

Applications

- Indoor linear applications

Benefits

- Enables wireless interoperability with multiple sensors/network systems
- Reduces complexity and cost of fixture by eliminating auxiliary components ordinarily required for powering sensors, switching fixture off and monitoring energy use
- 5-year limited warranty*

* View limited warranty at usa.lighting.philips.com/connect/tools_literature/warranties.wpd for details and restrictions.

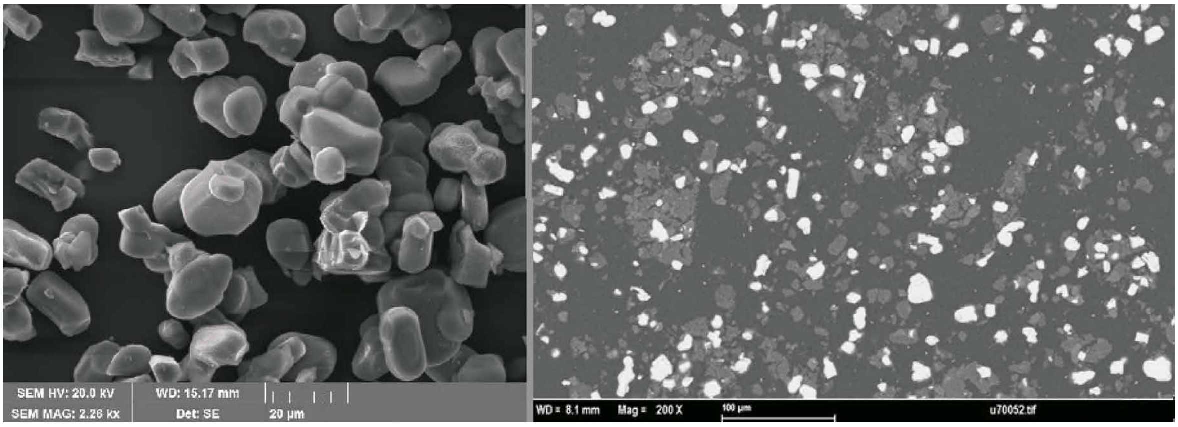


Figure 7: SEM image of uncoated phosphor material 1 at a magnification of 2.26kx (left) and a material contrast image of coated phosphor material 1, 200xBSE (right)

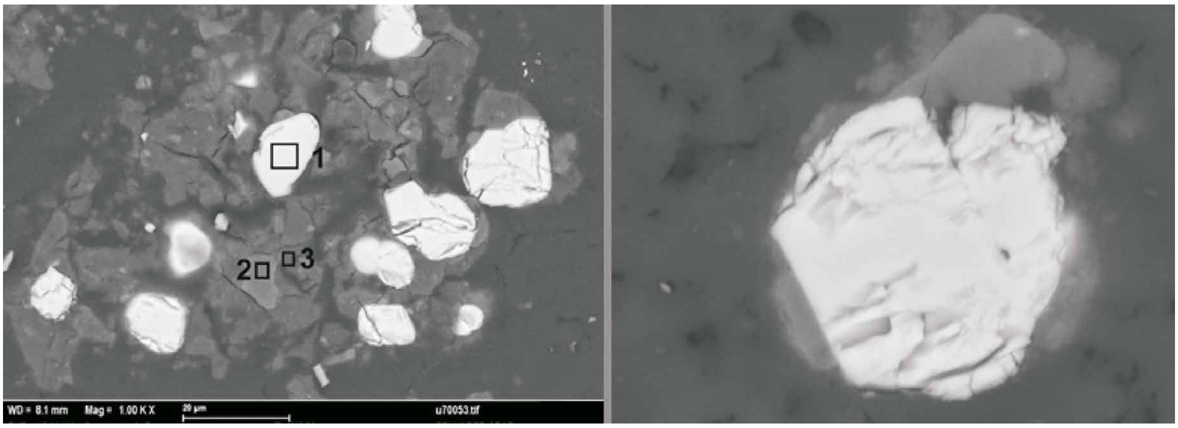


Figure 8: Material contrast image of coated phoshor material 1 particles 1000x BSE, 15 kV (left) and a single grain of coated phosphor material 1 at a magnification of 4000x BSE (right)

absorbance intensity increases with increasing amount of the Al_2O_3 layer [6]. Unfortunately v[Al—N] and v[Al—O] signals are difficult to distinguish because of the pronounced overlap of their bands. Figure 6 shows ATR-IR spectra of uncoated phosphor material, coated phosphor material 1 and 2 after the annealing process in the range of 1600-375 cm^{-1}. Approximate trends can be observed: decreasing absorbance intensity and formation of new bands in the area between 900-375 cm^{-1} were observed, but larger absorbance intensity for coated phosphor material 1 in the area from 650-550 cm^{-1}.

The morphological analysis of uncoated phosphor is shown in Figure 7 (left) and exhibits single particles with cylindrical structure (particle size distribution of 5-15 µm). Figure 7 (right) reveals a material contrast image of the fabricated cross section of Al_2O_3 coated phosphor particles 1, caused by backscattered electrons. Since heavy elements (high atomic number like Ca, Eu) backscatter electrons more strongly than light elements (low atomic number like O or Al), and thus appear brighter in the image, BSE are used to detect contrast between areas with different chemical compositions. Therefore, the brighter areas in figure 7 (right) can be ascribed to the $CaAlSiN_3$ phosphor and the darker areas to the precipitated Al_2O_3 and the dark background to the epoxy resin matrix. With larger magnification no homogeneous coating with Al_2O_3 on phosphor particles can be observed (Figure 8, left). In figure 9, phosphor particles with an inhomogeneous coating can be observed thereby showing two different modifications of Al_2O_3, one with agglomerates (area 2) and one with single particles (area 3). Beside that particles and agglomerates of Al_2O_3 are indicated. Figure 9 (right) shows an almost intact Al_2O_3 coating of a single particle with an irregular layer thickness up to 4 µm. The formation of different Al_2O_3 modifications was caused by the reaction conditions. The synthesis of Al_2O_3 coating on the phosphor was done in excess of educts $Al(NO_3)_3 \cdot 9H_2O$ and $NaHCO_3$. Agglomerates are formed when attractive forces overwhelm repulsive forces. The formation of agglomerates can be prevented by changing the reaction conditions of the synthesis like concentration of educts more specifically ion concentration and temperature.

Figure 9 (left upper corner) shows a material contrast image of coated phosphor material 2. The elements determined by EDX are dyed in different colours and labeled in the upper right corner of the pictures. Ca (turquoise), Al (yellow), Si (magenta) and N (green) are found in the brighter areas. Al (yellow) and O (blue) are also found in the darker areas around the brighter areas (phosphor), according to the formation of an Al_2O_3 layer. In contrast to phosphor material 1 no completely intact layer of Al_2O_3 was observed on coated phosphor material 2. Figure 10 shows the obtained EDX spectrum of the coated phosphor material 1, particular elements of the phosphors host lattice show significant peaks of Ca, Al, Si and N. Peaks of O and C can be assigned to the epoxy resin matrix.

Philips Fortimo LED Strips

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Fortimo LED Strip systems are ideal for use in narrow width luminaire designs for architectural applications that were not possible with fluorescent lighting before. Fortimo LED Strips offer best-in-class module efficiency of up to 163lm/W.

Features

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- High CRI options (CRI90) and 3 SDCM color consistency
- Variation of color temperatures (3000K, 3500K, 4000K and 5000K)
- Zhaga compliant

Applications

- Office/Industry/Retail

Benefits

- Slim width enables optimized luminaire design and new form factors
- High color rendering and excellent color consistency brings linear LED lighting to the next level for quality of light
- 5-year limited system warranty with Philips Advance Xitanium LED Drivers*

* View limited warranty at usa.lighting.philips.com/connect/tools_literature/warranties.wpd for details and restrictions.

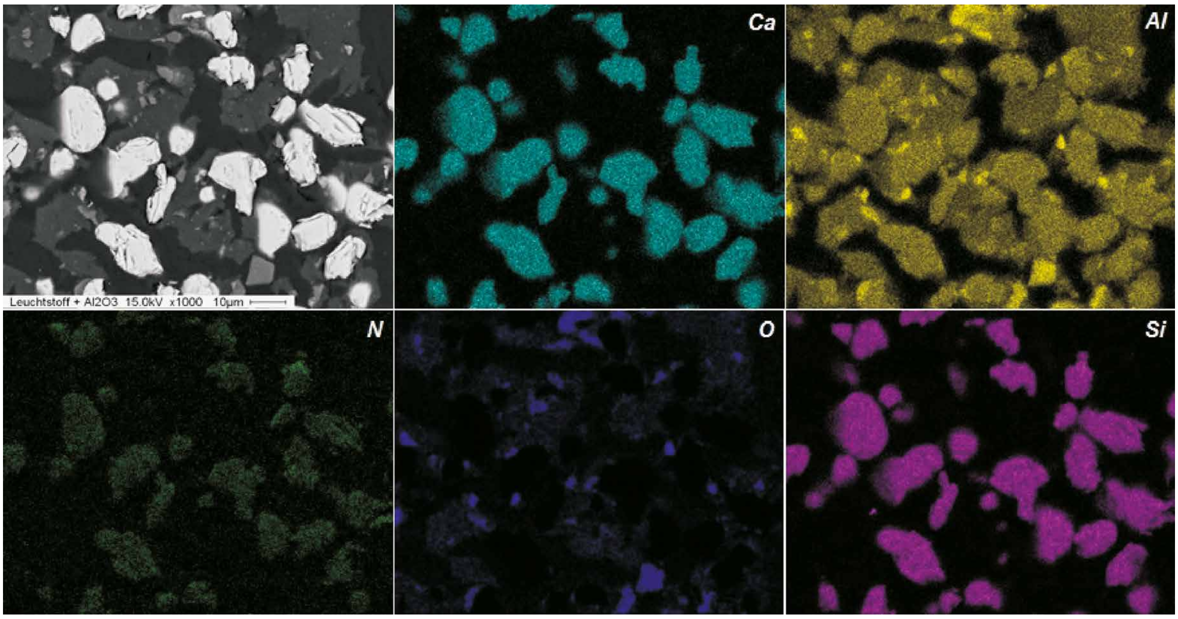

Figure 9:
Coated phosphor material 2 at a magnificastion of 1000x BSE

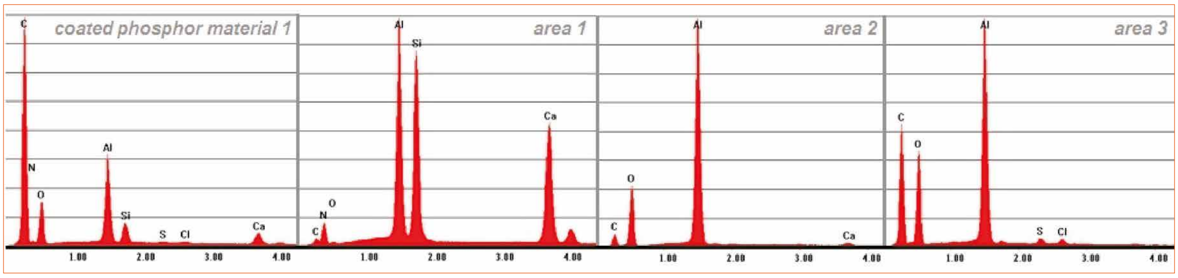

Figure 10:
EDX spectra of coated phosphor material 1, area 1, area 2 and area 3

Noticeable changes are observed in peak intensities of the elements like shown in figure 9 of area 1, area 2 and area 3. The results of the BSE image determined area 1 as the host lattice of the phosphor, therefore peaks for Ca, Al, Si and N are found, but also a high peak of C and a peak for O which stem from the epoxy resin. Area 2 shows a significant peak for Al and a larger peak for O than in area 1 due to the formation of Al_2O_3 after the coating and annealing process. Based on the obtained peaks in area 3 both epoxy resin and Al_2O_3 are coexistent. Area 2 and area 3 have similar spectra. They only differ in agglomeration of Al_2O_3. Area 3 contains more epoxy resin less Al_2O_3, area 2 more Al_2O_3.

Figure 11 shows the excitation and emission spectra of uncoated phosphor material at. The excitation spectrum shows a broad peak from the NUV to the VIS area with a peak maximum at 352 nm. The excitation of the host lattice and further energy transfer to the dopant Eu^{2+} can be ascribed to the peak maximum in the NUV region. The excitation peak corresponding to Eu^{2+} extends towards the visible region with a maximum at 430 nm. On this account the phosphor can be excited by conventional LED chips and is therefore suitable for use in chip-on-board technology.
The $CaAlSiN_3$:Eu^{2+} phosphor shows a broad symmetric single band in a range of 500-800 nm with an emission maximum at 643 nm which is typical for a 5d-4f transition of Eu^{2+} [3]. It covers a part of the visible light in the area between 550 nm and 750 nm (blue LED-Chip) and it is therefore a well suited phosphor for use in chip-on-board technology. The visible emission colour of uncoated phosphor is deep red. After the coating process the emission colour of unexcited particles changes from orange to brighter turbid orange, which can be ascribed to a not absolutely optically transparent precipitated layer of Al_2O_3. Emission spectra of uncoated phosphor material and coated phosphor material 1 are compared in figure 11. The shape and the width of the emission band did not change after the coating process.
A hypsochromical shift occurred with increasing number of Al_2O_3 coating steps (Figure 11, Table 3). This could also be caused by the used sample preparation method. Although the samples were made in the same way, the comparability can not be assured because the layer thickness could vary and hence a diverse concentration in the film can occur. Affirmative an oxidation of Eu^{2+} to Eu^{3+} was not observed.
The minimal shift of 3 nm of the emission maximum caused a negligible shift of CIE colour coordinates (Figures 11&12, Table 3). Furthermore a reduction of the quantum efficiency of coated phosphor material 1 compared to untreated phosphor occurred.

The quantum efficiency (QY) compared to uncoated phosphor decreased for 13% of coated phosphor material 1 and for coated phosphor material 2 for 16%.
The reduction of the quantum efficiency of coated phosphor material 1 could be caused by the thick layer of Al_2O_3 on the particles.

Philips Fortimo LED Spotlight

Module Gen 4

The Fortimo LED SLM Gen 4 is a next generation solution for spotlight and downlight applications. Philips provides a system proposition ranging from 1100 Lumen to 4500 Lumen in preset outputs, with the flexibility to tune as per the OEM's needs. The product leverages the latest Chip-on-Board LED technology with a Zhaga Book 3 compliant holder. Being a low voltage UL Class II electrical design and a UL recognized component, Fortimo LED SLM Gen 4 enables easy design-in with Philips Advance Xitanium LED Drivers.

Features

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Applications

- Retail/Hospitality/Supermarkets

Benefits

- Quality of light and punch
- Easy to design-in including UL and LM80

Figure 11:
Excitation and emission spectra of uncoated and coated phosphor material 1&2 with an emission maximum of 638 nm and 643 nm

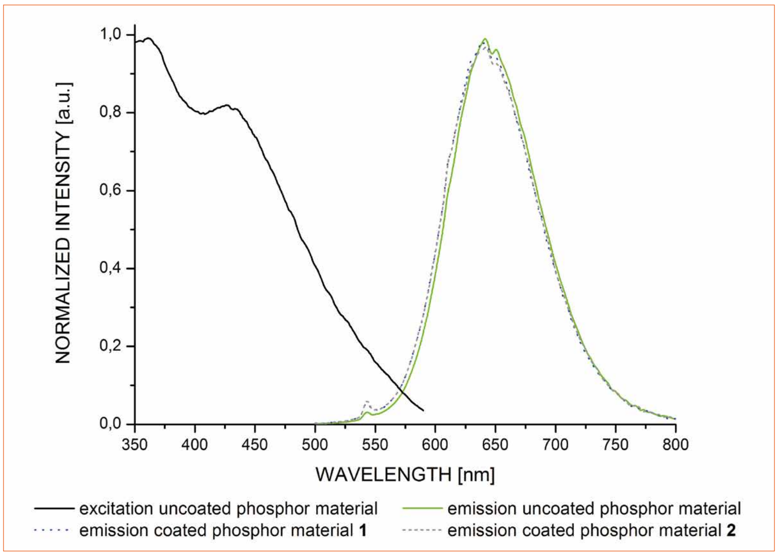

Figure 12:
CIE Diagramm of uncoated and coated phosphor materials 1&2

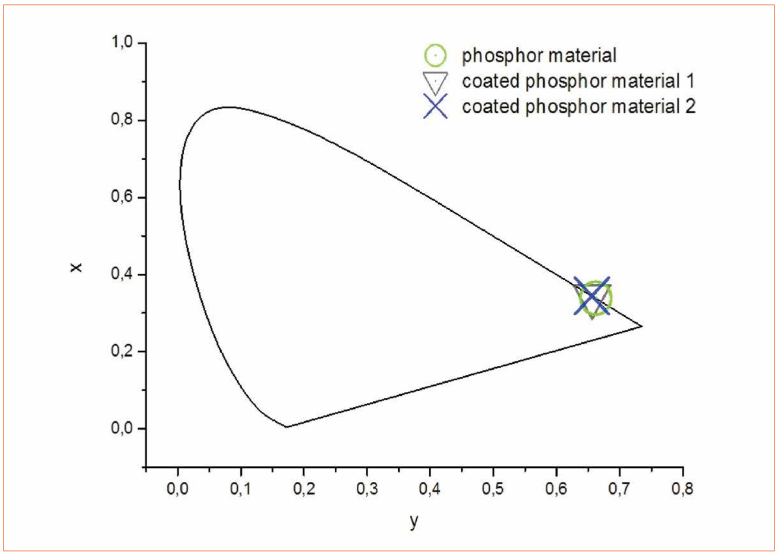

Table 3:
Luminescence properties of uncoated phosphor and coated phosphor material 1&2

Sample	λ_{MAX}, emission [nm]	x	y	QY [%]
Uncoated phosphor material	643	0.6625	0.3371	75
Coated phosphor material 1	640	0.6569	0.3427	65
Coated phosphor material 2	643	0.6563	0.3432	63

Moreover the images taken with SEM indicate the fact that phosphor particles were embedded in a matrix of Al_2O_3 and besides that the XRD analysis determined that the obtained coating is of amorphous nature (Figure 3). Therefore diffuse scattering of light at the Al_2O_3 layer may result in reduced excitation of Eu^{2+} and diminished quantum efficiencies.

Conclusion

In summary, we have demonstrated a route to coat $CaAlSiN_3$ phosphor. In regard to the use of coated phosphor particles in chip-on-board technology, the coating procedure itself does not influence the emission spectra seriously, no mentionable colour shift occurred (Figures 12&13). Moreover a colour shift due to an oxidation of Eu^{2+} to Eu^{3+} could not be observed. The ATR-IR analysis confirmed the transformation of $Al(OH)_3$ to Al_2O_3 after annealing it at a temperature of 400°C. The XRD analysis showed the amorphous nature of the formed Al_2O_3 coating. ■

Accknowledgements:

Thanks to Tridonic Jennersdorf GmbH who enabled me to work on that forward-looking topic in the course of my Master Thesis at Graz University of Technology. Thanks to Sergey Borisov from the Institute of Analytical Chemistry and Food Chemistry at Graz University of Technology. This work was supported by a grant from the Austrian Forschungsförderungsgesellschaft FFG, Projekt Nr. 842562.

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A Graphene-Based, Spectrally Tunable, Flexible Field-Effect Light-Emitting Device

The continuous tuning of the emission spectrum of a single light-emitting diode (LED) by an external electrical bias is of great technological significance as a crucial property in high-quality displays and may be used in high quality lighting applications, yet this capability has not been demonstrated in existing LEDs. Graphene, a tunable optical platform, is a promising medium to achieve this goal. Xiaomu Wang, He Tian, Mohammad Ali Mohammad, Cheng Li, Can Wu, Yi Yang, and Tian-Ling Ren from the Institute of Microelectronics at the Tsinghua University in Beijing and the Tsinghua National Laboratory for Information Science and Technology (TNList) demonstrate a bright spectrally tunable electroluminescence from blue (~450 nm) to red (~750 nm) at the graphene oxide/reduced-graphene oxide interface.

The solid-state light-emitting diode (LED) is a key component of today's semiconductor industry1. The successful development of LEDs has enabled plenty of applications such as high-performance communication, low-cost lighting and smart displays.
In modern LED industries, controlling the color of LEDs is a challenging task [2, 3, 4, 5, 6]. Traditional LEDs are available in different predefined colors whose emission wavelength is adjusted by complex material design and bandgap engineering. To date, the in situ controlling of color in a single device has never been realized, although it is highly desired.
Graphene and its derivative material-based photonic devices are currently the focus of intense study [7, 8, 9, 10, 11, 12]. Graphene is an amendable platform whose electronic and optical properties can be tailored by chemical and electrical means. This property is particularly interesting as it potentially provides a way to in situ control the color of LEDs. Although various high-performance graphene-based photonic devices have been reported [13, 14, 15, 16, 17], unfortunately the development of graphene-based LEDs has been unsuccessful owing to its vanishing bandgap.

A plausible strategy for realizing electroluminescence (EL) may be by creating discrete energy levels by utilizing functional groups, quantum confinement effect or other mid gap states. Unfortunately, the insulating nature of the photoluminescent graphene derivatives, such as functionalized graphene or solution-based graphene quantum dots, negatively affects the carrier injection and disables EL. In summary, a method to fabricate a graphene-based device with a non-vanishing bandgap and charge injection capability is still lacking.

In this article, we demonstrate a desirable combination of a bandgap structure and a bipolar carrier injection in a special type of semi-reduced graphene oxide (GO).
Our device formed on a laser-scribed GO surface consists of a series of rGO nanoclusters with many different sizes, which can selectively stimulate a single-color luminescence by controlling its doping level.
The semi-reduced GO network is with a mobility approaching 10 $cm^2 V^{-1} s^{-1}$, which supports the carrier injection. We report the observation of EL in these semi-reduced GO-based devices. The light-emission spectrum in our device is in situ adjusted from blue ($\lambda \sim 450$ nm) to red ($\lambda \sim 750$ nm) by electrical gating or conditioning the environmental doping. The device shows a high brightness of up to 6,000 $cd\,m^{-2}$, with efficiency around 1%.

Results

Fabrication and characterization of field-effect LED

Figure 1a schematically shows the structure of our all-graphene-based field-effect LED (GFLED). A planar side gate graphene field-effect transistor device was first prepared based on a laser-scribing method (see Methods for details) [18]. The light-emitting layer, which is the interface between the GO and rGO, was then uncovered by using current annealing to remove the highly conductive rGO channel. The typical length of the light-emitting region is 80-120 µm and is located in the centre of the narrow graphene field-effect transistor channel. This central location is determined by the geometric design as the Joule heating rapidly affects the narrowest part of the structure. It is worth mentioning here that the fabrication process was carried out in ambient conditions and does not require any high-vacuum environment, hazardous solution or high-temperature treatment.

