Report on the ForumLED conference

Lyon (France) on December 3-4, 2009

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The two-day ForumLED conference was organized, together with a trade show and exhibitors' workshops, as the opening event for the famous Lyons: *Festival of Light*. The Conference was attended by about 250 experts in field: researchers, engineers, light designers, architects. Main sessions of the Conference were:

- High-Brightness LED technology
- High Brightness LED packaging
- OLED technology
- Display
- Colour quality
- Characterisation, reliability, standards
- Drivers, controls
- Market challenges.

In the **session "HB LED technology"** high-level experts presented the status of the on-going developments on High Brightness LEDs and discussed the challenges in this field:

- Prof. Nicolas Grandjean, EPFL - Lausanne (Switzerland) in his talk "Physics and challenges of GaN based HB LEDs" discussed main issues related to the most popular white LEDs based on blue LEDs combined with yellow phosphors to create white light.
  - Blue LEDs based on GaN/InGaN are the most efficient source for HB LEDs used in lighting applications. Due to the absence of GaN substrates, GaN is typically grown on sapphire or silicon carbide. The key point for devices built with this technology is that they maintain high efficiency despite of the high density of dislocations generated during the GaN/InGaN films growth (this aspect is not valid for the other semiconductor materials)
  - One big issue for these devices is the so called "efficiency droop" (decrease of efficiency when the LED is driven at higher currents): this phenomenon may be related to Auger recombination that reduces the internal quantum efficiency of the device. However, there are mechanisms other than Auger which may also play an important role.

- Dr. Berthold Hahn, OSRAM Opto Semiconductors (Germany), presented the work "New developments for high power LEDs" and illustrated possible energy savings with Solid State Lighting;
  - according to ELC estimation, replacing today the existing installations with the best available alternatives (HID lamps, linear fluorescent lamps, compact fluorescent lamps, best-in-class LEDs for some specific applications) would save 30% of the energy used for lighting (actual worldwide electricity consumption for lighting: 2 651 TWh); in the next future an additional save of 40% will be possible combining LEDs, sensors and embedded software in ambient intelligent lighting networks. According to the results of the Ad-hoc Advisory Group for "ICT and Energy Efficiency" (European

Commission) potential savings in 2030 could be of 1300 TWh with reduction of 650 million tons of CO_2 emissions.

- In order to improve efficiency of LEDs, it is important to reduce: driver losses (about 10-20%), thermal losses (10-20%) and optical losses (10-20%): at the moment, for example, LEDs with efficacy of 105-110 lm/W are needed for a 70 lm/W luminaire.
- OSRAM Opto Semiconductors is focusing on the "ThinGaN chip technology" (UX:3 technology – Fig.1): the use of thin GaN films prevents internal light absorption and improves light extraction; at the moment light extraction is in the range of 80%, but additional optimization to extract radiation can be obtained by improving the roughening the film surface. UX:3 technology is leading to significant improvements: 134lm/W at 350 mA for cold white LEDs, 104 lm/W at 350 mA for warm white LEDs.

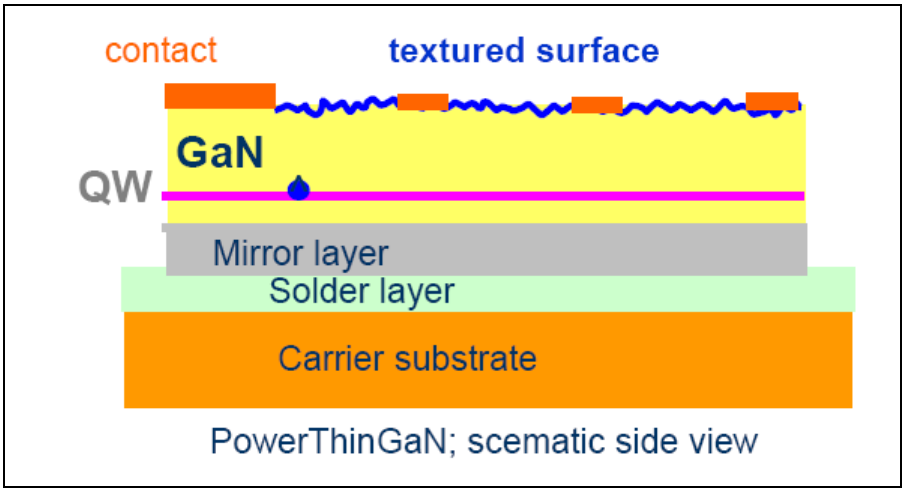


Fig.1: chip structure

- Mr. Allan Horn, Lumileds Lighting – Philips (UK) showed recent evolutions of LEDs in his presentation "Illumination Grade LEDS"
  - Efficacy of white LEDs is improving very quickly and, as illustrated in fig.2, should reach shortly the same level of the most efficient High Intensity Discharge lamps; at the moment high-power LEDs can provide white light even with efficacy of 100 lm/W; performance levels of 150 lm/W are expected within the next 3-5 years.