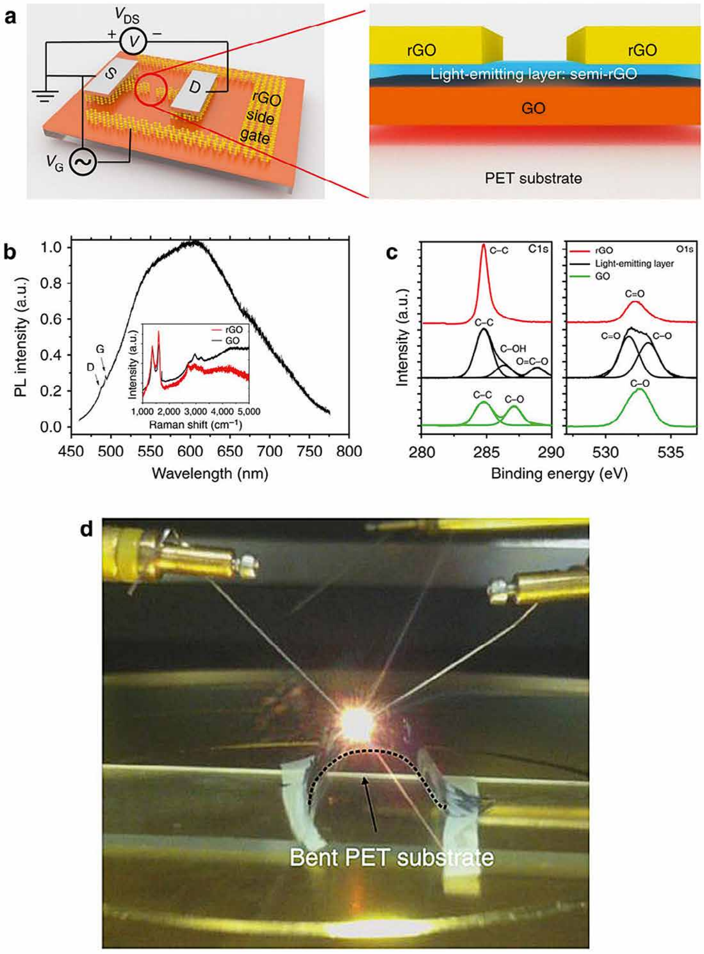

Figure 1: GFLED and characterization

Figure 1 shows the GFLED principle and characterization:

- Schematic of the GFLED. A distinct semi-reduced GO (blue) at the interface between GO (orange) and rGO (gold) is responsible for light emission (a)
- PL spectrum of light-emitting layer. The D and G Raman peaks are marked. Inset: Raman spectra of the GO and rGO samples. The GO and rGO samples do not show any PL signals (b)
- X-ray photoemission spectroscopy spectra of rGO (red), GO (green) and the light-emission layer (black). Spectra from the C1s and O1s orbitals are shown (c)
- Bright red light emission from the GFLED on a flexible polyethylene terephthalate (PET) substrate under a 12 V bias voltage and a 0.1 A drive current. The GFLED size is around 100 × 100 µm. The edge of the bent PET is marked by a dashed line. The bending radius is ~8 mm (d)

The exposed interfacial layer obtained by this method presents three major differences as compared with GO or rGO. First, this interfacial layer is ultra-flat. The RMS thickness obtained from atomic force microscope is several orders smaller than that of GO or rGO. Second, the interfacial layer is colorful, this is in stark contrast to the white colour of GO and the black colour of rGO. Third, and perhaps most importantly, a strong and broadband photoluminescence is solely observed in the interfacial layer, as shown in figure 1b (supplementary Figures 1-4 and Supplementary Note 1 for detailed comparison between the interfacial layer and bulk GO/rGO). The photo-luminescence (PL) spectra of the GO/rGO interfacial layer were obtained by exciting the samples with a continuous wave 457 nm laser with low excitation power (~100 µW). The interfacial layer showed very broad PL, ranging from about 470 to more than 720 nm (with ~0.8 eV full-width at half-maximum).

Generally speaking, the zero-bandgap nature of rGO results in a large non-radiative decay rate of stimulated electron-hole pairs, while the energy gap between the π and π* bands of GO is extremely large. All these factors imply that luminescence in rGO and GO should be impossible. The experimentally observed broad PL feature is a strong signature of the presence of localized states, similar as those in rGO quantum dots [19, 20]. These localized states can be understood by the formation of a transition state during the reduction process: There is a distinct partially reduced GO layer between the GO precursor and the thermally induced rGO as a result of the laser dosage gradient from the surface downwards.

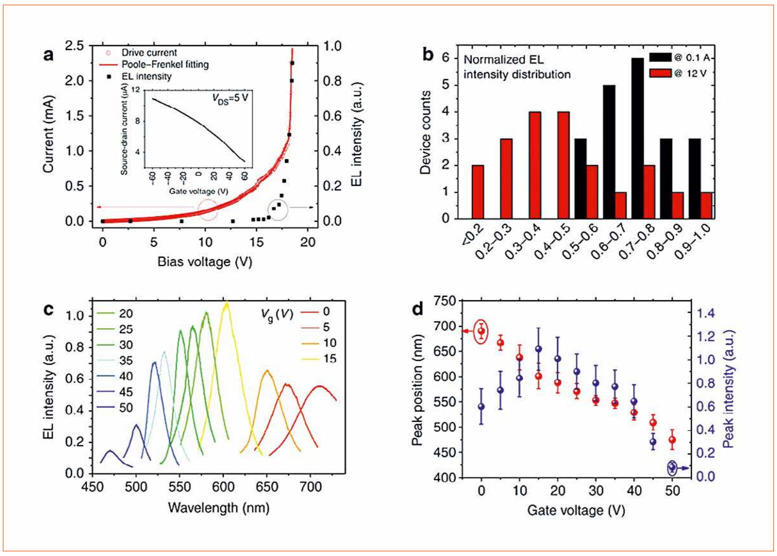

Figure 2:
Electroluminescence properties of GFLED

We performed X-ray photoemission spectroscopy to further characterize the chemical composition of the light-emitting layer. A collection of X-ray photoemission spectroscopy spectra is shown in figure 1c. Fundamentally, the light-emitting layer can be identified as an intermediate state between GO and rGO in terms of oxygen concentration. The C/O ratio for rGO, the interface layer and GO is 2.10, 0.77 and 0.57, respectively. The chemical states of carbon and oxygen in different layers also show pronounced variation. The C1s spectra of GO and rGO are similar as per the previously reported typical results [21]. For the GO case, in addition to a large carbon peak composed of graphitic sp2 and sp3 C-C bonds, another C-O clear peak can be observed due to the hydroxyls and epoxies. For the rGO case, the spectrum is dominated by the graphitic sp2 component and the C-O bonds only show a very minute component. However, the interfacial layer exhibits distinct features as compared with the GO and rGO. In addition to an intermediate carbon-carbon bond state, the interfacial layer is also rich in C=O bonds. These bonds are usually attributed to carbonyls. The presence of carbonyls in the GO basal plane signifies incomplete reduction [21]. A similar feature of the transition state was also observed in the O1s spectra. While rGO and GO are dominated by C=O and C-O peaks, respectively, the light-emitting layer is a mixture of C-O and C=O bonds. The two-component configuration has been used to characterize the transition state in the evolution of reduction of GO [22].

As described above, the interfacial layer is a special type of partially reduced GO. Generally speaking, the reduction of GO leads to creation of small (2-3 nm) ordered sp2 clusters isolated within the sp3 C-O matrix of GO7. Therefore, the partially reduced GO likely results in a series of discrete energy levels between π and π* bands by quantum confinement effect [19]. Incident laser stimulates electron-hole pairs in the π band and in these discrete states. Radiative recombination of the electron pairs thus gives rise to a PL effect (and also leads to EL, see discussion below). In this case, the degree of reduction of the rGO determines the features of the PL spectrum, similar to how porous silicon and colloidal quantum dot devices affect the spectrum [6, 23].

Spectrally adjustable EL

Once the energy levels with bandgaps are created, EL can be expected if bipolar carriers are injected into the device. Previously reported “gapped graphene” (such as GO and graphene quantum dots) is either an insulator or a liquid-phase material, which impair the carrier injection. Fortunately, the interfacial layer (although also a type of GO), is a p-type semiconductor with a good conductivity (Figure 2a inset; also see Supplementary Figures 5-7 and Supplementary Note 2 for characterization of its field effect). In addition, an enhanced carrier injection was also identified under a strong bias field, manifested by the rapidly increasing current versus bias voltage in figure 2a. Accompanied by the pronounced free carrier injection process in the device, we observed EL along the interfacial layer. The emitted light is bright and easily identified by the naked eye (Figure 1d). We fabricated 20 devices to characterize the bias-dependent EL intensity. Typical relative emission intensity versus different drain bias and the EL intensity distribution are plotted in figures 2 a&b, respectively. Notably, the EL intensity is controlled by drive current. As shown in figure 2b, the devices are relatively uniform under a fixed 0.1 A current bias ($I_{max}/I_{min} < 2$). In contrast, the relative EL intensity presents large device to device variation ($I_{max}/I_{min} \sim 10$) under a fixed 12 V voltage.

Figure 2 shows GFLED’s electroluminescence properties:

- Source-drain current (circles) and EL intensity (solid squares) versus source-drain bias voltage. The device used has a W/L ratio around 0.1/0.1 mm. The solid line shows the Poole-Frenkel fitting of the drive current. The EL peak is at 690 nm. Inset: source-drain current versus gate voltage of the same device, showing a p-type field effect (a)
- Histogram of EL intensity distribution under fixed voltage and current bias. The data have been obtained from 20 devices (b)
- Typical EL spectra of a single GFLED. Gate biases are from 0 to 50 V (c)
- Peak position (wavelength) and intensity of the GFLED EL versus gate voltage. The data have been collected from 19 devices. Error bars (standard uncertainty) are estimated from the device variations (d)

瑞豐光電

2835

Application and Features

0.2W

0.5W

1W

Features

- Macadam / Energy Star standard, with high consistency;
- Optimized PPA and PCT material, with more resistant to high temperature and high reliability.
- Product specification close to the market mainstream
- LM-80 test approved
- IP free

Applications

Fluorescent tube, bulb,candle light,ceiling light, grille light,down light, panel light, side light LED, high-efficiency tubes

Global Patent

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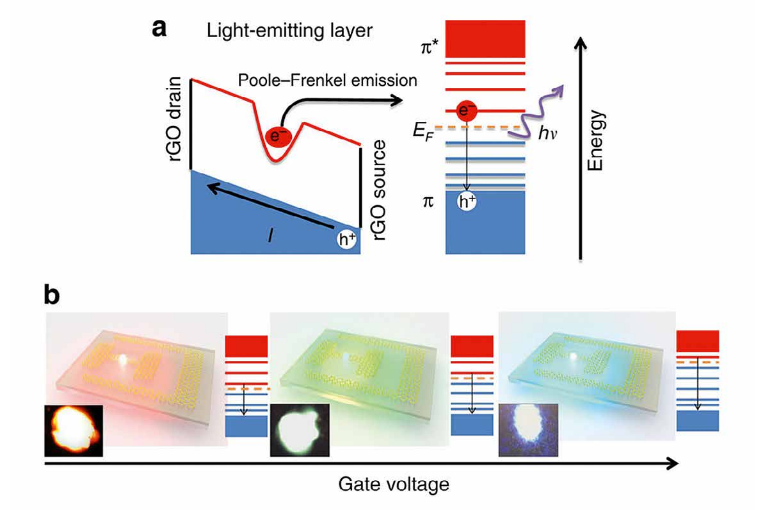

Figure 3: GFLED light-emission mechanism

An exceptional observation in this work is that the colour of EL emission can be continuously tuned from light blue to dark red by adjusting the Fermi levels. The Fermi level and the doping level of the GFLED can be modulated either electrically or chemically. In this paper, we use a side gate field to control the Fermi level; however, the colour also changes in response to ambient doping, enabling sensing applications. Typical emission images, spectra recorded at different side gate voltages during the EL measurement and spatially resolved EL are shown in figures 1d and 2c and Supplementary Figure 8. The EL peaks exhibit sharp single Lorentzian shapes. As shown in figure 2c, the peak emission wavelength shifts from 690 nm at zero gate voltage to 470 nm under 50 V gate voltage. On one hand, the EL peaks present similar narrow full-width at half-maximum (~0.2 eV), whereas on the other hand, the relative intensity of the EL is found to vary under different bias voltages. For instance, the maximum luminance and the luminous efficacy of the blue light are much lower than the red light. Approximately 4.8 lm/W (corresponding to ~0.7% external quantum efficiency, also see Supplementary Figures 9 and 10 for details) and 6,000 cd/m² red and green lights were measured under a 12 V bias and a 0.1 A drive current, whereas 0.67 lm/W (corresponding to ~0.1% external quantum efficiency) and 800 cd/m² blue light was measured under a 16.5 V bias and a 0.1 A drive current. Overall, the broad PL can be roughly regarded as the envelope of all these possible EL spectra. This strongly suggests that the EL results from a selective excitation of inhomogeneous luminescence of semi-reduced GO, as observed in previously reported rGO quantum dots. A possible explanation of the field effect-modified EL will be discussed in the following part.

Currently, the efficiency of GFLEDs is relatively low. We hypothesize that two factors limit the efficiency. First, as shown in Supplementary Figure 9, the efficiency tends to saturate at a large current density. We attribute this saturation to the inefficient injection of electrons caused by heat dissipation, that is, much of the supplied power is lost to heat dissipation. In other words, the saturation is caused by the inefficient injection of electrons (discussed below). The large amount of heat dissipated can also break the devices rapidly. The emission lifetime of these devices are several tens of seconds in ambient conditions. This short lifetime can be attributed to vigorous oxidation in air. However, these devices have a much longer half-life in vacuum and tests have revealed continuous and stable emission for up to 2 h, suggesting protective coatings may help to avoid structural damage in practical devices. Second, in the absence of an intersystem cross path, only singlet excitons can be harvested, which suggests that the efficiency upper limit of GFLED is 25%. Therefore, the promotion of efficiency requires improved carrier injection and introducing intersystem crossing in future works.

EL mechanism

Next, we proceed to discuss the possible EL mechanism. The simultaneously rapid increase of the current and EL intensity clearly indicates that carrier injection plays a central role in the EL process. Owing to the p-type nature of the light-emitting layer, electron injection is the key factor of understanding the EL process. At the current state, the exact mechanism of electron injection is not well known. On the basis of the various evidences, we hypothesize that the electric field-assisted thermal ionization, also known as Poole-Frenkel emission, is the most probable mechanism.

We performed temperature-dependent electrical measurements to investigate the electron injection process. Figure 3a shows the Poole-Frenkel plot of I-V characteristics of a typical device. As illustrated in the inset of figure 4, a linear relationship fits well to the measured conductivity in the Arrhenius plot, indicating the electrons inject into the system on a charge emission manner. The highly linear feature in the log(I) versus V1/2 plot signifies the I-V curves agree well with the Poole-Frenkel current law (see Supplementary Note 3 for details) [24]. The Poole-Frenkel effect is usually understood as a means by which trapped electrons get out of Coulomb binding and move to the conduction band. Figure 3a schematically shows how this effect applies to the GFLED. The oxide-rich light-emitting layer has a high density of electron trap states. Under high field, the localized electrons are excited into the lowest unoccupied discrete energy level. Radiative recombination between the thermally emitted electrons and the free holes results in the EL.

Figure 4:
GFLED two-terminal temperature-dependent transport

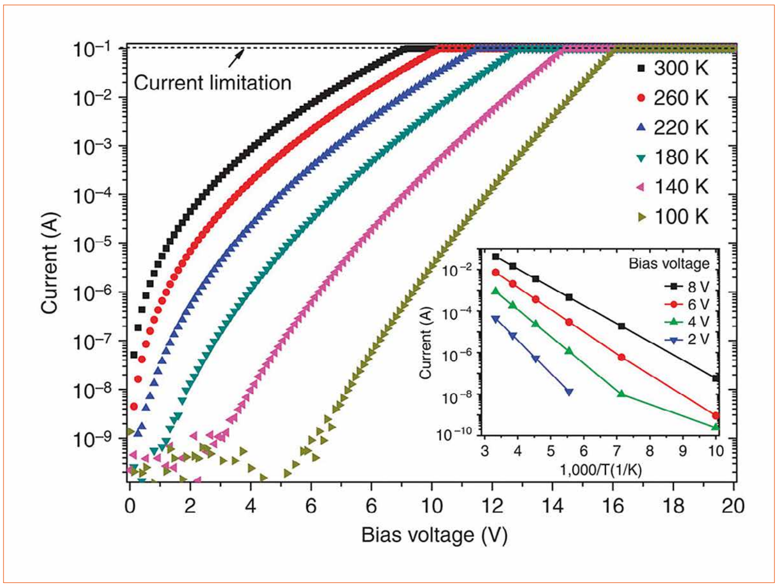

Figure 3 demonstrates the GFLED light-emission mechanism:

- A schematic of the charge injection process. The trapped electrons are excited to the lowest unoccupied discrete energy level by Poole-Frenkel emission. The excited electron recombines with the hole in the π band, resulting in photon emission (a)
- Schematic of the gate voltage-dependent EL. The Fermi level determines the lowest unoccupied energy state that mainly participates in the radiative recombination. Inset: corresponding emission images from a real device (b)

Figure 4 shows the source-drain current versus voltage bias at different temperatures:

- The current is limited to 0.1 A to avoid device breakdown. Inset: Arrhenius plot of source-drain current at bias voltages of 2, 4, 6, and 8 V

This mechanism also explains the observed spectral shift, as shown in figure 3b. Gating graphene lifts up the chemical potential and thus the energy level of the lowest unoccupied discrete state; therefore, the excited electron energy is increased. Through this way, the EL peak can be adjusted within the whole PL range; and the relative emission intensity is determined by the distribution of density of states of the discrete energy levels.

Several mechanisms, such as thermal emission [25], Fowler-Nordheim tunneling [26, 27] and impact excitations [28, 29, 30] may also cause the EL in the GFLED. However, none of them can consistently explain all the findings of this work. Here we discuss the validity of these possibilities to GFLEDs. First of all, the featureless electroluminescence peak would correspond to a local temperature above 4,500 K if the EL results from blackbody radiation coming from Joule heating. This would rule out thermal emission as the light-emitting mechanism. Second, Fowler-Nordheim tunneling, which is a main charge injection mechanism in porous silicon EL device, may also work for the GFLED [26]. Considering the planar device structure, the tunneling process most likely occurs around the drain electrode that holds the largest band bending. However, this contradicts the light emission observed in the middle of the device. Finally, impact excitation/ionization is another plausible EL mechanism and has been used to successfully describe the EL phenomenon in carbon nanotubes [28, 29, 30]. However, the threshold voltage in an impact ionization process is always accompanied by a negative temperature coefficient. Therefore, the observed positive temperature coefficient clearly rules out the impact ionization mechanism.

Discussion

In summary, we have reported the design and implementation of a LED device based on a special type of semi-reduced GO that forms in the rGO/GO interface. By yielding a series of discrete energy levels between the π-π* gap and injecting free carriers into those states, EL is successfully achieved. The in situ tuned wavelength of the EL exemplifies a kind of novel light-emitting device that is highly desired for high-color-quality displays and high-quality lightings. The precise spectral tunability, compact device structure, high performance and straightforward fabrication point to the commercial prospects of such a device. We anticipate our findings to be a prospective point for commercialization of graphene devices. Furthermore, the observance of EL itself addresses the lack of a light source component in graphene-based photonic devices, paving the way for all-graphene integrated photonics. This device opens the possibility of fabricating carbon-based photonic devices due to the henceforth availability of graphene-based LEDs.

Methods:

Sample preparation

GFLEDs were fabricated based on a side gate field-effect transistor structure. An ~1 μm thick GO (XFNANO Materials Tech) film was prepared by drop casting on a flexible polyethylene terephthalate substrate. Conductive rGO traces with ~100 μm width were then patterned by a previously reported laser-scribing method within a DVD drive [31]. Silver paste electrodes were fabricated to improve the contact. In the scribing process, the DVD drive's 788 nm laser (5 mW) was used to gradually reduce the stacked GO films to rGO. After that, the as-prepared devices were annealed by a 10 mA current to expose the interfacial layer.

Electrical measurement

Electrical measurements were carried out within a Lakeshore CPX-VF-457 cryogenic probe station using a Keithley 4200 semiconductor analyser. Electrical doping were achieved by using a side gate that surrounds the GFLED. The GO acts as a dielectric with a capacitance of 160 nF (see Supplementary Figure 5 for details).

PL and EL measurements

The luminescence measurements were performed using a Renishaw inVia micro-Raman spectroscope equipped with 457, 514 and 633 nm lasers. The spot diameter was around 1 μm under a × 100 objective lens. For PL measurements, the laser powers was set at 100 μW to avoid breaking the samples. The typical integrating time was 10 s. For EL measurements, a dual-channel Keithley 2612 source meter supplied the electrical and gate bias.

Acknowledgements/Citation:

This work was supported by National Natural Science Foundation (61434001), 973 Program (2015CB352100), National Key Project of Science and Technology (2011ZX02403-002) and Special Fund for Agroscientic Research in the Public Interest (201303107) of China. We are thankful for receiving support through the State Key Laboratory of Automotive Safety and Energy, Tsinghua University. H.T. is thankful for receiving support through the Ministry of Education Scholarship of China. M.A.M. is thankful for being supported by the postdoctoral fellowship (PDF) programme of the Natural Sciences and Engineering Research Council of Canada (NSERC).

Article citation

Wang, X. et al. A spectrally tunable all-graphene-based flexible field-effect light-emitting device.
Nat. Commun. 6:7767 doi: 10.1038/ncomms8767 (2015).
http://www.nature.com/ncomms/2015/150716/ncomms8767/abs/ncomms8767.html

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Author Footnotes:

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Competing financial interests:

The authors declare no competing financial interests.

Licensing:

SUPPLEMENTARY NOTES AND FIGURES

Supplementary Note 1: Comparison between GO, rGO and their Interfacial Layer

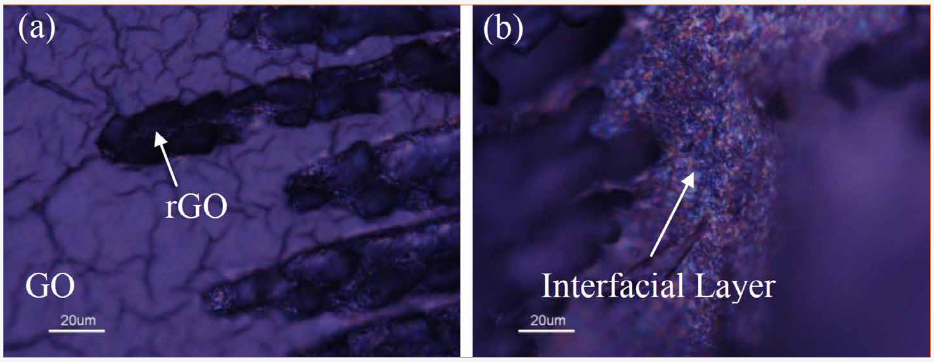
The interfacial layer between GO and rGO presents a totally different morphology and chemical properties as compared with both materials. The photograph of the interfacial layer exhibits a color - this is in contrast to the white color of GO and the black color of rGO, as shown in Supplementary Figure 1.

To further examine the light-emitting interficial layer, we performed nanoscale morphology analyses using AFM. The microscopic morphology present distinct features for the interfacial layer (Supplementary Figure 2) and GO (Supplementary Figure 3). Firstly, the interfical layer has a very small roughness (RMS 0.594 nm) in comparison with GO (4.28 nm). Secondly, several tiny and distinct ripples are recorded in the interfacial layer.

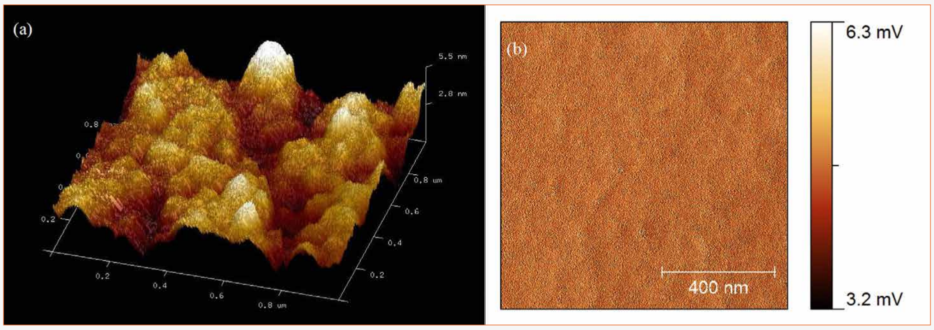
Finally, PL measurements were also carried out for GO and rGO, as shown in Supplementary Figure 4. As discussed in the main text of the manuscript, both GO and rGO present pronounced Raman signals only. Although a very weak and broad PL spectrum was observed in the rGO samples, it likely arises from the interfacial layer underneath the rGO. We believe this to be the case as the PL spectrum is strikingly similar to what was observed previously from the interfacial layer. It should be noted that due to the strong resonance energy transfer, graphene (and rGO) presents a strong luminescence quenching effect, suggesting the current annealing step is necessary for the rGO QD LEDs.

Supplementary Note 2: Field-Effect Characteristics of the GFLEDs

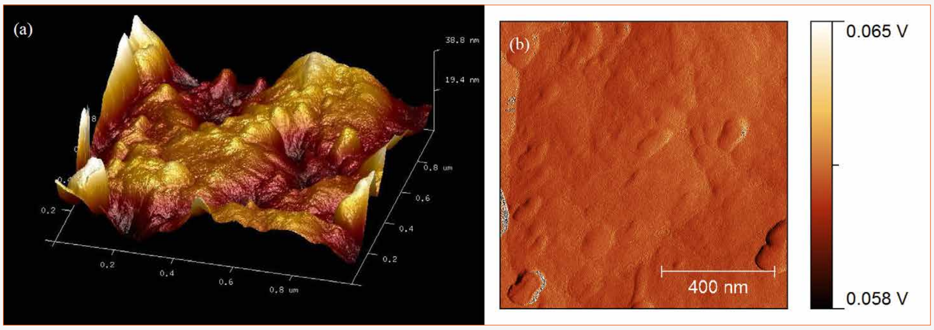
Firstly, we directly measured gating efficiency in our device based on a capacitor configuration which is similar as the Metal-Insulator-Semiconductor structure. As shown in the inset of the Supplementary Figure 5, we fabricated a capacitor by the laser scribing method. The two rGO regions were defined as two capacitor electrodes, which in our device



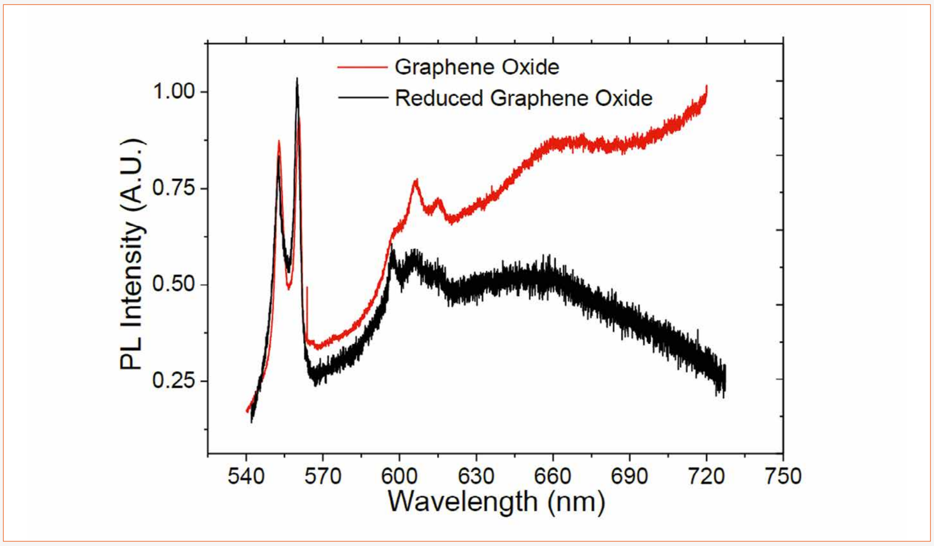
Supplementary Figure 1: GO, rGO and GO/rGO interfacial layer. Images of (a) rGO on GO prepared by laser scribing, and (b) the interfacial layer



Supplementary Figure 2: AFM images of the GO/rGO interfacial Layer. (a) The topography and (b) corresponding phase image are both shown



Supplementary Figure 3: AFM images of the GO. (a) The topography and (b) corresponding phase image are both shown



Supplementary Figure 4: PL measurements of GO and rGO act as the side gate and source electrode respectively. The C-f measurement of this structure clearly demonstrates our structure is with a capacitance around 4 × 10^{-4} F/m^2. For comparison, we also measured the capacitance of 300 nm SiO_2 substrate, which results in a 1.15 × 10^{-4} F/m^2 capacitance. After that, the electrical and optical characteristics of GFLED under gate bias are illustrated in Supplementary Figure 6.

Supplementary Note 3: Poole-Frenkel Modeling of the I-V Curve of GFLED

The I-V curve of the GFLED obeys a Poole-Frenkel relationship which describes the conductance of electricity in an electrical insulator. The physical process can be understood within a release of free carriers from deep traps. In the insulator, the electrons are generally trapped in localized states. Injected holes are accelerated by the strong electric field in the insulator and will transfer that electron enough energy to get out of its localized state, and move to the conduction band.

In this process, the source-drain drive current fits well to

$$I \propto E exp\left(\frac{-q \cdot (\Phi_B - \sqrt{(qE/\pi\varepsilon)})}{k_B \cdot T}\right) \quad (1)$$

where

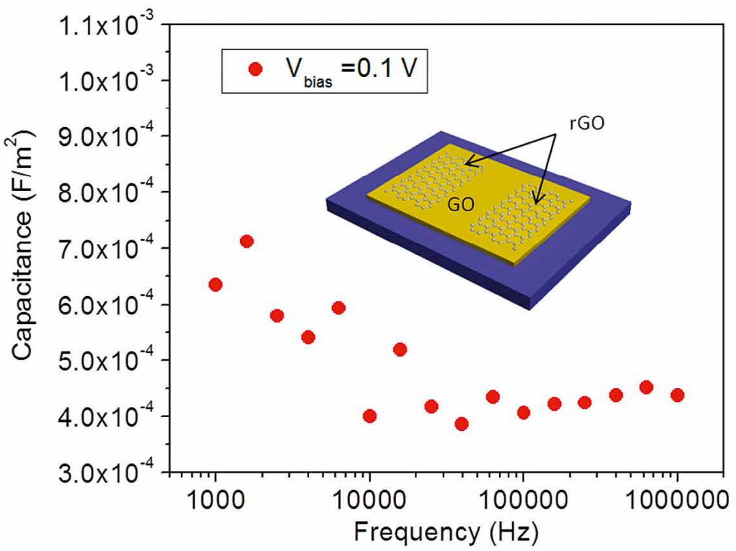
- q is unit charge
- k_B is Boltzmann constant
- T is temperature
- Φ_B is zero-bias built in potential between the metal and rGO QDs, and
- ε is electrical permittivity

The average applied electric field E can be expressed as

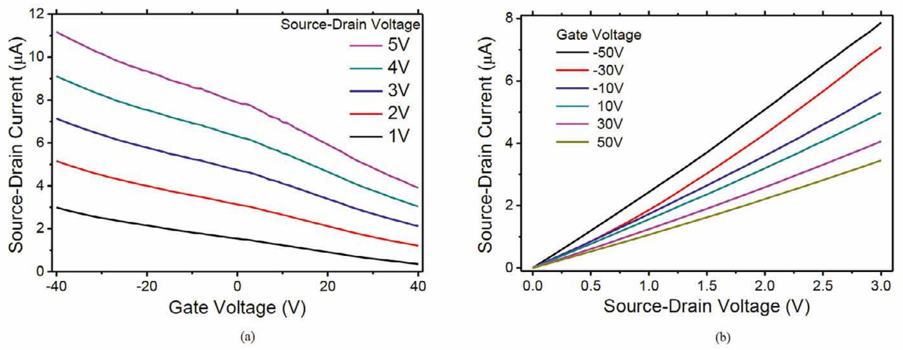
$$E = \frac{1}{l} \cdot (V - I \cdot R_S) \quad (2)$$

in which

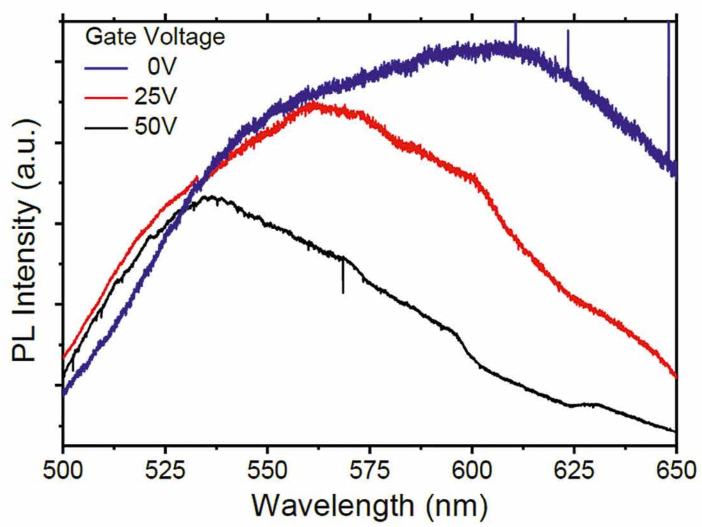
- V is the voltage across the LED
- l is the device channel length, and
- R_S is the parasitic contact resistance



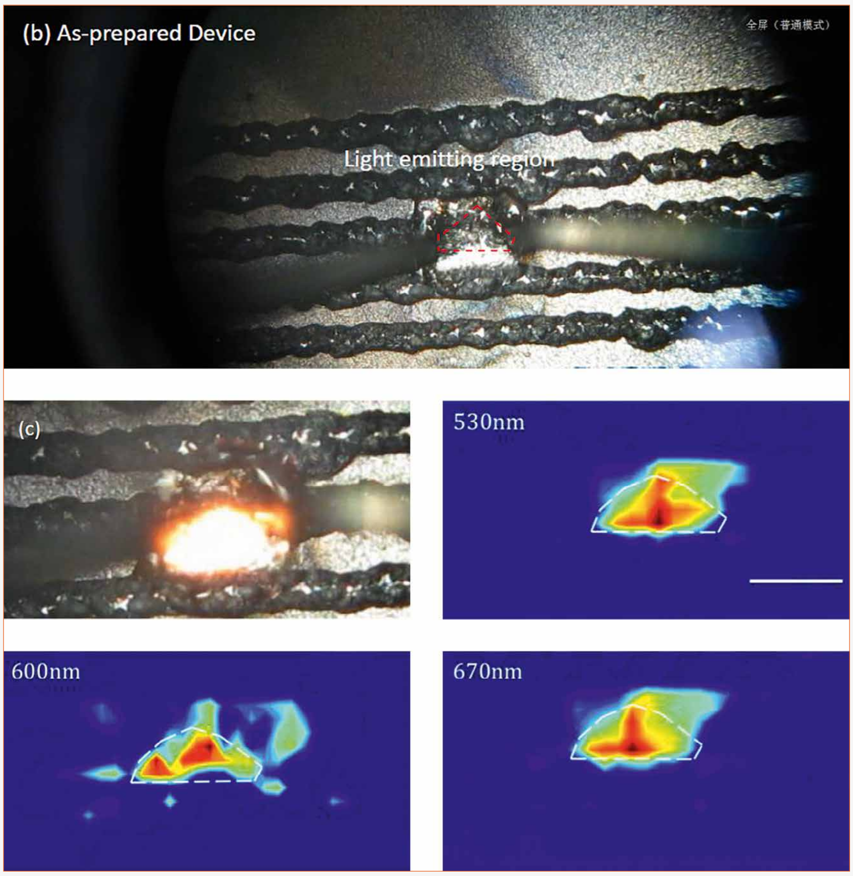
Supplementary Figure 5: Capacitance of GO dielectrics. C-f measurements were carried out on a Metal-Insulator-Metal structure. The two rGO regions were defined by laser-scribing as two capacitor electrodes, which in the GFLED act as the side gate and source electrode respectively



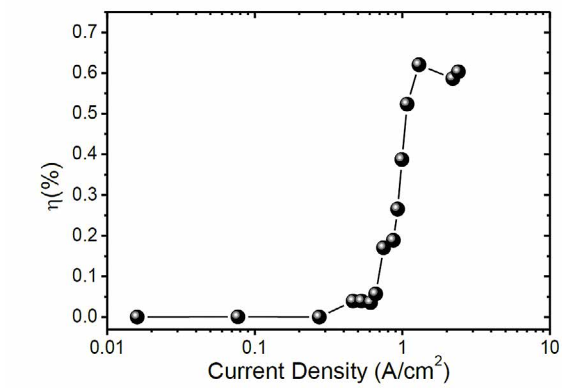
Supplementary Figure 6: Electrical Characteristics of GFLED (a) Transfer Curves of a typical GFLED under different source-drain bias (b) Output Curves of a typical GFLED under different source-drain bias



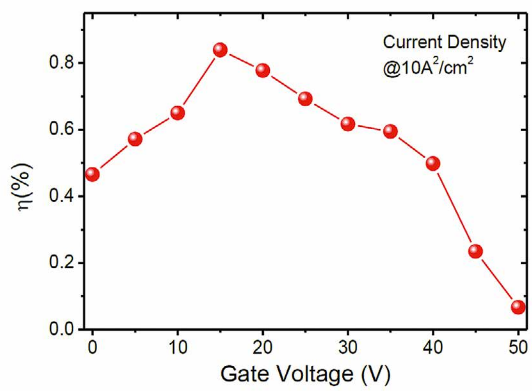
Supplementary Figure 7: Gate-Dependent PL of a typical GFLED



Supplementary Figure 8: Spatial resolution of GFLEDs. Spatially-resolved EL of (a) a working device and (b) the as-prepared device. (c) PL mapping at 530, 600 and 670 nm illustrate the emission sites of the device. (Scale bar: 100 μm)



Supplementary Figure 9: Efficiency of a GFLED as a function of current density



Supplementary Figure 10: Efficiency of a GFLED as a function of gate voltage

Measurement Uncertainty and Conformity Assessment in Photometry

The availability of reliable and accurate photometric data for LED devices is a basic requirement for designing good lighting systems, evaluating performance of products and comparing data between different laboratories. Peter Blattner, Head of Laboratory at METAS and Chairman of the Technical Committee of Photometry and Radiometry of the European Association of Metrology Institutes explains how to measure products and how to interpret data regarding measurement uncertainties and manufacturing tolerances according to the new new ISO/IEC Guide (Guide 98-4:2012). Furthermore, he discloses how to implement these guidelines in the industrial practice.

Conformity decisions are usually taken on the basis of measurement results. As a consequence of the measurements uncertainty these compliance statements cannot be made with absolute certainty. Similar to the evaluation of measurement uncertainty standardized procedures are needed for conformity statements. In 2012 the Joint Committee for Guides in Metrology JCGM published a guidance document (JCGM 106) addressing conformity assessment and measurement uncertainty in general. The new international LED measurement standard CIE S025:2015 published recently by the Commission Internationale d'éclairage (CIE) follows the international recommendations.

Introduction

Conformity assessment is a key element in product testing, industrial quality control or legal requirements for ensuring health and safety. In the field of light and lighting many cases of conformity assessments can be cited.

Some examples:

- The European Regulation 1194/2012 requires that the lamp power factor for LED-lamps with integrated control gear and lamp power larger than 25 W has to be larger than 0.9
- According to the EU Regulation 244/2012 the UVA+UVB content (i.e. ultraviolet hazard efficacy of luminous radiation) of compact fluorescent lamps shall be smaller than 2.0 mW/klm
- IEC 62471 (photobiological safety of lamps) classifies lamps according to the potential photo-biological hazard into risk groups
- LEDs are usually binned by the manufacturer for luminous flux and chromaticity

In conformity assessment usually a measurement result is used to decide if an item of interest conforms to a specified requirement. If the measurements were "exact", hence without measurement uncertainty, the conformity assessment would be straightforward: a measured value would be considered compliant if it is within the tolerance interval. In practice all measurements are subject to a measurement uncertainty. In this case accepting or rejecting an item when the measured value of its property of interest is close to a tolerance limit may result in an incorrect decision and lead to undesirable consequences. The presence of measurement uncertainty requires a more nuanced assessment taking into account the risks for the producer and the consumer. In order to perform conformity assessment in a unified way the Joint Committee for Guides in Metrology JCGM, consisting of different standardization, accreditation and metrology organizations including the Bureau International des Poids et Mesures (BIPM), the International Electrotechnical Commission (IEC), the International Organization for Standardization (ISO) and the International Laboratory Accreditation Cooperation (ILAC) has published in 2012 the guidance document JCGM 106:2012 [1].

This guide gives a clear mathematical concept for conformity assessments based on probability theory and shows, how the risk of incorrect conformity assessment can be quantitatively calculated. In addition, it outlines how these risks can be influenced through the introduction of guard bands and acceptance limits.

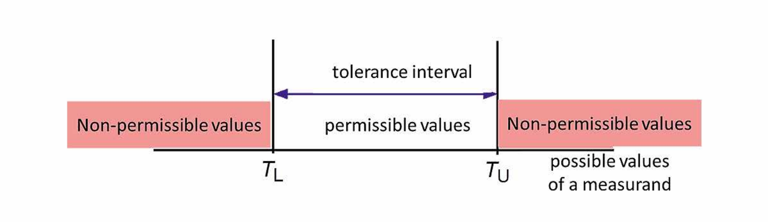


Figure 1:
Tolerance interval to define specific requirement. TL and TU are the lower limit and upper limit respectively

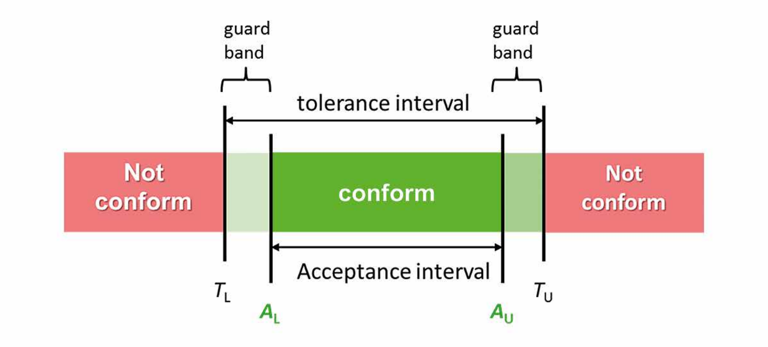


Figure 2:
Defining an acceptance interval smaller than the tolerance interval, the risk of wrong decisions by the producer is increased, whereby the consumer risk is decreased

Tolerance and Acceptance Intervals

A specific requirement typically takes the form of one or two tolerance limits that define an interval of permissible values, called a tolerance interval of a measurable property of the item (Figure 1).

An example of such a tolerance interval is given in the EU Regulation 874/2012 classifying lamps according to energy efficiency into different energy efficiency classes (A++, A+, A, B, C, D, E). In order that a non-directional lamp can be labeled as class A the energy efficiency index (k_{EEI}) has to lie between a lower limit T_L = 0.17 and an upper limit T_U = 0.24. If k_{EEI} is outside these limits a lamp may not be labeled as A. Suppose that a measurement of lamp A reveals a value of the energy efficiency index and its expanded uncertainty of $k_{EEI,A}$ = (0.20 ± 0.02) and for a lamp B of $k_{EEI,B}$ = (0.17 ± 0.02). In case A there is a good chance that the product is correctly labeled. However, in case B there is a probability of 50% that a wrong decision was made. Both the producer and consumer share the risk of a wrong decision.

By defining an acceptance interval of permissible measured values of a measurand, the risks of incorrect accept/reject decisions associated with measurement uncertainty can be balanced in such a way as to minimize the costs associated with incorrect decisions. Figure 2 shows an example of acceptance interval shifting the risk to the producer: the acceptance interval is smaller than the tolerance interval; hence fewer non-conforming products will be put on the market. The guarded acceptance rule protects the consumer and penalizes the producer. In the example mentioned above, the lamp producer could decide to declare a lamp to be class A if the measured energy efficiency index is larger than the A_L = 0.19. He would therefore reject lamp B even if there is 50% chance that the product complies. He therefore is accepting to reject more lamps than necessary. From a consumer point of view the risk of buying a lamp wrongly labeled would be reduced in this case.

Choosing the tolerance limits and acceptance limits are business or policy decisions that depend upon the consequences associated with deviations from intended product quality.

Risk Assessment

The presence of a measurement uncertainty induces possible wrong decisions presenting a potential risk for consumer and producer. The consumer has a certain risk that the object he gets does not conform, although it is rated at an inspection process as compliant. Conversely, the producer has an element of risk that an object through the inspection process is incorrectly declared as a reject.

In a conformity assessment, which allows for only the acceptance or rejection of a product, the following four situations are possible (Figure 3):

a) Correct acceptance: The measured value is located within the acceptance region and the "true" value is within the tolerance range. This is the desired result in the evaluation of a compliant measurement
b) False acceptance: The measured value is located within the acceptance interval although the "true" value is outside the tolerance range. The false acceptance is usually at the peril of the consumer or customer. Therefore this probability of false evaluation is referred to as consumer risk
c) Correct rejection: The measured value is outside the acceptance interval and the "true" value is out of tolerance. This is the desired result in the evaluation of a non-compliant measurand
d) False rejection: The measured value is outside the acceptance interval, although the "true" value is within the tolerance interval. The false rejection normally punishes the manufacturer or producer. Therefore this probability is referred to producer risk

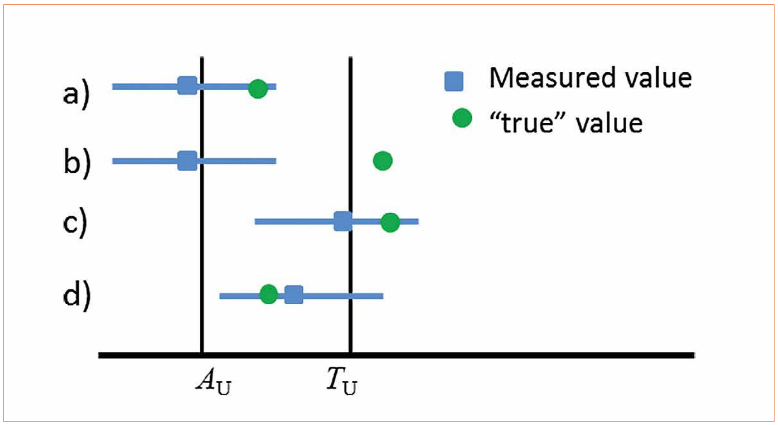


Figure 3:
Simple acceptance decision rules near an upper tolerance limit TU. Decisions to accept or reject inspected items are based on measured values (squares) in respect to the acceptance limit AU; the "true" values (disks) cannot be known. Cases (b) and (d) lead to incorrect decisions called false acceptance and false rejection, respectively

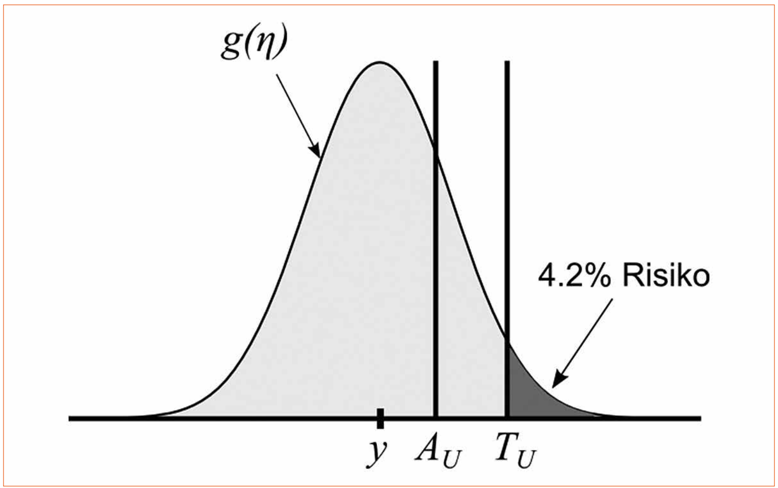


Figure 4:
Illustration of specific consumer risk for the unilateral acceptance and tolerance limit

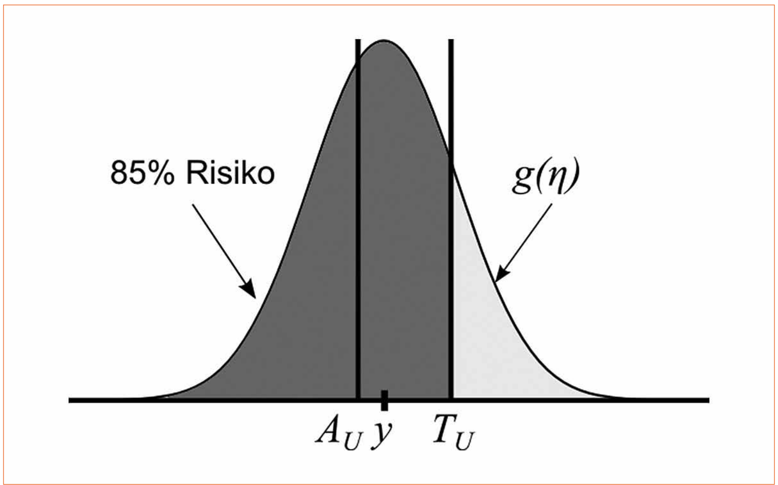


Figure 5:
Illustration of specific producer risk for the unilateral acceptance and tolerance limit

The terms consumer risk and producer risk are based on the idea that the conformity assessment is part of a production process. Knowing the measurement uncertainty of the measured quantity the probability of a false decision made in b) and d) can be calculated. In Figure 3 the upper limit of the acceptance interval A_U is lower than the upper limit of the tolerance interval T_U. Hence the producer has a higher risk than the consumer: case b is much less likely than case d as the "true value" is outside the range defined by the measurement value and its uncertainty.