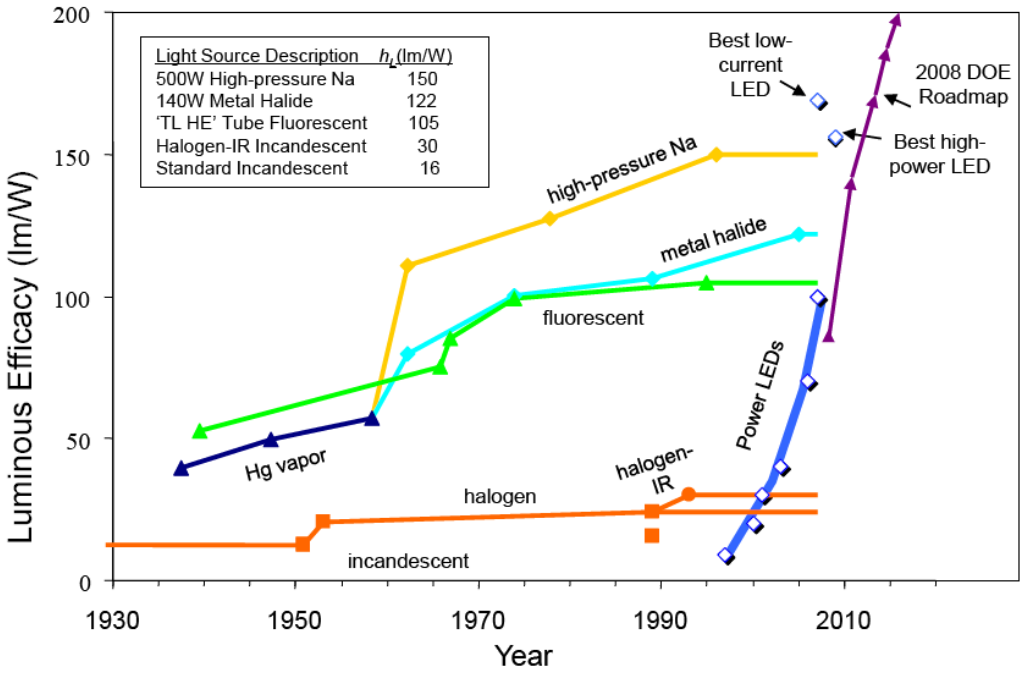


Fig.2: Efficacy evolution of best-in-class LEDs; comparison with discharge lamps

- One of the problems for LEDs is related to light output depreciation when the junction temperature of the device increases: this is a typical phenomenon that depresses LED performance, especially in the general lighting applications where junction temperature reaches 100℃ or more. By modifying the Epi-structure, Philips Lumileds stabilised the light output even at high temperatures in blue LEDs (for LUXEON Rebel LED, flux at $T_{junction}$=100℃ is 93% of the flux at $T_{junction}$=25℃).
- Philips Lumileds is also using the so called "*Thin Film Flip Chip*" technology (see Fig.3) so that optical elements can be placed in close proximity to the die and no wire-bonds are necessary; in addition, the adoption of the "Lumiramic Phosphor conversion technology" improves light color control by using pre-measured ceramic phosphor plates instead of phosphor powder.

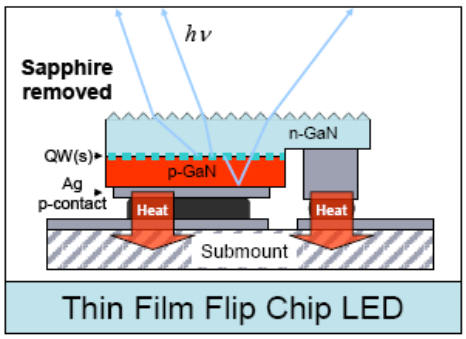


Fig.3: TF Flip-Chip technology

- Many efforts are in place to improve the LED system reliability in order to assure long-term lumen maintenance and to minimize catastrophic failures.

- Mr. Francois Levy, CEA-LETI (France), illustrated "Disruptive routes towards HB LEDs for general lighting"
  - A challenging long term project to develop new "ZnO planar LEDs" exploiting the possibility to grow low cost and large area ZnO substrates.