A more detailed consideration is based on the probability density function *g(η)*, which represents the uncertainty of the measured value *y*. Figure 4 illustrates a compliant measurement with one-sided acceptance and tolerance limits whereas figure 5 illustrates the opposite case in which the measured value is outside the acceptance region and non-conformity exists. From the two figures it is evident that the measured values that lie close to the acceptable limit, have the highest specific risk. Assessing the guard band and, thus the acceptance limits, affect the two risks in a complementary manner: The consumer risk is reduced by a greater guard band but at the same time the producer risk increases. Conversely, the producer risk is reduced with decreasing guard band and consumer risk is increased.

Figure 4 illustrates the specific consumer risk for the unilateral acceptance and tolerance limit. The measured value y is within the acceptance and tolerance interval as the value is lower than the acceptance limit A_U and tolerance limit T_U. The risk that the actual value still lies outside the tolerance limit is given by the darker area of the distribution defined by the upper tolerance limit T_U. In this specific case, the ratio of the dark area to the total area of the distribution and thus the specific consumer risk is about 4%.

Figure 5 illustrates the specific producer risk for the unilateral acceptance and tolerance limit. The measured value *y* is outside the acceptance but inside the tolerance interval as the value is higher than the acceptance limit A_U but lower than tolerance limit T_U. The risk that the actual value still lies inside the tolerance limit is given by the darker area of the distribution defined by the upper tolerance limit T_U. In this specific case, the ratio of the dark area to the total area of the distribution and thus the specific producer risk is about 85%.

Measurement Uncertainty Evaluation

In order to be able to perform quantitative risk calculations it is necessary to quantify the uncertainty of the measurement process. For this purpose international guidance documents exist: The Guide to the expression of uncertainty in measurement (GUM) [2] gives the general concept. In the field of photometry CIE has published the technical report CIE 198:2011 Determination of Measurement Uncertainties. These documents can be considered as the basis for all further CIE technical reports and standards related to measurement. An example is the most recent standard related to LED measurements published by CIE.

Global Risk

When assessing risks, a distinction between specific risk and global risk has to be made depending on the information available. The specific risk assesses the probability of misjudgments based on a concrete measurement on a specific item. As an example, the useful luminous flux and the power consumption of a retro-fit LED lamp is measured and the energy label of this specific lamp is determined. The possibility of misjudgment of this specific lamp is referred to as a specific risk.

The global risk assesses the average probability of misjudgments based on a set of measurements. In contrast to the specific risk the global risk is not based on the individual case, but takes into account all possible readings defined within the context. As an example, the global risk of wrong decisions on the energy label classification of a retrofit LED lamp production line could be estimated as not each product will have the same characteristics, but slight variations in the production are possible. Knowing the production process allows restricting the set of possible measured values to calculate the average risk of misjudgments in general for the product. This is referred to as global risks.

Global risks can be quantified as the knowledge of the production process that is characterized by a probability distribution similar to the measuring process. With a means of probability theory the two distributions (measuring process and prior knowledge about the possible values of the measured variable) can then be combined to obtain a two-dimensional combined probability distribution of possible values of the measured variable and possible readings. For the assessment of global risk, this two-dimensional distribution is evaluated. These calculations do not usually have analytical solutions and tabular values or numerical methods have to be used. One possibility consists in the calculation of the numerical simulation using computer software. The distributions are represented by random numbers. Using the random numbers, the production and the measurement process can be simulated step by step. To determine the risks, only simple arithmetic operations are then necessary. Figure 6 a& b illustrate such numerical simulations, referred to as Monte Carlo simulations. Each point corresponds to a certain "virtual" measurement value on a "virtual" product. The figures can be used to illustrate the global producer and consumer risks: The blue boxes on the left and right correspond to the case where the measurement values are within the acceptance limits but the product is actually outside the tolerance interval (wrong acceptance and therefore consumer risk). The red boxes on the top and the bottom correspond to the case where the measured values are outside the acceptance interval but the products would actually be within the specified tolerance interval (wrong rejection and therefore producer risk). The risks are quantified by simply counting the points in the boxes in respect to the total number of points on the graph.

Reducing Production Costs by Improving Measurement Capabilities

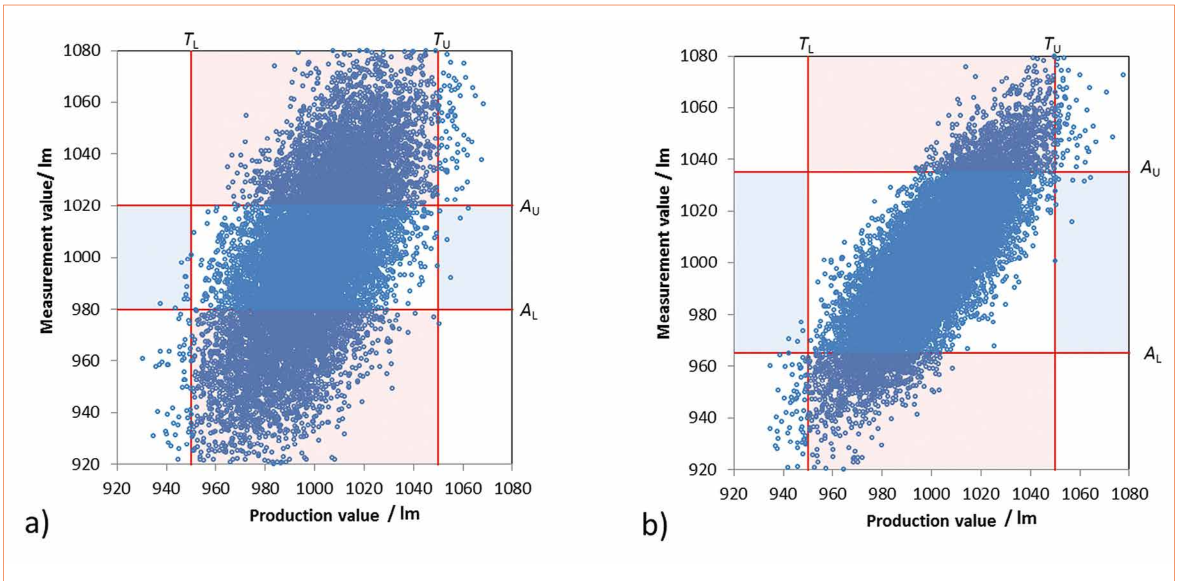
The global risk is an important parameter when it comes to planning a measuring system for conformity assessment. The following example illustrates the capacity of global risk assessment. Suppose that a LED lamp is binned according to its luminous flux. For a specific bin the lamp should be within 950 lm and 1050 lm (tolerance interval). The production is optimized to 1000 lm but has a spread of about 20 lm (standard deviation). For the measurement system, an expanded uncertainty of 5% (k = 2) is assumed. In order to minimize the consumer risk to 0.1% (hence 1 out of 1000 products on the market are wrong) the Monte Carlo simulation (Figure 6 a) shows that the acceptance interval has to be set from 980 lm to 1020 lm resulting in a producer risk of 53%: Hence, more than half of the products are rejected; resulting in high cost. If the measurement capabilities are improved, resulting in smaller uncertainties these costs can be reduced. Suppose that the measurement uncertainty is reduced to 3% (Figure 6 b). In this case the acceptance interval can be increased (965 lm to 1035 lm) in order to keep the consumer risk constant at 0.1% resulting in a much lower producer risk of 15%. Hence reducing the measurement uncertainty reduces the wrongly decided rejects. The investment into more accurate measurement equipment, more characterization work including the evaluation of measurement uncertainty and more careful measurements may, on a longer term, reduce the overall costs of production and quality control.

International LED Measurement Standard CIE S025

The International Commission on Illumination CIE published the first internationally agreed measurement standard for LEDs: CIE S025 [4] in March 2015. It provides requirements to perform reproducible photometric and colorimetric measurements on LED lamps, LED modules, and LED luminaires (LED devices) for operation with AC or DC supply voltages. It also provides advice for reporting the data. The standard was developed by the technical committee CIE TC2-71 in close collaboration with the European Standardization Committee CEN TC169 WG 7 (photometry). On the European level, EN 13032-4 [5] is technically equivalent to CIE S025.

The standard aims, in particular, to cover measurement methods for testing the compliance of LED devices with the photometric and colorimetric requirements of LED performance standards recently published by IEC [7, 8, 9]. Particular attention is given to the evaluation of measurement uncertainty. The measurement of photometric, colorimetric and electrical quantities of an LED usually depends on many parameters, and an exact evaluation of measurement uncertainty is demanding and time-consuming. It is recognized that many different categories of laboratories use this

Figure 6:
Risk assessment of the production of a 1000 lumen - lamp



standard, including manufacturers, public testing laboratories, R&D laboratories and National Metrology Institutes. These laboratories have a wide range of levels of expertise in testing and in the determination of uncertainties. In addition, a wide range of sophistication and accuracy of equipment and quality of laboratory environment are used. The purpose of this standard is that, by following this test method, it is expected that reasonable uncertainties of measurements, as needed for various regulations and applications, may be achieved by most of the laboratories. However, this test method cannot cover all the details of measurement instruments and possible mistakes that less experienced laboratories can make.

The standard lists a large number of possible contributions to the overall uncertainty.

Common to all measurements are

- Temperature setting and uncertainty on temperature measurement
- Electrical settings and uncertainty on electrical measurements (power supply, electrical measuring instruments)
- Fluctuation of light output of the DUT
- Calibration standard (calibration, ageing, calibration process, etc)
- Linearity of measuring instruments
- Reproducibility and repeatability (if applicable, default values for the equipment and generic type dependent figures may be used if this is not evaluated for the specific DUT)

In addition, contributions in specific cases are given (i.e. flatness of mirrors in goniophotometers, spatial non-uniformity of sphere responsivity in sphere photometers, or stray light of the spectroradiometer).

In the annex of the standard, different examples for measurement uncertainty evaluation are given. CIE Division 2 is preparing a new technical note [6] to give further guidance on the subject of measurement uncertainty.

Standard Test Conditions for LED Measurements

CIE S025 requires that measurements of the photometric, colorimetric and electrical characteristics of a LED device shall be performed by means of appropriate equipment and procedures under defined standard test conditions for operation of the device under test (DUT). CIE S025 uses the concept of conformity assessment introduced above:
A standard test condition includes a set value and a tolerance interval.
In addition, acceptance limits are defined for all parameters based on the measurement uncertainty.

As a general concept, the value and its expanded uncertainty (k = 2, 95% confidence interval) have to lie within the tolerance interval.
This corresponds to shifting the risk to the producers.

An example: The set value of the rated supply current of the DUT (LED modules with DC current input) is 300 mA. The standard defines a tolerance interval of ±0,2% for DC current (i.e. 0.6 mA). If the measurement of this current has an uncertainty of 0.2 mA the supply current measurement must be in the acceptance interval (300.0 ± 0.4) mA.

In some cases the defined tolerance interval seems not to be in agreement with other international standards. CIE S025 defines a tolerance interval for ambient temperature as ±1.2°C. In IEC standard typically a tolerance of ±1°C is required. However CIE requires that the measurement uncertainty of the measurement shall be considered. In practice it is well possible to perform measurements of ambient temperature with an uncertainty of 0.2°C. In this case the acceptance interval of the ambient temperature measurement is ± 1°C. If the ambient measurement has a larger uncertainty (i.e. 0.5°C) the acceptance interval will be reduced to ± 0.7°C. Measurement uncertainties are not directly addressed within the IEC performance standards.

Figure 6 shows the risk assessment of the production of a 1000 lumen lamp. The specification limits are shown on the horizontal axis, the acceptance limits on the vertical axis. The producer risk is given by the relative number of points within the red boxes. The consumer risk relates to the relative number of points within the blue boxes. Reducing the measurement uncertainty while keeping the same consumer risk (Figure b) in respect to figure a allows for increasing the acceptance interval and hence reducing the production losses.

Conclusion

Conformity assessment is a key element in product testing and industrial quality control. In the presence of a measurement uncertainty, the application of statistical methods result in the quantification of potential risks for consumer and producer. In order to be able to perform quantitative risk calculations it is necessary to evaluate the uncertainty of the measurement process. In the field of LED photometry the new international measurement standard CIE S025 gives clear guidance on the evaluation of measurement uncertainty. ■

References:
[1] ISO/IEC Guide 98-4: 2012 - Uncertainty of measurement - Part 4: Role of measurement uncertainty in conformity assessment, also JCGM 106:2012
[2] ISO/IEC Guide 98-3:2008 - Uncertainty of measurement - Part 3: Guide to the expression of uncertainty in measurement (GUM:1995), also JCGM 100:2008
[3] CIE 198:2011 - Determination of Measurement Uncertainties in Photometry and its supplements
[4] CIE S 025/E:2015 - Test Method for LED Lamps, LED Luminaires and LED Modules
[5] EN 13032-4:2015 - Light and lighting - Measurement and presentation of photometric data of lamps and luminaires - Part 4: LED lamps, modules and luminaires (in press)
[6] Technical note on the evaluation of measurement uncertainty for LED testing, (in preparation by CIE TC 2-71)
[7] IEC 62717 ed1.0 (2014) - LED Modules for General Lighting - Performance requirements
[8] IEC 62722-1 ed1.0 (2014) - Luminaire performance - Part 1: General requirements
[9] IEC 62722-2-1 ed1.0 (2014) - Luminaire performance - Part 2-1: Particular requirements for LED luminaires

Chip Arrays in SMD Packages - A New Class of LEDs

Several companies have recently launched products that can commonly be referred as a new class of LEDs - Chip Arrays in SMD packages. These high-power LED packages can deliver between 300 and 1500 lm and are providing serious competition for Chip-on-Board arrays in this flux category. Ralph Bertram, System Expert at Osram Opto Semiconductors gives an overview of the benefits and drawbacks of these packages in LED retrofit lamps as well as in different types of luminaires. Case studies illustrate the huge benefits that CAS can generate when used in spotlights and in omnidirectional light sources. It also addresses lifetime and reliability concerns and shows how the right choice of products and good thermal design can satisfy even high demands.

The recently launched Chip Arrays in SMD packages (CAS) combine the high efficacy and light output of CoB LEDs with cost-effective and reliable assembly using Pick&Place electronics. The PCB (Printed Circuit Board) is no longer part of the CoB but part of the luminaire again, so there is greater freedom of design for manufacturers. This opens up additional possibilities for including features such as thermal fuses, connectors or even driver components directly on the LED board. Thanks to these interesting features, high-power LED packages are providing serious competition for Chip-on-Board arrays in this flux category.

All Chip Array LEDs in SMD packages available on the market feature a luminous flux of more than 300 lm - but some can even deliver in excess of 1200 lm. Because of these high flux levels, retrofits with equivalent wattages of 25 to 75 W are feasible with only one LED package. Leading lighting manufacturers have tailored their products exactly to the lumen packages needed for directional and omnidirectional retrofits, ensuring sufficient efficacy to reach EU Energy class A+. Common package form factors include dimensions of 5 x 5 mm, 7 x 7 mm and even 9.5 x 9.5 mm. As in the case of Chip-on-Board LEDs, the light of CAS LEDs is generated by an array of volume-emitting ("Sapphire") LED chips. However, the CAS chips are mounted on a highly reflective leadframe material or even on a ceramic substrate. All of these chips emit blue light and are embedded in a phosphor-filled silicone material that generates white light. Therefore, simply by exchanging the reflective PCB material with a leadframe, manufacturers can ensure easy SMD assembly without compromising the efficacy or other positive properties of CoB LEDs. Table 1 compares lumen packages, system costs and other characteristics of different types of LED.

Table 1: Comparison of different LEDs with regard to lumen packages, efficacy, system costs and reliability

	CoB	CAS leadframe-based package	CAS ceramic package	3030 leadframe-based package	Ceramic HP-LED
lm/package	300-10,000 lm	300-1200 lm	~400-1600 lm	~110 lm	100-1200 lm
Efficacy	++	+	+	+	++
Features	Easy manual assembly	Cost-efficient, SMT assembly	High-temperature operation possible	Cost-efficient, but multi-spot appearance	Greatest robustness
System costs	Relatively high LED costs for a small lumen package	Savings through LED price, system and assembly costs	Savings through system and assembly costs	Commodity product with lowest price	Higher LED costs
Reliability	Basic	Basic	Good	Basic	Excellent

Many Benefits, Several Challenging Drawbacks

The first generation of CAS LEDs was designed for use in retrofits, especially for directional MR and PAR lamps. Therefore, the lumen packages of these first products were optimally adjusted to replace halogen lamps with 20 to 50 W. Accordingly, they were used as single light sources without providing multiple spots or multiple shadows. Consequently, they satisfied the wishes of many customers who wanted to achieve the same look and feel with the new LEDs as with the halogen lamps they had been using before.
Until then, this had only been possible with CoB LEDs. They need hand-soldering or you manually have to insert the parts into holders. Meanwhile, the first manufacturers realized that this package type could also be used for higher wattages, enabling only one LED to be incorporated in omnidirectional retrofits. In this application, the other benefits of CAS LEDs come into play. Thanks to their SMD packages, automated assembly is possible and the use of connectors or even driver components on the LED PCB can pave the way for full automation of retrofit production. These characteristics of retrofits also can be applied to luminaires. With cost-efficient Chip Array SMD LEDs, a large variety of luminaires, including downlights, tracklights and spotlights, can be produced without compromising appearance.

Figure 1: The new Duris S 10 from is an example of a CAS LED

Despite all these benefits, there are also a few things that have to be considered when designing with CAS LEDs. Owing to their higher luminous flux, the thermal load that impacts on a CAS package is in the range of several watts. We should therefore take a close look at the thermal properties of these products: Most CAS LEDs are leadframe-based, so the LED chips are placed directly on the copper-based leadframe. The thermal resistance of the package itself (from junction to solder point) is excellent and even better than that of CoB products (e.g. 1.2 K/W for a 10 W device). However, unlike in CoB products the heat is not yet in the metal core of the PCB, it still has to cross the dielectric. Therefore, the additional thermal resistance of the dielectric has to be included.
Of course, this depends on the material used for the PCB. For an average-performance PCB the value is around 1.3 K/W, making the total thermal resistance slightly higher than that of a CoB. By using proper PCB design there should be no need for additional electrical isolation against the heat sink.
In this case, the PCB should easily withstand several thousand volts as required during certification testing according to IEC 61347 or UL 1310. For the 10 W device mentioned above, our thermal simulations have shown a rise in the typical junction temperature against a heat sink of 29 K, compared to 21 K for a CoB (Figure 2).

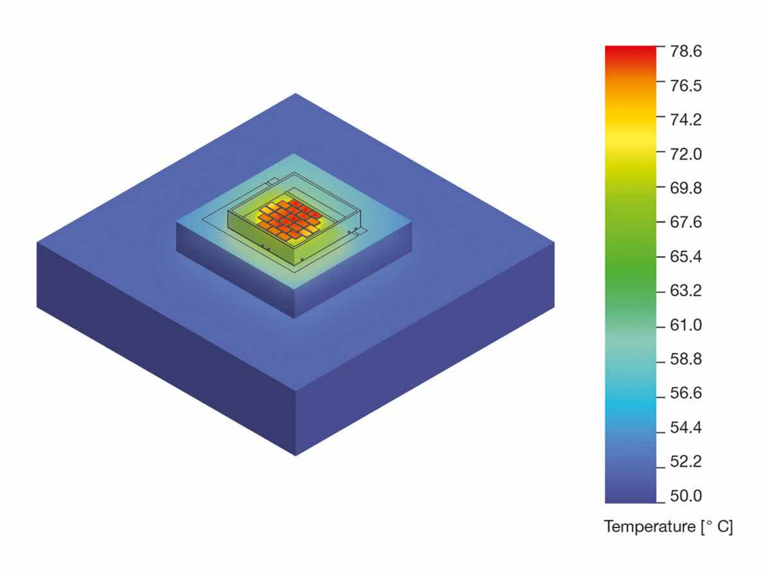


Figure 2: Thermal simulation for a Duris S10 CAS device on a hot plate

With regard to the optics and color of CAS LEDs, a few interesting aspects have come to light.
Like CoB LEDs, Chip Array SMD packages of the first generation featured a circular light-emitting surface (LES) so there was little concern in terms of optics design. For a 5050 device the typical diameter is 4.6 mm, emitting 300 to 500 lm. However, since the packages are square by nature it was discovered that efficacy can be significantly increased if the light-emitting surface is also square. This results in an increase in the effective diameter up to 5.7 mm. This is usually not very significant but it does have an impact on optics design. Compared to CoB LEDs in the same power class, the diameter of the CAS LES is still small (6 to 10 mm).

Another important aspect to consider is color consistency: Since the CAS will probably function as the only light source in an end product; color binning has to be carried out carefully to avoid unpleasant color variations from lamp to lamp when mounted in the same installation. Unfortunately, because of the production processes involved, no manufacturer can yet achieve a distribution below 3 MacAdam steps, as is standard in CoBs. A proper assessment should be conducted to see whether a larger color variation can be accepted in a project or tighter bins need to be purchased at extra price.

Figure 3:
LM-80 data (lifetime) of the first generation of the Osram Duris S8. Tests with the second generation with improved design are currently ongoing

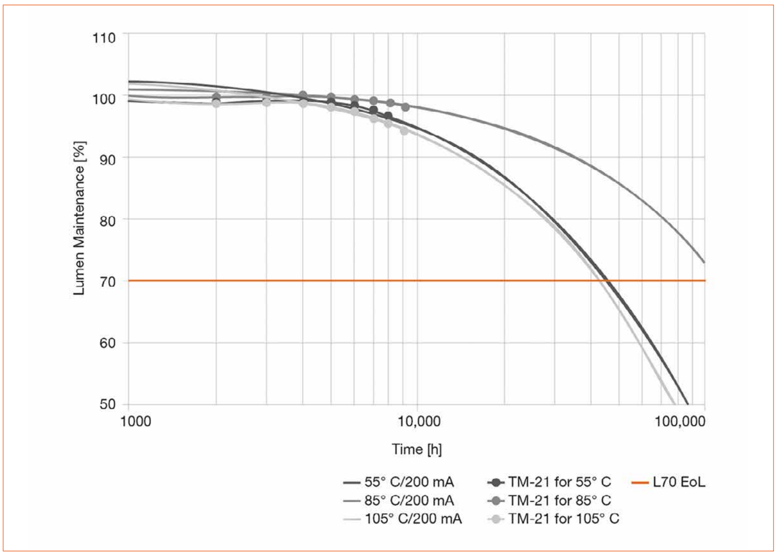
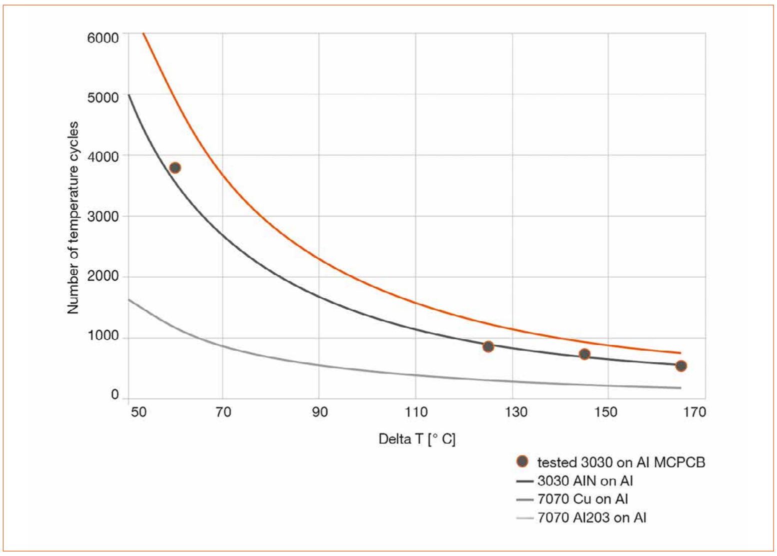


Figure 4:
First solder joint failures detectable by a sudden increase in forward voltage. The number of temperature cycles is dependent on the difference in temperature



One of the main concerns with the new package class is robustness. Is it good enough for the intended applications? Since most of the designs available on the market contain the soft metal silver in their leadframe material and plastics as their housing material, these concerns have to be taken seriously. Below we take a look at the different materials in the CAS package.

Chips and phosphor

The volume-emitting chips as well as the phosphor-filled silicone resins that are responsible for light conversion are the same as used in other LED types. So no reduced - or improved - performance is to be expected here.

Leadframe

The leadframe is both the supporting mechanical structure and the thermal and electrical contact to the board. As in CoBs, the leadframe of CAS LEDs also serves as a mirror to help emit the light from the package.
It therefore needs to have excellent reflectivity properties and it should typically be silver-coated. So the presence of corrosive (especially sulfuric) gases leads to accelerated aging that reduces the brightness of the chips. If CoBs or CAS LEDs are used in harsh environments proper shielding against such substances is recommended.

Housing material

Most of the concerns with mid-power LEDs and with Chip Array SMD LEDs relate to the aging of plastic materials at high temperatures and intense light levels. Indeed, the early polyphthalamide (PPA) packages were mostly limited by this effect. Nevertheless, a proper design will limit the exposure of the package material to blue light. Even this material can exhibit long lifetimes as recently demonstrated in a tunnel project in Shanghai [1]. Since in large packages the plastic surface exposed to light can be minimized in relation to the mirror or leadframe surface, package aging can be reduced to a minimum. If the latest generation of epoxy-based material is used, the packages can exhibit LM-80-lifetimes that are sufficient for most applications (Figure 3).

Choosing the Right CAS Design for an Application

As mentioned above, customers can choose between leadframe-based and ceramics-based CAS LEDs. By using ceramics, the thermal resistance of the package will be greater than with a copper leadframe. However, because of the inherently better robustness of this package type higher driving temperatures are also possible - at the expense of some efficacy. A decision should therefore be taken case by case based on system comparisons as to which material is the best for achieving the values of efficacy, costs and lifetime intended for the product.

In consumer retrofit applications lighting solutions such as lamps or luminaires need to withstand several on-off cycles per day. This is why temperature cycle stability is critical in these applications. As the difference in thermal expansion between the copper leadframe and the aluminum core of the board is minimal, it is advisable to use leadframe-based CAS LEDs for applications in which frequent and/or high temperature cycles are expected. The strain on the solder joints is greater as the device gets larger. Figure 4 shows how many cycles have to take place until detectable failures in solder joints occur, as a function of the difference in temperature. In this graph there are data points for a 3030 aluminum nitride ceramic package as well as calculations according to the Coffin-Manson model for a 30-minute temperature cycle.

Practical Test: CAS LEDs Used in Lighting Solutions

Both omnidirectional and directional retrofits can benefit from the use of Chip Array SMD LEDs.

In A-lamps and candelabra-type lamps, CAS LEDs can replace a number of smaller mid-power LEDs at a comparable price. This enables the use of “virtual-filament” optics in a larger range of power classes than at present.

In MR 16-type retrofits, CAS LEDs offer a cost-effective solution for single-source halogen look-alike lamps, removing the infamous “multi-shadow” effect. However, the design of the optics here is challenging. According to the basic rules of optics, the size of a lens on a larger source has to be proportionally greater than for a smaller source. As you only need one instead of three or four lenses, the diameter of the optics can be comparable (Figure 5). On the other hand, the lens is higher, requiring an additional amount of precious space inside the MR 16 shape.

Overall, the number of chips in a CAS is similar to existing designs, so the forward voltage and power requirements are compatible with existing drivers. Quite a variety of CAS LEDs is available in different power classes so all typical retrofit lumen packages can be easily achieved. But there is an additional factor often overlooked in retrofit designs. When it comes to mass production, the assembly costs are a significant part of the total product costs. So automated assembly should be used wherever possible. Today, more and more retrofits are designed with SMD connectors on the LED board that add little to the bill of materials, but result in considerable savings and additional reliability on the assembly side. This is the main reason why it is highly likely that SMD components will ultimately prevail over semi-automated assembly of CoB LEDs in all high-volume applications.

CAS LEDs in Professional Downlights

Professional (6-inch to 8-inch) downlights used in office buildings and shops are often based on Chip-on-board LEDs because a single light source in the center of the luminaire offers a certain degree of lighting

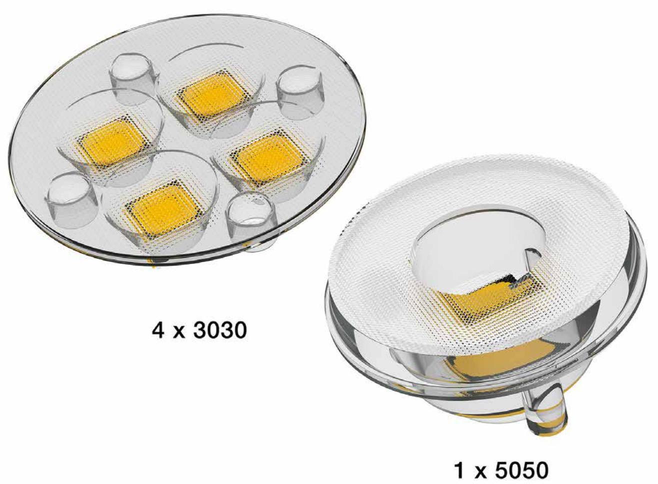


Figure 5: **One CAS LED can replace three or four smaller LEDs in an MR16 lamp**

control. And it provides the look and feel of a halogen or HID bulb that has been missing in compact-fluorescent-based downlights over the last few decades.

However, the brightness levels of 2000 to 3000 lm are still too high to be achieved by a single CAS LED. So how can system costs be reduced here? The answer is a cluster of CAS LEDs. The size of a 2 x 2 array of 7070 LEDs is still smaller than a CoB with an LES of 22 mm (diameter).
After adoption of the PCB layout the CoB previously used can simply be replaced without any other changes to fixture design. This leads to even more light output or greater efficacy compared to CoBs.
Similar designs can be produced with 5050 CAS LEDs or CoBs with an LES of 14.5 mm. The space between the single LEDs is so small that there is virtually no difference to a "real" CoB.

However, real advantages can be achieved when the PCB is used for more than just providing a thermal interface. For example thermal fuses or even parts of the driver or the control electronics can be included on the LED pcb. Mounting holes can be placed where the manufacturer needs them and not where the CoB manufacturer placed them. Affordable poke-in connectors are also available that can be assembled directly together with the LEDs so there is no further need for manual soldering or fiddly holders.

Conclusion

A detailed study shows that CAS LEDs have a few drawbacks that need to be taken into consideration, such as the additional thermal resistance, depending on the material used for the pcb, or color binning that has to be carried out carefully to avoid unpleasant color variations from lamp to lamp. However, there are more benefits of this new type of LEDs, notably the smaller LES and the considerable cost advantage compared to CoBs. But the main reason for using CAS LEDs is probably the easier assembly that will ultimately prevail over semi-automated assembly of CoB LEDs in all high-volume applications. Until then, manufacturers have to know the trade-offs in thermal performance, lifetime and color consistency and can easily choose the type of LED that is perfect for their lighting application. ■

References:
[1] Alexander Wilm, Osram Opto Semiconductors, "LED Tunnel Lamp - A Reality Check: 50,000 Hours Field Data and Lifetime", LED professional Symposium 2015, Bregenz

Mastering Thermal Issues in LED PCB Design & Laminate Selection

LED applications are not the only applications that are driving the need for thermal issues to be considered and mastered in PCB design, but they are certainly amongst the most challenging. Designing LED PCBs requires many considerations and key are those that arise from multiple heat sources in close proximity. Martin Cotton, Director OEM Technology of Ventec Europe describes the process and criteria used when designing PCBs (Printed Circuit Boards) for use in LED applications using thermally conductive IMS (Insulated Metal Substrates). He goes into technical detail with charts and diagrams that explain everything the designer would need to consider when selecting a laminate and commencing a design.

A PCB design for LED lighting products belongs to the most challenging tasks, a proper process and criteria is very helpful when designing PCBs (Printed Circuit Boards) for use in these applications using thermally conductive IMS (Insulated Metal Substrates). Therefore, the requirements for thermal management and the various issues that form the development of design rules and build structure for the Printed Circuit Board will be outlined in the article. Furthermore, the manufacturers specification and those provided by the laminate vendor are considered to create workable design rules that include coin cavity and adjacency dimensions.
It looks at options for thermally conductive laminates; glass reinforced thermally conductive prepregs, thermally conductive dielectrics and IMS (Insulated Metal Substrates) materials.

A focus is on the make-up of these IMS in the form of copper-laminate-aluminum or copper-laminate-copper, considering the various characteristics, benefits and the thermal conductivity and impedance of each option.

Introduction

Various methods have been considered, tested and used in the dissipation of heat from the PCB and from the devices on the PCB. The most obvious and perhaps the traditional solution is the heatsink - a piece of metal with a large surface area provide space for the heat to flow into the air having been swiftly and efficiently removed by conduction from the device or heat source. As well as device mounted heatsinks, PCB mounted heatsinks are often used to connect the heat source to as large an area of conductive material as possible, often covering the entire unoccupied surface area of the PCB.

Figure 1:
The images below show the thermal impact of LEDs and of other devices such as processors

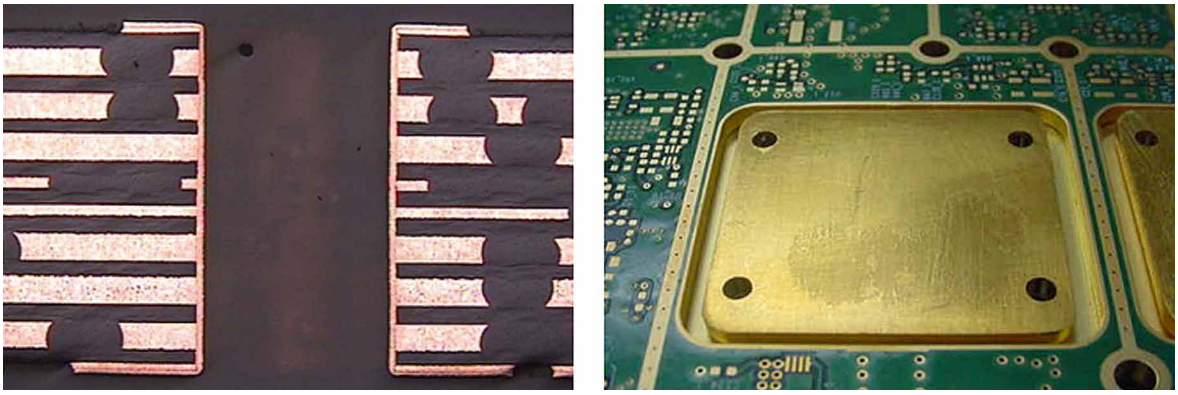


Figure 2:
Various methods are used during the PCB fabrication process to provide heat dissipation via areas of copper called coins

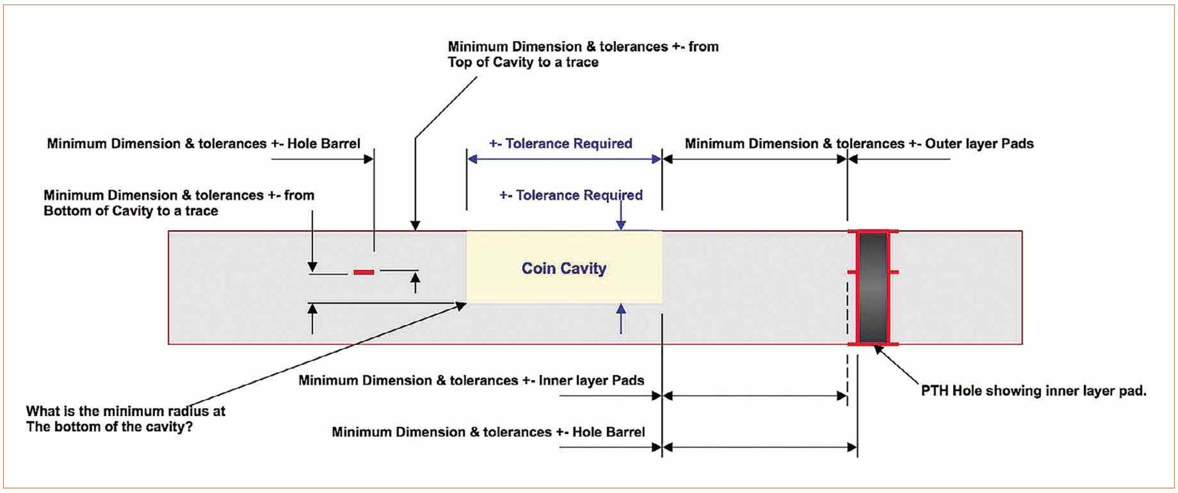


Figure 3:
Coin dimensions & tolerances

More recently, laminate technology has come to the fore and the use of in-PCB heatsinks, such as coins, has become more prominent with large areas of copper being used as "heatdumps" to deposit and dissipate thermal energy. These are sometimes within a space milled into the PCB surface, but can even be on inner layers and sometimes on multiple layers connected by through-hole plating. In simple terms a coin is a thermal heatsink within a PCB.

It is tempting to take a very industrial approach to heatsinking, placing a heatsink as large as you can fit on the offending device. This is a somewhat unscientific approach and may result in shifting the problem elsewhere as well as being more costly than the designed and calculated solution.

Designing with Coins

The coin cavity cross section design is critical and minimum clearance as well as maximum and minimum tolerances are generically required. As can be seen in figure 3, the size of the coins is critical along with its proximity to other PCB features such as through-holes and inner layer traces and other components on the PCB. These dimensions will differ when the board is conventional PTH (Plated Through-Hole) as compared to boards that use micro-via technology.

For this reason early consideration of the heat dissipation requirements are essential. Creating design rules that apply to the coin cavity should be done at the same stage as the specification of the laminate and the other design rules around layer count, track and space, etc.

Design rules are required and start with what a designer wishes to produce. They are conjoint feedback from manufacturing and design on what minimum or maximum dimensions apply, plus the tolerances associated with those manufacturing processes. The designer will be pulling together data from a broad team of participants starting with the hardware designer who should provide detail on the devices used and their thermal characteristics. This data, combined with that from the PCB manufacturer and the laminate supplier, will ensure the correct choice of materials is made and the process tolerances are applied along with the dimensional demands from the thermal requirements and challenges. These dimensions and tolerances are then applied to any drawings required by manufacturing to produce the product and shared and approved by the various stakeholders to ensure all parties have an input into the most desirable, effective and economic choice of heat dissipation, laminate selection and fabrication methodology.

Design rules are created not only for what we are currently able to produce, but also to push the boundaries of what we might need to build in the future. This drives the technology roadmaps of the parties involved, largely the fabricator and laminate manufacturer.

Table 1:
A typical set of coin design rules and associate dimensions

Description	Requirement / mm
Coin depression/Protrusion (Top layer)	+/- 50 um**
Gap on top side, Maximum	80 um
Gap on top side, Maximum	80 um
Boundary between coin and laminate	80 um
Coin edge to hole wall	.2 mm****
Coin edge to hole wall	.2 mm****
Cavity edge to hole wall	1 mm***
Coin top thickness	.35 mm min
Coin base thickness	.45 mm min
Boundary between coin and laminate	80 um
Gap on bottom side, Maximum	80 um
Gap on bottom side, Maximum	80 um
Dielectric thickness, Minimum	20-100 um^
Min Cu around Coin on Outer layers	.8 mm
Coin protrusion (bottom)	+/- 50 um**
Circuitry to coin distance - Inner layer (non-critical)	.8 mm
Hole wall-Hole wall spacing	.25 mm
Coin base width	hole drill dia + E + F
Thermal/Ground hole size	> .5 mm
Assembly hole size	min .5 mm
Hole wall to coin distance	.2 mm****
Circuitry to Coin Distance, Outer Layers	.8 mm
Coin size	8-20 mm***
Coin size	8-20 mm***
Internal Plane Layer to Coin Distance (minimum)	.8 mm
Maximum Board Layers	20****
Construction Restrictions	core of same thickness

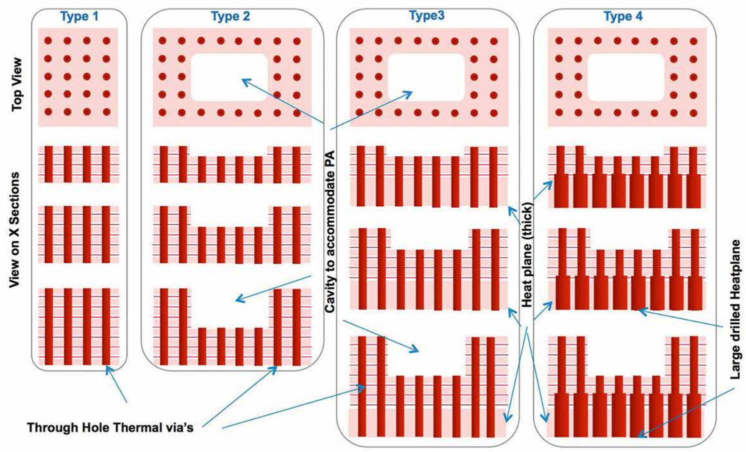


Figure 4:
Heatsinks could become connector routes as well as thermal coins

Development programs come out from these "design" requirements, and they should. As laminate producers we want to make products that meet and surpass current and future demand. We should avoiding developing technology because we can, and focus on developing what we, our customers, and our customers' customers need.

Consideration needs to be given to the laminate thickness when specifying the minimum distance between coins. Coins can be of varying thicknesses and can also be on the same or the opposite sides of the PCB. These all have different thermal impacts as well as dielectric considerations, while some strategies may impact on potential delamination. The PCB is a three dimensional component and the impact in the X, Y & Z axis needs to be considered in detail.

Each coin cannot be treated in isolation. They all impact upon each other and proximity is critical, as is the differing heat load of each coin. High load coins will need to be separated from each other, sometimes by laminate and other times by low load coins.

Replacing Coins with "Local" Heatsinks Using IMS Materials

Thermally Conductive IMS PCBs offer various solutions, with various component parts. These include:

- Thermally conductive laminates
- Glass reinforced (VT-4Ax) thermally conductive prepregs, unsupported (VT-4Bx) thermally conductive dielectrics
- Insulated metal substrate (IMS) materials

As an alternative or replacement to coins, this provides the ability to manufacture or fabricate local heatsinks on the PCB.

Coining and local heatsinks are very specific solutions, aimed at prime components and focused at a component level. IMS is broader and is less focused, but perhaps needs a better and more detailed design strategy, particularly if you want to move it away from a specific PCB by PCB solution or technology level to a more generic solution. Certainly the LED industry is asking a lot of questions and making great demands for better thermal management. The PCB fabrication industry and the laminate producers need to work in concert with the PCB and hardware design community to ensure they specify and create the best solutions.

As part of the design process it is essential to create a test process that considers all the elements in creating a workable solution. It is easy to study the data sheets and compare materials that way,

Figure 5: Examples of data sheets

but each project needs to be carefully considered, as many factors impact upon the final selection of material.

Many experienced designers and engineers will say that whilst the data sheet is the ideal starting point, it does not provide the whole answer. This is not because vendors set out to produce misleading data, it is because data sheets are based on tests performed by the vendor in a certain environment and in certain circumstances that will inevitably be different from your derived data.

Studying the data sheets requires the consideration of many elements, not least the material build.
Also important to consider are the thermal conductivity of the various materials as well as the thickness of the copper, the dielectric and the aluminum and aluminum alloy.

Reaching out and building a close relationship with the technical team at the laminate vendor will be very valuable at this point. They should be able to walk you through the selection criteria for their materials. Some vendors will have elements of design expertise within their team, but some may not. Working with a vendor with a sound understanding of the design principals is very important if you are to use the right material rather than one which will work because it is vastly over-specified for the task at hand and hence too expensive.

When doing the thermal calculation it is also essential to consider the thermal configuration and not just the resistance or conductivity, but also the thermal impedance, which many consider a more consistent and accurate measurement.

One influencing factor is environmental. Where will the PCB operate? Will it be potted? Will the flow of air around it change in different applications and will it deteriorate over time? A key factor in selection is reliability, but just building in the maximum reliability and maximum heat dissipation is an expensive and lazy solution, which will doubtless be costly.

Another environmental factor is the surrounding product and the impact that it has on thermal management. If the product dissipates heat in a way that negatively impacts on other products, that will automatically create and problem. Conversely other products or devices in close proximity will impact the thermal performance of the design.

Also important in material selection are mechanical properties and mechanical stresses that the product may be under in the field.

Manufacturing processes have to be considered and the fabricator and assembler will each have their input into the best solution. In this process you will also need to consider compliance to agency or customer approvals.

Conclusion

At the end of the day the solution needs to suit the product and be cost effective, not belt and braces because we don't understand the parameters at play. Short cuts will result in one of two outcomes:
A product that isn't fit for purpose; or a product that is so over-engineered that it fails to be a cost effective solution.