In the **session "High Brightness LED packaging"** it was pointed out that packaging is a key issue for HB LEDs, especially regarding management of the heat released by the devices.
A general overview was provided by Mr. Adrien Gasse, CEA-LETI (France), presenting "Challenges of HB LED Packaging"

- It is important to study the optimum packaging at "component level" (see fig.4) in order to assure good hermeticity, suitable optical management (light extraction, colorimetry, beam shaping) and efficient thermal management (it is fundamental to keep the temperature of the junction as low as possible).

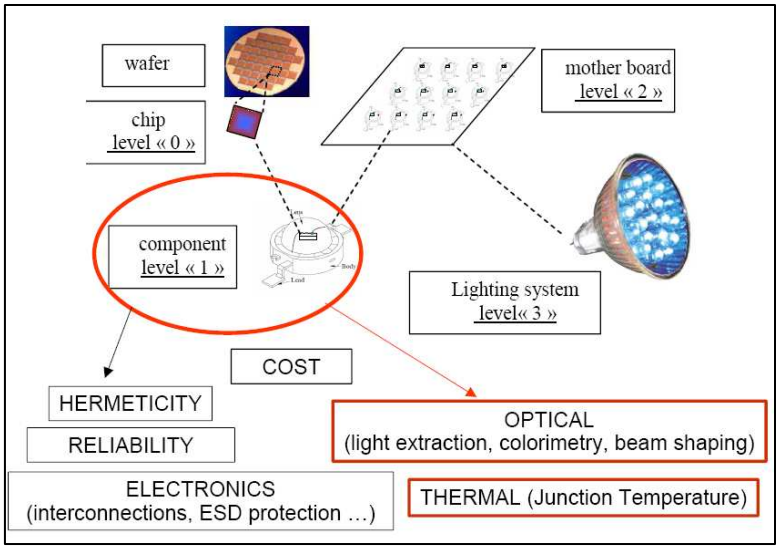
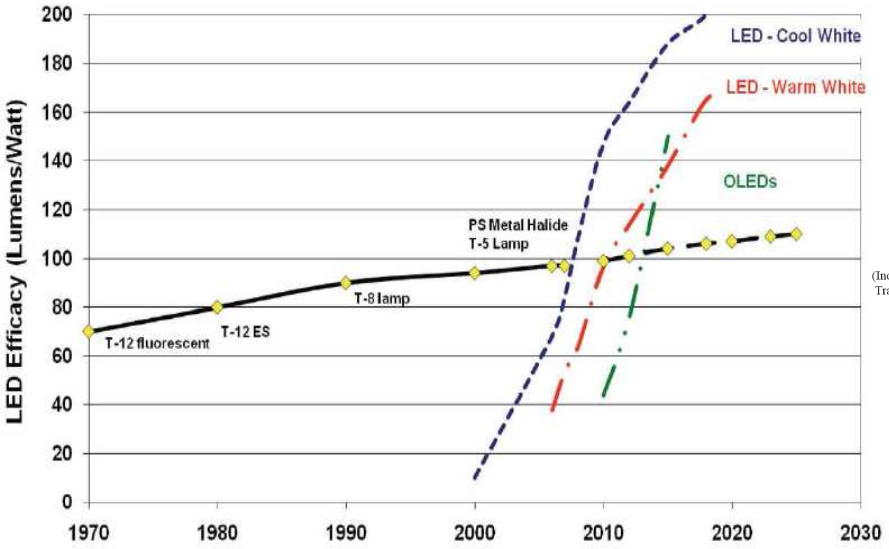


Fig.4: LED packaging

In the **sessions "OLED technology" and "Displays"** it was pointed out that initially OLEDs were developed to replace plasma displays and LCD screens, but over time the technology is demonstrating its ability to penetrate also the field of lighting:

- Tom Munters, Philips Lighting (Germany), gave a review on "OLED for lighting applications: status and outlook"
  - OLEDs emit homogeneous light over the complete flat surface; these thin devices can be innovative light sources, interesting for flexible and elegant design;
  - Projections indicate that in a few years OLEDs efficacy can achieve values of 100lm/W or more (Fig.5).

Projections from US DoE 3/09



OLED technology: layer build-up

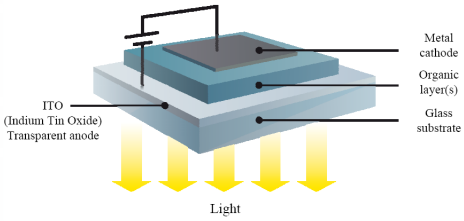


Fig.5: Efficacies of OLEDs compared with those of LEDs

- Few months ago Philips proposed on the market "Lumiblade", the first OLED light source. Different shapes and dimensions are available. Declared lifetime is of 10 000 hours. The efficacy is still at 10-20 lm/W, but it is expected that it will double every two-three years.