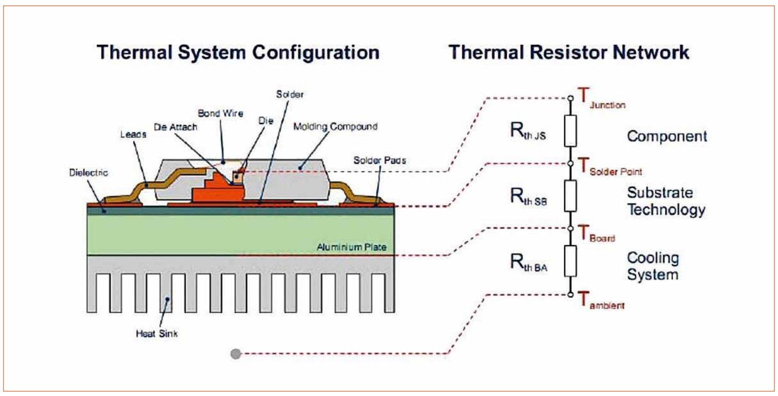


Figure 6: Thermal system configuration

Shine Bright at the
World's Premier Lighting Fair

The 17th edition of **HKTDC Hong Kong International Lighting Fair (Autumn Edition)** will be staged from 27-30 Oct 2015 at the Hong Kong Convention and Exhibition Centre (HKCEC). This must-attend event for the industry serves as an international marketplace for high-quality lighting products, solutions and services. Last year, the fair attracted some 2500 exhibitors from 37 countries and regions and over 37,000 buyers from 135 countries and regions.

LED & Green Lighting In Demand

In light of environmental concerns, energy-efficient and long lasting products continue to see strong demand.

For instance, markets such as the US, the European Union and the Chinese Mainland have either banned or plan to ban incandescent light-bulbs, raising the demand for 'green' lighting products. The fair's **LED & Green Lighting Zone** showcases eco-friendly lighting for commercial, residential, advertising and other outdoor applications.

Specialty Zones in Spotlight

Hall of Aurora provides an elegant space for branded collections of high quality lighting fixtures. With an increasingly affluent and sophisticated consumer base in emerging markets, such products are seeing growing demand. Leading brands taking part in the zone include BJB, Citizen, EGLO, Ford, Fulham, Fumagalli, Neo-Neon, Philips, Seoul Semiconductor, Viribright and many more.

Smart Lighting & Solutions Zone will be offering state-of-the-art technology for smart homes, offices and commercial premises. Other zones highlights include **Advertising Lighting Zone**, **Household Lighting and Avenue of Inspiration**. Related product zones are grouped together in the fairground to facilitate buyers to find first-choice exhibitors easily and efficiently.

Also, **My Favourite Lighting Products 2015** will return this year promoting innovative and creative lighting product designs. Award winning entries will be showcased throughout the fair period.

New Launching "World of Outdoor Lighting & Lighting Accessories" at AsiaWorld-Expo

This year, the outdoor lighting, lighting accessories and parts and components product zone will relocate from the HKCEC to the AsiaWorld-Expo, creating the World of Outdoor Lighting & Lighting Accessories. The brand new event will run concurrently with the HKTDC Hong Kong International Building and Hardware Fair and the Eco Expo Asia, to attract more exhibitors and create cross-sector collaboration opportunities.

HKTDC Hong Kong International Lighting Fair (Autumn Edition) 2015
Date: 27-30 Oct 2015 (Tue-Fri)
Venue: Hong Kong Convention & Exhibition Centre
Exhibit Categories: Commercial Lighting, Green Lighting, Household Lighting, LED Lighting, Advertising Lighting, Smart Lighting & Lighting Solutions, Testing, Certification & Inspection, Trade Services & Publications, etc.

World of Outdoor Lighting & Lighting Accessories 2015
Date: 28-31 Oct 2015 (Wed-Sat)
Venue: Hall 8, AsiaWorld-Expo, Hong Kong
Exhibit Categories: Outdoor Lighting, Lighting Accessories, Parts & Components specifically and exclusively for commercial/industrial use

Eco Expo Asia 2015 – International Trade Fair on Environmental Protection
Date: 28-31 Oct 2015 (Wed-Sat)
Venue: Halls 3 & 6, AsiaWorld-Expo, Hong Kong

Hong Kong International Building and Hardware Fair 2015
Date: 28-31 Oct 2015 (Wed-Sat)
Venue: Halls 6 & 8, AsiaWorld-Expo, Hong Kong

Concurrent Fairs Website: **Eco Expo Asia** www.ecoexpoasia.com/ex/20
International Building and Hardware Fair www.hktdc.com/ex/hkbdh/45
World of Outdoor Lighting & Lighting Accessories www.hktdc.com/ex/woolla/20

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ZHAGA SPECIAL: NEW BOOKS 2015 - TECHNICAL PAPERS

Zhaga Evolves: Focus on Component Standardization Drives New Book Development

With new specifications covering COB LED arrays, LED drivers, and other LED modules and light engines, Zhaga is making rapid progress in standardizing these types of components in response to the needs of the market. Musa Unmehopa, Secretary General of the Zhaga Consortium, and Tim Whitaker, Director of Marketing Communications of the Zhaga Consortium, describe how Zhaga is evolving and changing its focus in a number of areas.

In the five years since its inception, the international Zhaga Consortium has made rapid progress towards its central goal of standardizing a broad range of LED modules, LED light engines and related components.

The Zhaga specifications, known as Books, remove arbitrary and unnecessary variations in various properties, such as physical dimensions, making it easier for luminaire makers to base their designs on interchangeable components that are available from multiple different suppliers.

Products based on several of the Zhaga Books are already in common use in the global lighting market. Form-factors standardized by Zhaga, such as linear Book 7 modules or circular Book 3 modules, can be found in the portfolios of many leading lighting-component suppliers around the world. Meanwhile, Zhaga continues to develop new specifications that reflect the needs of luminaire makers and other stakeholders.

Meeting the Needs of the Market

Zhaga is currently going through a period of evolution, reflecting the changing demands of the global lighting marketplace. One major change for Zhaga is the creation of separate specifications for LED modules and LED drivers (also referred to as electronic control gear). This approach will enable luminaire makers to use different combinations of LED modules and drivers, according to their own unique requirements. Of course, this also requires that the electrical interface between modules and drivers is defined correctly. One consequence of this work is the creation of a new specification, entitled Book 13, which focuses entirely on LED drivers.

Zhaga has also made rapid progress in defining a new specification that covers chip-on-board (COB) LED arrays, in response to requests from many key stakeholders in the industry. As discussed below, the forthcoming Zhaga Book 12 will include a family of different COB module sizes.

Other new Books are also being developed by Zhaga to meet the requirements of the lighting industry, including both circular and linear light sources. One new specification, Book 14, will describe linear modules with cap-holder systems that enable end-user replacement. Other proposals include both driver-integrated LED light engines, as well as LED modules with separate drivers.

Zhaga has also undergone an exercise to ensure that its specifications only cover the properties necessary to enable interchangeability, while at the same time, allowing unrestricted possibilities for other aspects of component design.

Separate Books for Modules and Drivers

As stated above, Zhaga is now writing separate Books for LED modules and LED drivers. Previously, all Zhaga Books defined a complete LED light engine (LLE). Zhaga defines an LLE as a combination of one or more LED modules and a suitable driver, where the driver can be either separate from the LED module(s), or integrated inside the LLE. For LLEs with an integrated driver, Zhaga Books will continue to define the complete LLE.

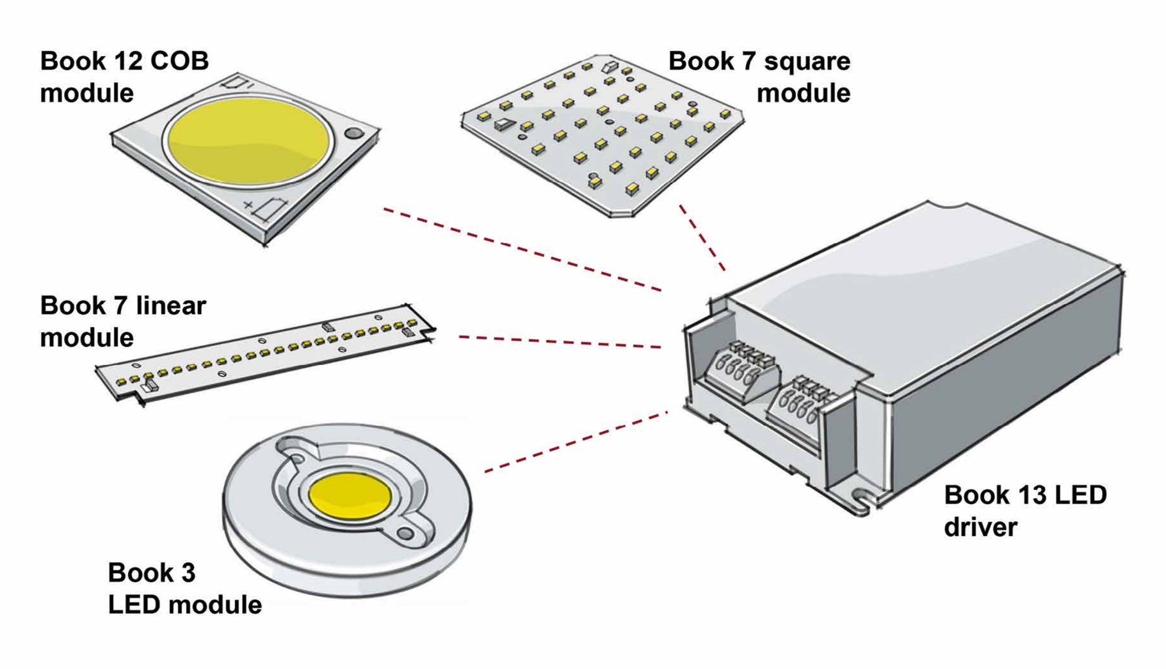


Figure 1:
For LED modules that are powered by a separate LED driver, Zhaga is writing individual Books for different LED module types. Meanwhile, a broad range of LED driver types are described in Book 13, some of which can be used in multiple applications to supply power to different LED module types

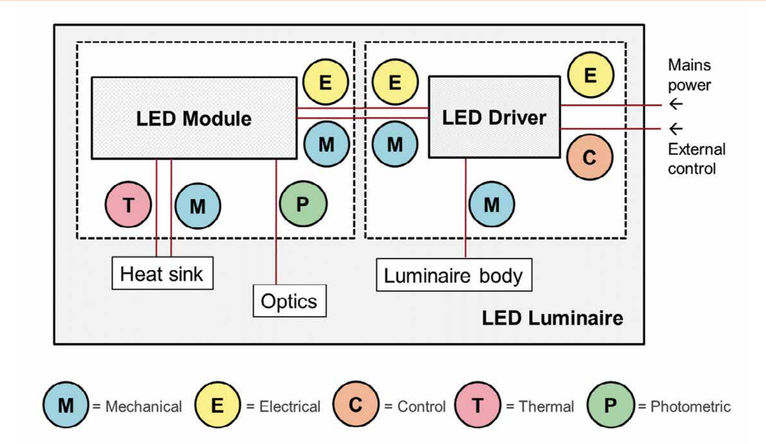


Figure 2:
This schematic diagram gives an example of some of the interfaces defined by Zhaga for an LED module with separate driver. The dashed boundary lines show which interfaces are included in the module and driver Books, respectively. In this example, the LED module Book defines the thermal and mechanical interfaces with the luminaire's heat sink, the photometric interface of the module with the luminaire's optics, and also the mechanical and electrical interfaces with the driver

However, for all LLEs where the driver and module(s) are separate, individual Books will be written that cover each different LED module type or family (Figure 1). The corresponding drivers will be described in a single new specification, Book 13. This change will be applied retrospectively to existing Books with separate modules and drivers.

Interfaces

The Zhaga Books are interface specifications, and each defines an LLE and/or associated components (including LED modules and drivers) by means of the mechanical, photometric, electrical, thermal, and control interfaces of the product to its environment. In many cases, the "environment" is an LED luminaire.

By specifying interfaces, this makes such LLEs or components interchangeable in the sense that it is easy to replace one LLE or component with another, even if they have been made by different manufacturers.

Previously, when Zhaga Books defined complete LLEs, all the specified interfaces were between the LLE and the luminaire. Now that separate Books are being written for LED modules and drivers, this changes the specific interfaces that are included in each Book. Figure 2 shows a schematic image of an LED luminaire containing a separate LED module and driver. The dashed boundary lines show which interfaces are included in either the module Book or the driver Book. Note that the scenario shown in figure 2 can vary from Book to Book.

Book 13 Defines LED Drivers

A typical LED driver can be used in multiple applications to supply power to different LED module types. The purpose of the Book 13 specification is to help luminaire makers and other stakeholders to compare the properties of different LED drivers. For example, a luminaire maker may wish to determine which drivers are compatible with different LED modules, and whether a driver will fit inside a given luminaire.

Two crucial aspects that determine if different drivers are interchangeable are the mechanical and electrical interfaces between the driver and module. The electrical interface is discussed in the next section of this article.

To enable the physical interchangeability of drivers in a luminaire, the mechanical dimensions must be clearly specified. To serve all applications, Zhaga Book 13 defines a range of driver form-factors. In addition to the maximum outer dimensions (demarcation) of the driver, each form-factor is characterized by both the position and number of mounting holes, and the position of the electrical wiring to the LED module and to the mains power source.

In total, across all form-factors, Book 13 includes 78 drivers with different dimensions. Two categories, designated Types A and B, have been developed by Zhaga. With a total of 27 different driver dimensions, Types A and B can serve nearly all applications, both for compact luminaires (Type A - 13 different size categories) and for areal lighting (Type B - 14 different sizes) over a very wide range of output powers. Zhaga recommends that the new form-factors in Types A and B should be adopted for new luminaire and driver designs.

However, the consortium also acknowledges that there are many existing driver products in the market, and these will require a long, gradual phase-out period. For this reason, a broad range of additional driver designations (types 1-8) are also included in Book 13.

Component Interchangeability and DMI

The new Book 13 is part of Zhaga's efforts to enable LED luminaire manufacturers to use different LED modules in their luminaires without having to use a different LED driver for each module, or vice versa. Zhaga refers to this as "independent (or component) interchangeability" of LED drivers and modules.

With separate specifications for LED modules and LED drivers, this also requires that the electrical interface between modules and drivers is defined correctly.

To avoid duplicated efforts in the industry, Zhaga decided not to write a new specification for this driver-module interface (DMI). Instead, Book 13 references a specification written by MD-SIG. This is an external industry association which is not part of Zhaga, but in which several Zhaga members participate.

The DMI comprises two separate parts; the information interface and the power interface. Further information on the DMI and MD-SIG can be found in the article beginning on page 106.

Zhaga Standardizes COB Arrays

COB arrays are already in widespread use throughout the LED lighting industry, but different manufacturers offer a wide range of alternative sizes. For luminaire makers and other stakeholders such as suppliers of optics and COB holders, this creates problems and limits their options to use alternative products from different suppliers without changing their luminaire or holder designs.

In consultation with many interested parties, Zhaga was asked to standardize properties such as the mechanical dimensions of the module, the position of electrodes, and the diameter of the light-emitting surface (LES). The results of Zhaga's work can be found in the first edition of Book 12, its specification describing LED modules that typically use COB technology.

The specification defines a family of six rectangular or square modules with a circular LES. The modules have the following dimensions: 12 x 15 mm, 16 x 19 mm, 19 x 19 mm, 20 x 24 mm, 24 x 24 mm, and 28 x 28 mm. Further details about Zhaga's efforts to standardize COB LED arrays are documented in the article beginning on page 96.

Choosing the Right Parameters

Another recent activity by Zhaga members was to undertake a comprehensive review of the parameters included in each of its specifications. The goal was to ensure that the full parameter set of each Book includes all the characteristics necessary to enable interchangeability of LLEs, drivers, modules and other components.

Parameter or Property Type	Not Specified by Zhaga	Restricted	Listed on Product Datasheet
Requirement for Zhaga Compliance	No requirement	Little or no variation is permitted	Value is not restricted. Value must be shown on product datasheet
Relevance to Interchangeability	Not relevant, or data available from other sources	Essential	Values required to enable comparison of products
Implications for Design Freedom	Full design freedom	Limited or no design freedom	Full design freedom
Implications for Zhaga Testing	Not tested	Fully tested to ensure compliance	Test lab compares measured values with manufacturer's datasheet. Some parameters not tested
Examples	Efficacy (lm/W), choice of materials	Screw-hole size and position; max. outer dimensions of LED module and corresponding demarcation area in luminaire	Luminous flux, maximum operating temperature

Table 1:
Comparison of parameter types for LED modules and their relationship with Zhaga specifications. Zhaga only restricts a small number of parameters, enabling maximum design freedom. The parameters that are required on datasheets allow meaningful comparison of products

The starting point was to create an exhaustive list of properties associated with the components described in each Zhaga Book. A number of luminaire makers and other stakeholders were asked to explain their requirements and preferences for each of the properties, in order to determine which properties should be included in each Book.

The characteristic properties of the LED light sources were assigned to one of three groups (Table 1). The first group includes properties that are not relevant to interchangeability, or are readily available elsewhere, and are therefore not included in the Zhaga specifications.

The second group of properties includes those that are considered essential to interchangeability, and are restricted by the Zhaga specifications, such that little or no variation is allowed. Many properties in this group relate to the mechanical fit.

The third group contains parameters where the value must be known in order for a customer to determine if one light source is interchangeable with another. However, Zhaga does not restrict the actual values of these properties. One example is luminous flux. Typically, for each Book, Zhaga will define a set of categories based on luminous flux ranges. A product can have any value of luminous flux, but the flux range must be stated on the datasheet. This enables a customer looking for closely-matched interchangeable products to select from alternatives that are in the same flux category.

Because Zhaga requires LLE manufacturers to provide a detailed set of parameters for each product, this allows luminaire makers to make meaningful comparisons and informed choices based on dependable data. However, it is important to note that many properties are not restricted by Zhaga. This promotes design freedom by only restricting those parameters that are essential to ensure interchangeability.

Certified Products

Products that have been tested by an independent testing lab, and are fully compliant with all the requirements of one of the Zhaga Books, are allowed to carry the Zhaga logo. This symbol conveys the assurance of interchangeability, but also means that the product is traceable through Zhaga's online Certified Products Database [1].

The database has been updated recently, and now has a very comprehensive search functionality. This allows potential purchasers to compare products, based not only on which Book the product belongs to, but also by looking at various key properties. For example, when selecting a Book 3 LED module, the user can not only choose the desired LES category, but can also compare luminous flux, color-rendering index, correlated color temperature and other properties.

New Books and Extended Families

Book 9

Zhaga extended its library of specifications in June 2015 with the publication of Book 9. Compared with earlier Books, which are aimed at professional lighting applications, Book 9 represents a shift towards the consumer sector. Book 9 LLEs comprise a non-socketable LED module with a ring-shaped light-emitting surface (LES) and a separate LED driver (Figure 3). The LED modules are small in size - the LES diameters are 12 mm or 25 mm - with simple construction and a low profile (4 mm height). The light output is typically in the order of several hundred to around one thousand lumens. These features mean that Book 9 LED light engines are highly suited for use in LED luminaires for consumer lighting applications, such as small spotlights, track lighting and other compact luminaires. However, Zhaga does not restrict the applications that can be addressed.

Books 3, 10 and 11

Zhaga is building on the success of Book 3, which defines 50-mm-diameter modules for spotlighting and related applications. The range of spotlight modules is being extended to both larger (75 mm diameter) and smaller (35 mm diameter) sizes, which are designated Book 10 and Book 11, respectively. Book 11 was published by Zhaga in July 2015. In fact, due to the similarities in these modules, Zhaga has already decided to merge these Books into a single specification.

Book 7

LED modules using the form-factors in Zhaga Book 7 are now a common sight in the market. Included in

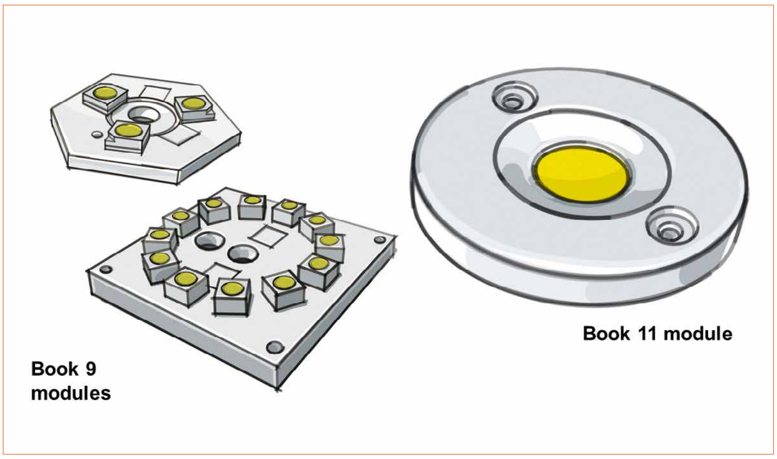


Figure 3: There are two categories of Book 9 modules (left). These have a ring-shaped light-emitting surface with a diameter of either 12 mm or 25 mm. Book 11 modules (right) have an overall diameter of 35 mm, compared with 50 mm for Book 3 modules

Book 7 is a scaled family of linear modules, with lengths of 280 or 560 mm and widths of 20, 40 or 60 mm. Recently, two additional square modules with sides of 380 and 560 mm have been added to Book 7. Such modules are suited for indoor lighting applications such as office lighting.

Book 14

The latest proposal to reach the Book-writing phase is Book 14, which will define specifications for linear, socketable (tool-less replaceable) light engines and modules with a cap-holder fit system.

The Book will include versions with integrated drivers and versions with separate drivers. Three length designations (lengths of approx. 1400 mm, 1120 mm and 560 mm) are likely to be included.

New Proposals

Zhaga is now reviewing a series of new proposals from its member companies:

- Planar, large-diameter, circular LLEs (with integrated driver) for potential use in flat, circular luminaires with a homogeneous, low-glare surface
- Rectangular LED modules (with separate driver) for use in combination with lens plates, in outdoor lighting applications
- Circular, small-diameter, spotlight-type LLEs (with integrated driver) for use in applications such as compact spot-type indoor luminaires (e.g. track lights)

These proposals were made after Zhaga identified opportunities and set priorities for new specifications that will provide most benefit to the LED lighting industry.

Conclusions

By listening to feedback from stakeholders, and responding in a timely and efficient manner, the Zhaga Consortium is continuing to provide an important contribution to the ongoing growth and development of the LED lighting industry. Changes have been put in place that will enable component interchangeability of LED modules and drivers, as requested by the market. Zhaga is also expanding its portfolio of specifications for LLEs, modules and drivers, and is building scaled families of interchangeable products that provide choice for luminaire makers alongside the benefits of standardization. ■

References:

[1] Zhaga online Certified Products Database : www.zhagastandard.org/products/certified

Chip-on-Board LED Modules Standardized in Zhaga Book 12

In order to address the complexity of dealing with a wide range of Chip-on-board (COB) LED modules, the Zhaga Consortium has standardized a family of form-factors in its new specification, Book 12. Martin Creusen and Charles Knibbeler from Philips Lighting, Manfred Scheubeck from OSRAM Opto Semiconductors, Ingo Arnrich from BJB and Nico van Stiphout from Molex discuss the numerous issues that have been addressed by Zhaga, leading to a mechanical interface specification for these components.

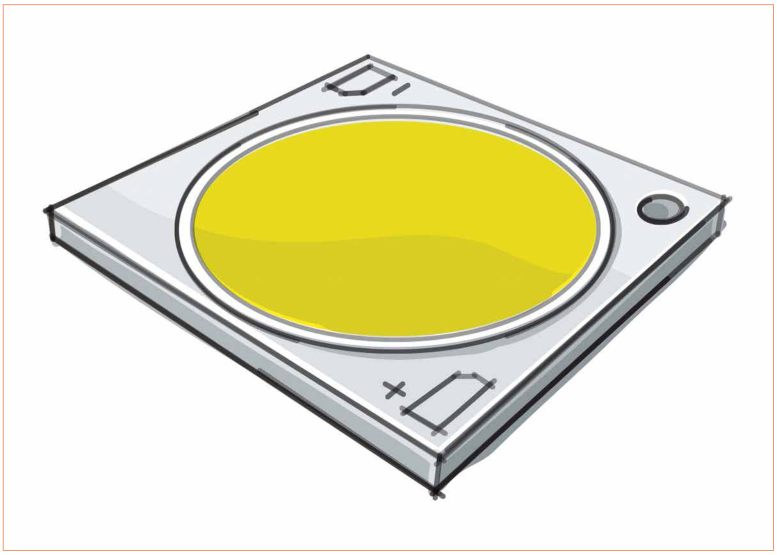


Figure 1: Zhaga Book 12 specifies a family of square and rectangular LED modules with a circular light-emitting surface (LES). Typically these modules use chip-on-board (COB) technology, but this is not mandatory

Chip-on-board (COB) [i] LED arrays are already in widespread use throughout the LED lighting industry, serving a broad range of indoor and outdoor applications. To address this market, many alternative COB form-factors have been developed and are being supplied by multiple COB manufacturers. However, most of these form-factors offer only arbitrary variations in non-competitive properties such as outer dimensions and electrode positions. This increases the complexity of luminaire development and of the supply chain for lighting OEMs.

As a result, stakeholders such as suppliers of COB holders or optics have to accommodate numerous slightly different solutions to supplement this complex COB portfolio. In addition, for luminaire makers this also limits the options to use alternative products from different suppliers without the need to change their luminaire designs.

COB Form-Factors

Many Zhaga members were concerned about this growing redundant diversity. Consequently, they initiated a standardization request and started a so-called Zhaga taskforce. The first task was to analyze and make an inventory of the existing COB market landscape by consulting many different stakeholders, such as manufacturers of COB modules, COB holders and LED luminaires.

Although focusing only on the mainstream COB market, with COB dimensions from 12 to 28 mm, this quickly resulted in a long list of more than 50 different COB form-factors. A short list of five categories was derived, applying a 4 mm interval between 12 and 28 mm, to attain five evenly-spread COB categories of rectangular and square COB modules.

To ensure the future robustness of the upcoming Zhaga COB specification, a rectangular shape was selected for the smaller form-factors (i.e. 12 x 15, 16 x 19 and 20 x 24 mm). For the larger form-factors (i.e. 24 x 24 and 28 x 28 mm) a square shape was selected. This was to safeguard sufficient area for future integration of additional functions and features, as well as to ensure ease of manual handling in the case of smaller COBs. The 19 x 19 mm form-factor was added alongside the 20 x 24 mm category as a compromise between cost effectiveness and long-term robustness of the specification.

Note that the first phase of Zhaga COB standardization focuses only on the basic COB functionality, and does not include additional functions such as multi-channel LED driving or auxiliary sensors. Also, COB dimensions larger than 28 mm or smaller than 12 mm have not been taken into account (yet).

For each COB size, the functional COB area can be calculated by subtracting the area of the maximum light-emitting surface (LES) from the overall area of the COB module. In figure 2, the remaining functional COB area is plotted as a function of the smallest COB dimension. For the smaller COB form-factors, the rectangular shape ensures that at least 100 mm² is available for further function and feature integration, whereas for larger square COB form-factors the remaining area is already sufficiently large.

Also, another advantage when using rectangular-shaped COBs is LES diameter maximization. This is because the creepage distance and clearance (C&C) requirements between contact pads and active dies are not a bottleneck in that case.

The resulting six COB form-factors defined by Zhaga allow COB-array makers to focus on areas where they can offer value-added differentiation to customers, such as thermal properties, quality of light or luminous efficacy. For supporting companies supplying complementary products such as COB holders and optical elements, the concise set of six form-factors will help to proliferate the accompanying ecosystem. Moreover, for lighting OEMs and customers, this Zhaga specification simplifies the comparison and selection of products.

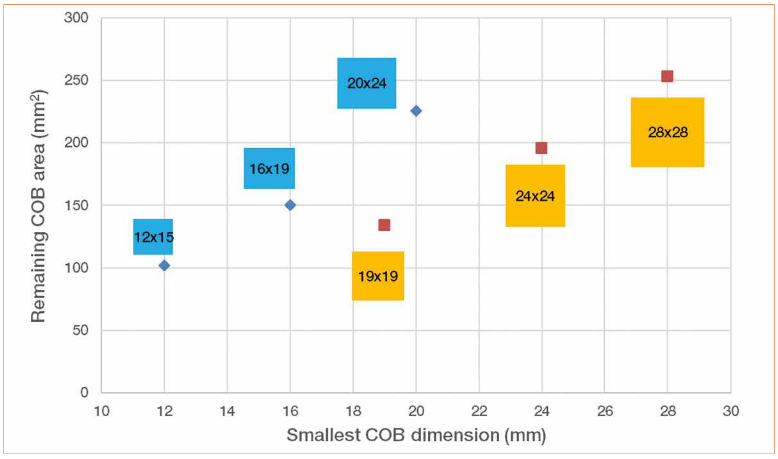


Figure 2: For each COB size, the remaining functional COB area (after subtracting the maximum LES area from the total area) is plotted as a function of the smallest COB dimension

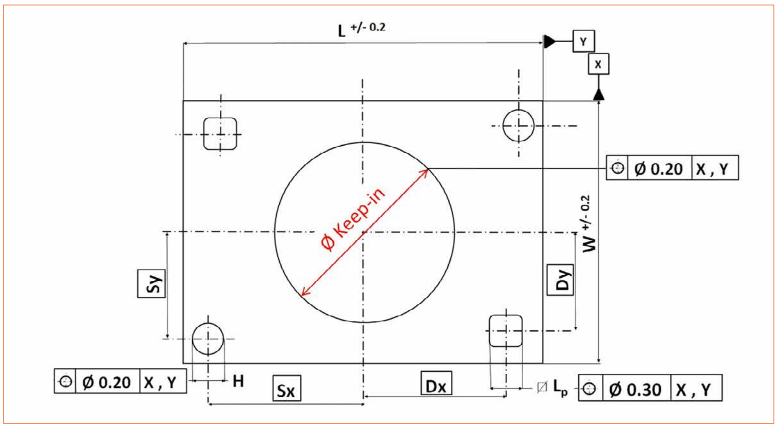


Figure 3: COB module specification including key dimensions defined according to the geometric dimensioning and tolerancing (GD&T) method. Values of the different dimensions for each COB category are shown in table 1

Mechanical Interface Specification

GD&T method

For COB product specifications, a wide range of different mechanical interface definitions are currently being used, and these vary significantly between the different COB manufacturers. Also, not all the key tolerances are always included in the accompanying product drawings. This unnecessarily complicates the design-in process for suppliers of components such as COB holders, heatsinks or optics. Moreover, most of the COB specifications do not take into account the risk of tolerance stack-up, which is critical to determine the mechanical fit between, for example, COB modules and COB holders.

Therefore, the Zhaga taskforce introduced a generic system for defining and communicating engineering tolerances, a method called geometric dimensioning and tolerancing (GD&T).

This GD&T system defines the basic dimensions as nominal values and outlines the allowed variation in form and size. Figure 3 shows an example of the center position and minimum size of the electrical contact pads and mounting holes as specified according to the GD&T method.

Contact pads

To avoid the need for manual soldering, COB modules are often used in combination with COB holders. For this application, the position and minimum size of the COB electrical contact pads are key dimensions and therefore are also part of the Zhaga specification. The required minimum size of the contact pads is actually a result of the overall mechanical tolerance chain of both COB module and holder.

In order to avoid needlessly-large minimum contact areas, Zhaga requested data for the actual tolerances in COB and holder manufacturing instead of the usually-communicated commercial tolerances.

Table 1:
Overview of the contact-pad positions (Dx,Dy), and minimum length and width of the square contact area (Lp), for the different COB categories. Also shown for the two largest COB categories is the position of the mounting holes (Sx, Sy), which have a diameter ΦH (for all dimensions, the units are mm)

LED Module Category	W	L	Sx	Sy	ØH	Dx	Dy	Lp
C28x28	28.0	28.0	11.4	11.4	3.1	11.1	11.1	2.0
C24x24	24.0	24.0	9.4	9.4	3.1	9.1	9.1	2.0
C20x24	20.0	24.0	-	-	-	9.1	7.1	2.0
C19x19	19.0	19.0	-	-	-	7.525	7.525	1.75
C16x19	16.0	19.0	-	-	-	7.525	6.025	1.75
C12x15	12.0	15.0	-	-	-	5.6	4.1	1.6

A square-shaped minimum area with rounded corners was agreed upon to allow sufficient design freedom for the COB holder manufacturers. A rectangular- or triangular-shaped contact pad would also have been possible, but would have constrained the position and direction of the contacting beams in the COB holder.

Next, the center positions of the electrical contact pads were designated, taking into account typical creepage distance and clearance (C&C) requirements. Table 1 shows the resulting contact-pad positions (Dx, Dy) and minimum contact-pad dimensions (Lp) for the different COB categories.

Keep-in zone

The keep-in zone defines the region of the COB where it is permitted to place LED components as well as other features such as the dam surrounding the phosphor area. The center of this keep-in zone coincides with the mechanical reference point. Outside this keep-in zone, the LED module is not permitted to have any features that protrude above the PCB top surface, with the exception of PCB tracks and contact pads.

The Zhaga specification defines the maximum keep-in zone diameter. For a specific COB module, this depends not only on its COB category (i.e. the overall module dimensions) but also on its LES category. The COB category limits the keep-in zone diameter due either to the overall COB outline, or to the position of the contact pads as listed in Table 1. In addition, the keep-in zone is restricted by the LES category. Each LES category has a maximum diameter for the optics contact area (OCA) of the LED module, which corresponds to a minimum reflector opening.

The LES and OCA categories in the COB specification are the same as those used in the different Zhaga specifications covering LED modules for spotlighting-type applications. Currently these specifications are Books 3, 10 and 11 (Books 3 and 11 are published, Book 10 is in development), but in future they will be combined into a single Book.

The combination of a COB module and a suitably-sized COB holder can create a product that effectively replicates a spot LED module as described in either Book 3, 10 or 11.

Table 2 shows the resulting maximum keep-in diameter both as a function of the LED module category and the LES category. The keep-in zone typically includes the dam surrounding the LES area.

Mounting holes and mousebites

For holderless mounting, the COB modules can have optional mounting holes or indents with a designated position and diameter (Figure 3). The larger COB categories (i.e. C28x28 and C24x24) can have mounting holes suited to accommodate M3 screws. The smaller COB categories can have indents at the corners, also known as mousebites, with a radius intended also for M3 screws.

Thickness

For best performance and a secure fit of the COB holders it was necessary to limit the thickness variation of the COB modules to 1.0±0.15 mm. Therefore, the thickness does not include a thermal interface material (TIM). Usage of a suitable TIM is always recommended but it should be either thin enough to keep the COB within the thickness tolerance or the TIM area should be extended and overlap with the holder.

Table 2:
Maximum keep-in diameter (mm), which depends on both LES category and LED module category. Note that the smaller COB module sizes cannot accommodate the larger LES sizes (indicated by x)

		LES category					
		LES6.3	LES9	LES13.5	LES19	LES23	LES30
LED module category	C28x28	8.3	11.0	15.5	21.0	25.0	26.8
	C24x24	8.3	11.0	15.5	21.0	21.1	x
	C20x24	8.3	11.0	15.5	18.5	x	x
	C19x19	8.3	11.0	15.5	17.0	x	x
	C16x19	8.3	11.0	15.0	15.0	x	x
	C12x15	8.3	9.8	9.8	x	x	x

Conclusion

In a very short period of time, Zhaga members have worked together to produce the first edition 1.0 of Zhaga Book 12. This defines a family of six form-factors, and includes critical dimensions such as the position and minimum size of the electrical contact pads, and the size of the keep-in zone.

An updated version of the specification, which will also include the definition of the COB module-holder interfaces, can be expected in due course. Moreover, Zhaga has already decided that the COB-holder-to-luminaire interface definition will be included in future editions of the Zhaga Books covering LED modules for spotlighting applications.

Testing for COB product compliance with Zhaga Book 12 will be carried out by independent testing facilities operated by one of several Authorized Testing Centers appointed by Zhaga [1]. Compliant and certified products are listed on the Zhaga website and are entitled to carry the Zhaga logo.

After finalization of phase 1 of COB standardization, which is limited to basic COB functionality, work will be started on a second standardization phase. This will aim to include additional features and higher integration levels, for example multi-channel, optical feedback and sensors. ■

Remarks:

[i] Chip-on-board (COB) is a manufacturing technology in which the LED chips are mounted directly onto a printed circuit board (PCB). The phosphor coating necessary to produce white light is either applied to each individual chip, or applied across the entire array

References:

[1] Certification & Authorized Testing Centers: www.zhagastandard.org/books/certification

Light-Emitting Surface (LES) Concept Enables Comparison of Photometric Properties

The concept of the light-emitting surface (LES) has been developed by the Zhaga Consortium to enable comparisons of the photometric properties of different LED light engines. Stefan Lorenz, a Systems Architect with Osram GmbH, describes the theory behind the LES and how it applies to the different Zhaga Books.

The amazing speed at which LED technology is evolving has surprised not only the experts in solid-state technology. This development is a problem to those who need to rely on a certain constancy in light-source design for longer than a year - which is everyone who wants to sustain a lighting solution or fixture for more than that time.

To solve this conflict, the Zhaga Consortium is establishing a set of specifications which separate the internal technology of the light source from external features necessary to maintain a long-term constancy in the application.

Zhaga specifications describe LED light engines (LLEs) and related components including LED modules and LED drivers. These specifications are called “Books” and define certain features of these LLEs and components which are needed to keep them interchangeable.

This article deals with the concept of the light-emitting surface (LES), as it was developed by the Zhaga Consortium. LES is designed to enable the easy evaluation of the optical emission of an LLE or LED module without reference to its internal technology.

Figure 1:
Three „classic“ light engines that share common mechanical, electrical, and optical properties.
Left: A light engine with large and homogeneous light-emitting surface (LES) i.e. the outer envelope of the lamp.
Middle: A light engine with a small LES, using standard filament technology.
Right: A light engine with a small LES, using halogen technology.
All three light engines are compatible in most luminaires made for them

Compatible and Interchangeable

The ability to interchange LED light engines in one luminaire doesn't imply that one will get exactly the same behaviour with all LLEs. This becomes obvious if you think about substituting a 100 lm/W LLE with a 130 lm/W LLE, for example. The new LLE will result in a more energy-efficient luminaire assembly, of course.

Figure 1 shows an example of "well-known interchangeable light engines", which have different technologies and light-emission characteristics.

Zhaga defines two degrees of similarity that two (different) LLEs can achieve in a certain luminaire. The basic degree is "compatible"; two LLEs are said to be compatible if they have similar mechanical, thermal, and electrical properties. In other words, they are compatible if they fit into a luminaire designed for this type of LLE, and if they can be operated. The examples in figure 1 are compatible in the Zhaga sense.

The more advanced degree of similarity between LLEs is "interchangeable". This term includes "compatible", and adds, on top, a comparable photometric performance. Thus, in order to evaluate interchangeability, a suitable description of photometric properties is needed.

The Light-Emitting Surface

The primary concept developed and used by Zhaga to judge comparable photometric properties in different LLEs is the light-emitting surface (LES). This characterises the area and position of light emission from an LLE in a general way, so that the balance is kept between independence of technology and easy evaluation of similarity in the application.

Unlike classical light sources (such as those in figure 1), normal LLEs do not emit light in all directions. So the first requirement for two LLEs to be interchangeable is that the light emission takes place at a comparable position on each LLE, and in a comparable direction. The rough shape of the emission area should also be comparable. Two LLEs with a similar LES then should produce comparable photometric properties in a luminaire.

The LES of the middle and right-hand bulbs in figure 1 are quite similar in shape and light-emission direction, while the left-hand bulb's LES has a completely different shape. The typical application of the LLE determines how similar two LLEs have to be for them to be interchangeable. Each individual Zhaga specification defines its own acceptable range. For the figure 1 light bulbs, all three might be called interchangeable as light sources in shaded luminaires, but in open view, the left bulb is not interchangeable with either of the others.

The basic idea of the LES is well represented even in the light bulb example: Position, shape and direction of light emission must be similar in a light source to generate comparable photometric properties in a certain application. The LES concept provides an easy method to describe and compare these parameters in abstract specifications and actual light sources.

Beyond the Light-Emitting Surface

Not all optical properties of an LED light engine can be described by the LES concept. Some, like the luminous flux, are better specified separately and independently. Others, like the far-field luminous intensity distribution, are associated with the LLE, but not directly connected to the LES.

The information on full near- and far-field emission of a light source is usually provided in the form of ray files. These contain sufficient statistical information to simulate the optical properties of an LLE by software. They can even contain information on colour (colour over angle as well as colour related to emission position), whereas the LES is a purely intensity-based concept for reasons of simplicity. The disadvantage of ray files - bulkiness and need for computer-based evaluation - is addressed by the LES concept: a simple method to easily compare LLEs of different technologies.

Ideal LES, Actual LES and LES Range

To be independent from a specific implementation, Zhaga has to describe an "ideal" LES for each application. This ideal LES is a simplified geometrical two-dimensional surface, which characterises the ideal location and shape of the light emission in the LLE. It does not need to be an actual physical surface, but is the idealized, simplified area of light emission in an ideal interchangeable LLE.

Figure 2 shows the ideal LES for an LED module according to Zhaga Book 3. The LES has a circular shape, a fixed diameter, and a fixed height above the LED module backplane.

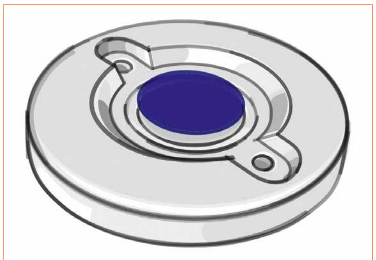
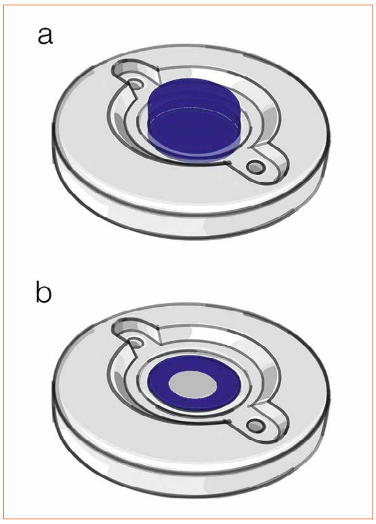


Figure 2: A Zhaga Book 3 LED module. The Ideal Light-Emitting Surface (LES) is indicated as blue disc. Note that the disc is elevated above the actual LED module's physical features in this example

The "actual" LES of an LLE implementation might deviate from the ideal LES in several aspects such as size, homogeneity, symmetry and vertical position (height). The allowed degree of variation from the ideal LES (the LES "range") depends on the application, and is specified such that all LLEs which are within the allowed variation range will produce comparable photometric outputs in the application.



Figures 3 a&b: (a) LES height range for a Zhaga Book 3 module. The vertical position of the LES can be anywhere in the indicated range (including below the physical surface of the module/LLE). (b) LES diameter range for the same module. The actual LES outer diameter needs to be within the indicated ring

Figure 4: Actual LES shown in red and LES range shown in blue for a Book 3 LED module. Top view: Actual LES is smaller than the maximum LES diameter, but larger than the minimum LES diameter. Side view: Actual LES is above the individual LED domes, and well within the LES height range

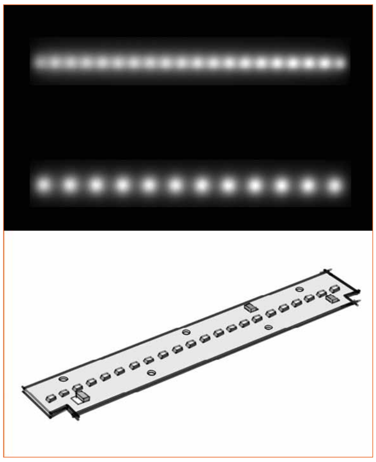


Figure 5: Two standardized LES images from Zhaga Book 7 modules, with either sparse or dense LED placement on the LES. Also shown is a typical Book 7 LED module

Figure 3 shows the LES height range and LES diameter range of a spotlight Book 3 module. The vertical position (height) of the actual LES can be within a range around the ideal LES height.

The diameter of the actual LES can be smaller than the ideal LES diameter, down to a minimum diameter. This range is depicted by the ring in figure 3. The outer diameter of the actual LES is required to be within this ring.

Differences from Physical Features

An example of an actual LES is shown in figure 4, for a real LED module especially suitable for narrow beam applications. The top view shows that the LEDs form a non-circular pattern. The LES diameter range is superimposed in blue. The actual LES, which is limited by a circle around the LEDs, is indicated in red. The side view shows the vertical position of the actual LES and the LES range. The actual LES is within the LES range, so the LED module shown here is compatible with other Zhaga LED modules.

Optics Design for LES

The concept of interchangeable LLEs puts a burden on the design of the luminaire optics, if the luminaire's LLE is meant to be interchanged. The LES is the commonality that an optics designer can expect from the various LLEs that the luminaire should operate with. As a consequence, optics design should not be based on a single LLE, but rather on the ideal LES laid down in the Zhaga specification (Book) in question. Interchangeability at the Zhaga level is then automatically ensured without additional efforts. Further optimization with ray files would be counterproductive, as it would reduce the interchangeability in favour of a single peak design.

Supplementary LES Information

The inner structure of the actual LES can have quite an impact on comparable photometric performance in certain applications. For that reason, some Zhaga Books have extra requirements on the LES.

Extra Information: Zhaga Book 7

Zhaga Book 7 describes rectangular LLEs with an external driver, which are often used in luminaires formerly equipped with linear fluorescent tubes. To allow for a certain degree of versatility, the LES definition in Zhaga Book 7 is minimal, but requires extra information to be provided with each LLE. The only common property of the LES in Zhaga Book 7 is that it is located at the top of the LED module. This is already sufficient for many applications in which Book 7 LLEs are used.

More information on the structure of the LES is given in Zhaga Book 7 by a luminance measurement in a test luminaire (Figure 5). The resulting image gives an impression of the homogeneity that can be achieved with the tested LED module. The user can decide if the appearance of the LLE is suitable for his application.

Additional Restrictions: Book 3 and Book 4

A more detailed specification and some limitations are needed for the high-intensity LLEs in Book 4 and the circular LED modules in Book 3, for example. Here, more specifications on the inner structure of the LES are necessary to ensure that the LLE is interchangeable and works satisfactorily with typical luminaire optics. A minimum size for the LES is ensured as well as the already-specified maximum size. Also, the LES needs to be sufficiently homogeneous to avoid artefacts - especially in strongly directional luminaires.

The ideal LES shapes are circular for Book 3 and rectangular for Book 4 (Figure 6). Deviations from the LES can result in unexpected beam shapes. The actual LES can be only a little smaller than the ideal LES size, but at the cost of deviations in the beam shape. The acceptable variation sets the lower limit in the LES range.

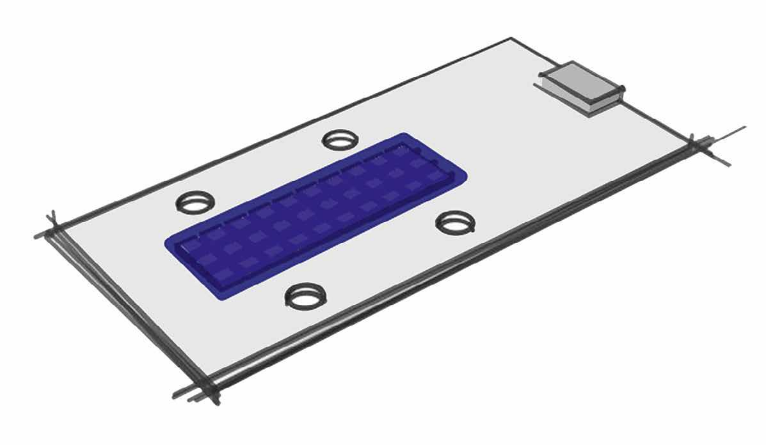


Figure 6:
Typical Book 4 LED module, showing the maximum LES dimensions

The actual LES must have uniform luminance and a high degree of symmetry, to avoid hotspots or asymmetries magnified by the luminaire optics. Both Zhaga Books 3 and 4 require the determination of centre balance and uniformity. In addition, the circular LES of Zhaga Book 3 is evaluated for rotational symmetry, while the rectangular LES in Zhaga Book 4 needs horizontal and vertical symmetry measurements.

All these limitations and measurements are implemented in Books 3 and 4 to ensure that no LLE deviates too much from the ideal LES. All parameters have some range of freedom, which can be exploited to construct actual LLEs, but the sum of all deviations must be small enough to avoid non-comparable behaviour in the luminaire optics designed for the typical LES.

Both Books 3 and 4 have a very well-defined LES, due to the typical application requirements they are designed for. The well-defined LES guarantees that interchange of LED light engines is possible with minimum variation.

Summary

The challenge of defining a technology-independent and simple description of light emission from LED light engines has been accepted by Zhaga. The LES concept is a simple method to ensure photometric comparability of different LLEs. Zhaga Books specify an ideal LES, with an allowed range of actual variations just small enough so that the individual LLEs are still comparable in their application. The actual LES can be easily compared, without reference to the actual LED technology inside the LLE.

Since its introduction by Zhaga, the concept of LES is well accepted in the lighting community as an easy categorisation for the new opportunities of LED lighting. ■

Remarks:

[1] An LED light engine (LLE) combines one or more LED modules with an LED driver. The driver can either be integrated inside the LLE, or the LED module(s) and driver can be separate from each other. The light-emitting surface (LES) is associated either with the integrated LLE, or with the LED module in cases where the driver is separate. In this article, the terms “LLE” and “LED module” are used interchangeably

Zhaga Determines Thermal Fit of LED Light Engines and Luminaires

Thermal fit is an essential aspect of determining if LED light engines and luminaires are compatible with each other. Zhaga specifications include a standardized data set to enable users to perform an easy check of the thermal fit conditions, as explained by Uli Mathis from Tridonic and Toine Staring from Philips Lighting.

Specification of the thermal interface of LED light engines and LED modules is an essential part of ensuring that Zhaga components are interchangeable. Through its various specifications, Zhaga has developed methods to evaluate the thermal compatibility or thermal fit of different light engines or modules with a particular luminaire.

There are different requirements for replacing an LED light engine depending on who carries out the replacement. This is taken into consideration by Zhaga when specifying different types of light engine. End users who typically replace a socketable light engine with a new one have different requirements from professional users, such as luminaire manufacturers, who use products from several suppliers in the same type of luminaire.

This article discusses the thermal interface between LED light sources and luminaires, and provides ways to determine the thermal fit for both end users and luminaire manufacturers.

Introducing the Thermal Interface

Like all light sources, LED light sources produce heat. This heat is transported away from the LED light source via a heat sink that is typically part of a luminaire. The description of this thermal interface includes the requirements for the heat flux from the light source to the luminaire and further to the ambient of the luminaire.

As shown schematically in Figure 1, the path of the heat flux from the LED light engine to the ambient contains a thermal resistance (R_{th}). The magnitude of this thermal resistance depends on the surface of the heat sink (luminaire), the contact material between the LED and the heat sink, and on the thermal power.

The thermal resistance of the luminaire is measured with a thermal test engine, which has dimensions that are similar to those of an LED light engine. The heat generated by this thermal test engine is provided by a resistor that is supplied with a rated current. By measuring the temperature t_r at a reference point on the thermal test engine and the temperature t_a in the vicinity of the luminaire, the thermal resistance R_{th} can be calculated from the power P_{th} that is applied to the heating resistor.

For R_{th}, thermal resistance:

$$R_{th} = \frac{t_r - t_a}{P_{th}} \qquad (1)$$

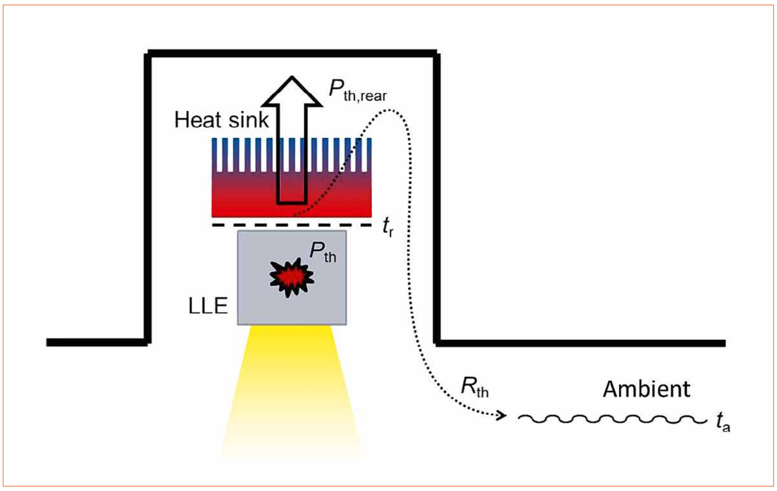


Figure 1: Schematic diagram of a luminaire in a recessed environment. The LED light engine (LLE) generates heat at a rate of P_{th} while $P_{th,rear}$ is the heat flux (or thermal power) of the LLE through the interface with the luminaire heat sink. The path of the heat flux (dotted arrow) from the LLE to the environment is characterized by a thermal resistance R_{th}

Meanwhile, the maximum allowed thermal resistance of the LED light engine ($R_{th,max}$) is given in the manufacturer's literature, and is calculated:

For $R_{th,max}$, *max. thermal resistance:*

$$R_{th,max} = \frac{t_{r,max} - t_a}{P_{th}} \quad (2)$$

Where $t_{r,max}$ is the maximum operating temperature of the light engine.

Replacement by End Users

If an end user is going to replace an LED light engine, this procedure must be as simple as replacing an incandescent lamp. The thermal fit is clearly defined if the thermal resistance (R_{th}) of the luminaire is smaller than or equal to the maximum allowed thermal resistance ($R_{th,\ max}$) of the light engine. Even so, a simpler method has been worked out by Zhaga. The reason is that the dependence of the thermal resistance on the applied thermal power complicates matters.

The method developed by Zhaga consists of a coding system which works in a similar way to the thermal fit of incandescent lamps. In this case, the power of the lamp is compared with the maximum allowed power in the luminaire (e.g. 60 W maximum).

For Zhaga-based LED light engines the equivalent fit is coded with *P**. This value *P** is a combination of the maximum allowed temperature and the actual thermal power of the light engine. The luminaire will be marked with P^*_{max} and the light engine with *P**.

Table 1 gives an example of how thermal fit codes can help a consumer in the decision process for purchasing or replacing a socketable LED light engine.

	Evaluation using thermal fit code *P**	Evaluation using thermal resistance R_{th}
Light engine	Thermal fit code *P** = 20	$R_{th,max}$ = 5.0 K/W @ P_{th} = 15 W
Luminaire	Thermal fit code P^*_{max} = 25	R_{th} = 4.0 K/W @ P_{th} = 10 W R_{th} = 3.5 K/W @ P_{th} = 20 W
Conclusion	Thermal fit is OK because *P** value of light engine (20) is less than P^*_{max} of the luminaire (25)	Thermal fit is OK because R_{th} value of luminaire is less than $R_{th,max}$ value of light engine (5 K/W)

Table 1:
Alternative ways for an end user to evaluate whether an LED light engine has a thermal fit with a luminaire

Replacement by Luminaire Manufacturers

Luminaire manufacturers have many possibilities for calculating the thermal fit of light sources, including Zhaga light engines, in their luminaires. Approaches such as using simulation programs or performing measurements in a laboratory will allow a very precise determination of the thermal fit.

Based on the thermal power that is provided in the data set of the light engine, the expected temperatures can be calculated for the luminaire. If the calculated temperature is below the maximum value that is specified for the light engine, the thermal fit is OK in combination with this luminaire.

By measuring the temperature at the thermal reference point(s) of the light engine, the thermal fit can be confirmed.

For replacing the Zhaga light engine by a similar type of light engine from the same manufacturer or from another manufacturer, a professional lighting expert can make a simple calculation to check the thermal fit of the replacement product. He only needs to compare the thermal power and the thermal limits of the new light engine with the original one.

Thermal data

The following thermal data are offered for Zhaga LED light engines that are intended for use by luminaire manufacturers:

- Total thermal power (P_{th}) of the light engine
- Thermal power ($P_{th,rear}$) at the rear of the light engine
- Maximum operating temperature ($t_{r,max}$) of the light engine
- Rated ambient temperature (t_a) of the luminaire

Evaluation of the thermal fit

There are two ways to evaluate the thermal fit of a Zhaga light engine in a luminaire. The first method is simulation of the thermal fit. The temperature tr at the reference point is calculated using the dimensions of the luminaire, the thermal power Pth of the light engine, and the ambient temperature ta. If $t_r \leq t_{r,max}$ then the light engine fits in the luminaire from a thermal point of view.

The second method is measurement of the actual temperature inside the luminaire when operating under rated conditions. If $t_r \leq t_{r,max}$ then the thermal fit of the Zhaga light engine is confirmed.

Conclusion

Zhaga LED light engines and Zhaga LED modules are supplied with a standardized data set which allows an easy check of the thermal fit of the LED light source with the luminaire.

There are several methods to evaluate the thermal fit conditions. These are carefully selected to meet the needs of light engines which are replaced either directly by the end user, or by professionals such as luminaire manufacturers. ■

DMI Specification Defines Electrical Interface between LED Drivers and Modules

Enabling LED modules and LED drivers to be fully interchangeable at the component level requires a specification for the electrical interface between the driver and module (DMI). Arnulf Rupp of Osram GmbH, a member of both the Zhaga Consortium and MD-SIG, explains the role of both organizations in developing and implementing a consistent, easy to use, cross-vendor DMI specification.

The rapid evolution of LED technology has catapulted solid-state lighting (SSL) from spearhead innovation into a phase of steady market growth within only a few years.
The new phase of LED lighting brings its own challenges. While the benefits of LED-equipped lighting fixtures over products based on traditional light sources is now indisputable in most applications, LED technology itself is still in rapid development. Keeping designs up to date and competitive leads to frequent redesign cycles, which the lighting industry was not required to manage back in the days of halogen, fluorescent and high-pressure discharge lamps.

From design to delivery, even the availability of certain technology generations may be an issue from time to time. Updating designs, adapting LED drive currents for ever-improving LED lumen efficiencies, and redesigning LED layouts to accommodate the latest in technology, have all become time-consuming and expensive baseload activities in the development departments of the lighting industry. This calls for stable, easy to use and reliable design-in methodologies based on well-defined interfaces among the building blocks for LED lighting.

The Zhaga Consortium has done a very good job in providing terms and definitions to describe many of those interfaces in a vendor- and technology-neutral way. Until recently, however, Zhaga lacked definitions for the interface between the LED driver (also known as electronic control gear, or ECG) and the LED module.

From its outset, Zhaga purposely excluded the driver-to-module interface (DMI) from its scope, because standardization in that area was considered to be limiting to design freedom and technical progress. At that time, it was expected that LED drivers and LED modules would always be designed as a system, similar to driver-integrated light engines and LED retrofit lamps.

The industry, however, faced availability issues for all the desired combinations of features such as form factor, photometric properties, dimming interfaces and power grid voltages. A different solution had to be found. LED drivers and LED modules, if not integrated in one product, remain separate building blocks, and the system integrator must manage the matching of components along the DMI interface.

Demand for Standardizing the DMI

Driven by the need for a flexible matching of components, LED driver manufacturers invented adjustable or programmable constant-current drivers capable of covering a wide range of load conditions in one product. Such products are often called window drivers, current-adjustable drivers or programmable drivers. A multitude of techniques for setting the output current is available in the market; voltage-controlled output current, resistor setting, programming through the DALI line, programming through a dedicated setting interface, interfacing with additional circuits on the LED module, programming through modulated signals on the mains input, and near-field communication.

Even within the very common resistor-settable products, the actual resistor values for setting a given current may differ from one vendor to another. In addition, the terminology used by the manufacturers to specify output characteristics, operating ranges and setting methods have become vendor-specific in many details. As an example, the specified output voltage and current ranges may or may not include margins for setting tolerances or current ripple effects.

The confusion and inconsistency in the market leads to a strong need for harmonization and standardization. At the same time, the existence of all these technologies has largely eliminated the initial concern that standardizing the interface between the LED driver and LED module would limit design freedom and technical progress. A set of current-adjustable window drivers, which may even have overlapping output voltage and current ranges, is an ideal situation for designing new LED luminaires and for upgrading of existing products. What remains is the need for a consistent, easy to use and cross-vendor-standardized DMI interface specification. This is where a new industry alliance, the Module Driver interface Special Interest Group (MD-SIG), aims to serve the market.

MD-SIG and LEDset

MD-SIG is a global lighting-industry consortium introducing LEDset as a multi-vendor specification for the interface between LED drivers and LED modules. The alliance has a global focus and is open to all interested parties. It aims to simplify matching of components and to reduce the interchange risk resulting from deviating terminologies for the parameters defining the DMI.

When used in combination with specifications created by the Zhaga Consortium, LEDset will enable manufacturers of LED luminaires to interchange LED modules and LED drivers made by different vendors. For that purpose LEDset1, the first specification released by MD-SIG, provides a standardized method of current setting and will introduce well-defined parameter sets for both LED drivers and LED modules.

It is not the aim of LEDset1 to provide a one-size-fits-all solution. LEDset1 rather targets a wide range of simple constant-current LED boards connected with output-current-adjustable drivers.
The system integrator still has to verify key parameters defined in the parameter set for component matching.

MD-SIG specifications are publicly available on the organization's website (md-sig.org). The use of the LEDset logo on products, however, requires companies to be a member of MD-SIG.

The LEDset1 information interface is already available for download on the MD-SIG website. It defines how the output current is set during luminaire production or through information exchange between driver and module. The related power interface, defining the parameter set for the output characteristics of the driver and the operating range of the module, is currently a work in progress. Further specifications may follow, for example a digital interface for LED module to driver communication and programming.

LEDset Interface Characteristics

MD-SIG has chosen to start with a specification harmonizing the very common analog current-setting methods. Even such simple and lightweight technology can already fulfill many of the typical industry requirements for the DMI.

MD-SIG defined a set of minimum requirements the specification has to address. This minimum set also respects the needs communicated by Zhaga for independent interchangeability of drivers and modules. The minimum feature requirements are:

- Output current setting at the production line of the fixture OEM
- Plug and play option with the current setting circuit included on the LED module
- Cross-vendor parameter set for specifying window drivers
- Live current adjustment e.g. for an optional thermal de-rating
- Interfacing with multiple equivalent LED modules connected in parallel and/or in series

The LEDset1 interface uses a simple analog technique to realize the required features. A LEDset1 driver acts as a current-controlled current source. In un-dimmed operation, the driver output current equals the current I_{set} at the LEDset terminal multiplied with a fixed factor of one thousand. For the supply of the setting circuit, the LEDset terminal provides a fixed reference voltage of 5 V. The setting circuit is a current sink connected between the LEDset terminal and the lower voltage (LED-) output terminal. In the simplest case, the setting circuit can be a simple resistor with a value R_{set} of:

$$R_{set} = \frac{5V}{I_{out}} \cdot 1000 \qquad (1)$$

where I_{out} is the desired output current.

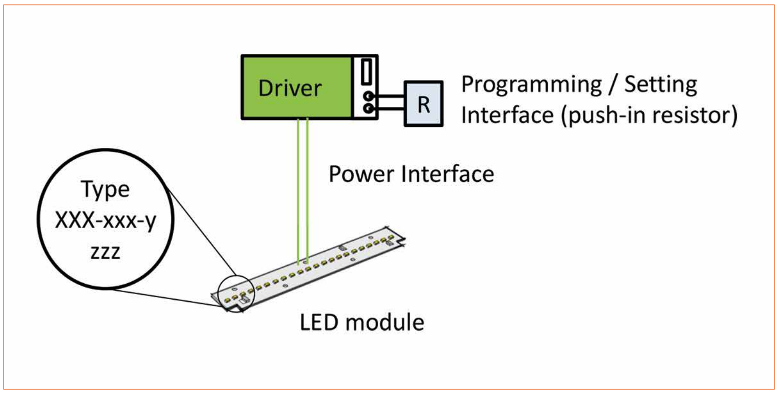


Figure 1: Push-in resistor for configuring the drive current on the luminaire production line. The corresponding electrical setup is shown in figure 2

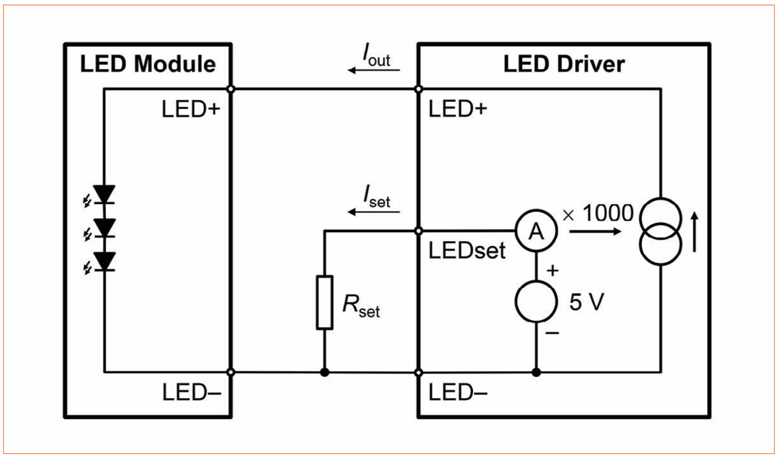


Figure 2: A setting circuit using a LED_{set}1 driver with an external coding resistor (R_{set}). The value of R_{set} determines the driver output current (I_{out}) according to Equation 1

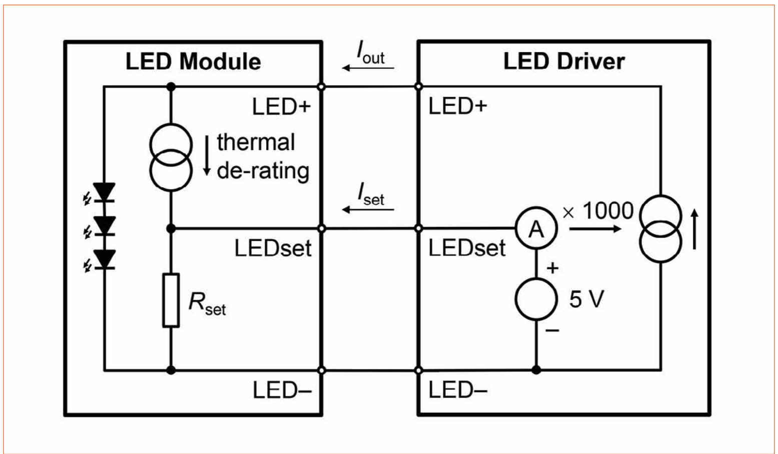


Figure 3: An alternative setting circuit, where the control circuit including the coding resistor (R_{set}) is on the LED module

Figure 1 illustrates the case of a coding resistor plugged into the driver for setting the drive current. The schematic in figure 2 shows the electrical setup corresponding to the diagram infigure 1. The setting circuit may also be installed on the LED board; this would require a third wire connecting the LEDset terminals at the LED module and the driver.

Figure 3 illustrates a case where the coding resistor is on the LED module together with another temperature-controlled current source to realize the desired temperature de-rating.
The specification document provides more details on these application cases and further options on how to apply LEDset1.

Driver Module Interface in Zhaga

Independent interchangeability of drivers and modules, the architecture Zhaga is now aiming for, requires independent specifications for both components as well as a DMI specification to connect them. Zhaga has created a document structure with one common LED driver specification, or Book, for all LED drivers (Book 13) and multiple Books for the different LED module form-factors (e.g. Book 3, 7, 11 etc.).

Zhaga decided not to duplicate the effort for the development of a DMI specification but rather to adopt an external specification fitting its needs. Both sides of the Zhaga system will reference the LEDset1 interface specification as the recommended DMI. Besides the DMI reference, Book 13 includes the proven set of Zhaga driver form-factor designations. Thus, it enables full mechanical and electrical interchangeability with a limited set of well-defined matching parameters. LED module books featuring the DMI will follow.

MD-SIG specifications provide testing instructions for vendors or test houses to ensure compliance with the requirements. For the use of the LEDset1 logo on the product, MD-SIG requires proper documentation of testing results by the member making the product. Zhaga will include the DMI in its third-party certification scheme along with the verification of other Zhaga-specified properties to ensure full interoperability with independent testing.

Conclusion

The Module Driver interface Special Interest Group (MD-SIG) writes specifications for a smart electrical interface between LED drivers and LED modules. This is the critical link essential for independent interchangeability of SSL components. Zhaga is using MD-SIG specifications in its latest driver and module Books. This is an important step forward in the maturation of SSL technology. The cooperation between Zhaga and MD-SIG now enables a higher degree of cross-vendor interchangeability at the component level. This simplifies design work, helping to reduce R&D costs, and increases component availability for new designs and product upgrades. ■

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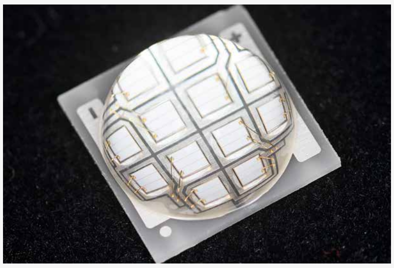
Cover-page

Artwork: Thomas Klobassa, ©LED professional 2015

Main Image: Arno Grabher-Meyer, LED professional

Product: TSLC multi chip UV-LED package



At LED Lighting Taiwan 2015, TSLC showcased several advanced UV LED packages

Next LpR

TRENDS & INNOVATIONS
Issue 52 - Nov/Dec 2015 - Short Overview

TECHNOLOGIES

230 V AC Driven LED Modules with Strongly Reduced Flicker

These days, designing a new LED luminaire can be very challenging. Included in those challenges are selecting the right LEDs and a suitable power supply unit. This process has now been simplified substantially by AC technology. A new approach is presented that allows direct control of the LEDs with 230 V AC and generates virtually flicker-free light with good dimming properties. ■

Software in Digitally Controlled LED Drivers

LED lights are controlled by a wide variety of LED drivers built around different switching topologies and control methods. This article discusses a new emerging trend, whereby, instead of dedicated ASICs or general purpose microcontrollers, hybrid digital controllers control the LED drivers with a combination of dedicated hardware building blocks, configuration software and runtime algorithms. ■

ENGINEERING

Avoiding End-Product Design and Functionality Issues with Plastic Simulation Technology

As regulations, consumer demand and material expectations evolve for LED lighting, companies are required to produce more sophisticated lighting units in shorter-to-market development times. Product simulation technology at the material level offers OEMs a cost-efficient approach to developing the exact product they need without wasting time or materials. It will be shown how plastic suppliers can help OEMS achieve these goals by foreseeing trouble areas ahead of time and developing the specific material properties when involved sooner in the production process. ■

RESEARCH

"Best Papers" at LpS 2015

The author(s) of the best scientific paper will be presented with the Scientific Award again this year. The winning paper will be presented at the LpS and printed in the proceedings booklet as well as being published in the 52nd issue of LED professional Review. ■

EVENTS

LpS 2015 Post Show Report

Up to the time of this printing, nine product launches were registered for the LpS 2015. In addition, a record number of exhibitors will be showing their products. Top-notch speakers will contribute to the quality of the event with their fascinating lectures. For those not able to attend and those who attended but would like a brief summary, the news, activities, and proceedings of the three days will be depicted in this report. ■

subject to change

Imprint

LED professional Review (LpR), ISSN 1993-890X

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