- Arto Maaninen, VTT Technical Research Centre (Finland), explained in his contribution "All-printed OLEDs" that OLEDs have potential to be processed in continuous roll-to-roll processes;
  - Low-cost roll-to-roll processes can allow the production of low resolution segment displays suitable for new applications.
  - Main goal of VTT is to develop a cost-effective manufacturing technology for the realization of flexible OLEDs.

- Dr. David FYFE, Cambridge Display Technology (England), gave his talk on "OLED, battling the Headwinds of LCD":
  - According to his view, in the field of displays, OLEDs will win against LCDs, first on power efficiency and later on manufacturing cost-advantages.

In the **session "Colour quality"** it was remarked that LEDs (white LEDs, coloured LEDs and mixed coloured LEDs) offer opportunities to manipulate light spectra in order to reach attractive effects. Thanks to these possibilities they are interesting for shop lighting, museum lighting, street lighting and even general lighting. The spectral power distribution of LEDs differs from that of conventional light sources, and this has consequences in the evaluation of their colour. The colour rendering of LED light shows systematic differences with respect to traditional light sources. Therefore the evaluations of LEDs colour characteristics need new metrics.

The speakers of the **session "Characterisation, reliability, standardisation"** pointed out that crucial problems related to new LED technology are how to measure performances and reliability of the solid state light sources in comparison to those of conventional lamps. Unfortunately, many of the standard measurement procedures used for traditional light sources do not apply to LEDs. Then, as it is very hard to compare performance of the devices when measurements methods are not standardised, it is fundamental to define the standards needed for LED characterisation: many standards to measure characteristics of LED lights, LED luminaries, LED modules are missing, especially in Europe.

- Dr. Yoshi Ohno, NIST (USA), explained in his talk "Promotion and standardization of LED lighting in USA that DOE (Department of Energy – USA) promoted specific programs (Energy Star, CALiPER) to support research, development and commercial application of Solid State Lighting technology. A series of standards for test methods and measurements on specific LEDs characteristics have been developed and approved (method for electrical and photometric measurement, method for LED lumen maintenance measurement), other standards are in preparation.

In the **session "Market challenges"** main general issues and expected LED market evolution were discussed.

- Tim Whittaker, LEDs Magazine editor (UK), gave an interesting contribution with a talk on "Market transformation: challenges for the LED Industry"
  - Key advantages of LEDs are related to flexibility of lighting effects, long lifetime, low Total Cost of Ownership, environmental friendly characteristics (no mercury), energy efficiency. However, it is important to know that LEDs are not always the optimum solution because they are not the answer for every lighting situation.

Fig.6: general overview of the market outlook for LEDs

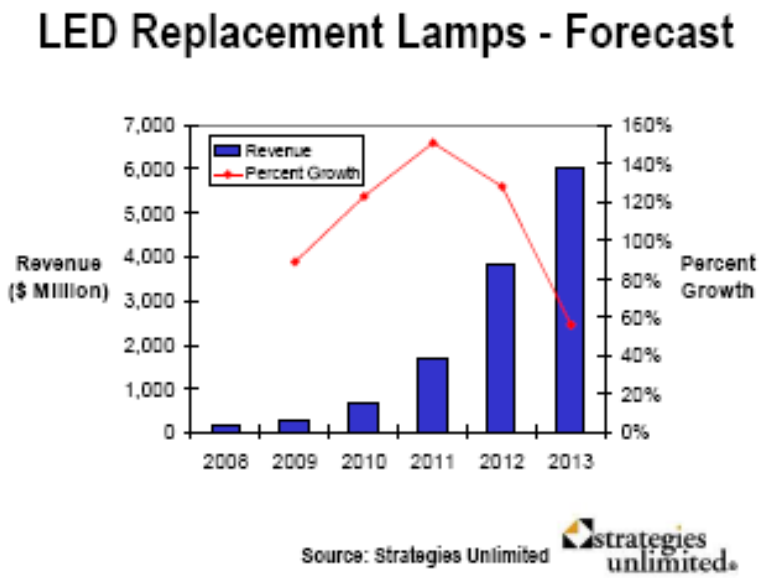


Fig.7: overview of the market outlook for LEDS in general lighting

- Actual barriers to wide adoption of LEDs for general lighting are:
  - At high current it is possible to obtain more lumens, but efficacy is lower (lower performance at high temperatures);
  - Systems with higher colour rendering have usually lower efficacy;
  - Efficacy is lower for warm white LEDs versus cool white LEDs;
  - Efficiencies of the optical components and of the drivers have to be improved.
- It is expected that LED can penetrate a wide range of lighting applications: the rate and extent of penetration are dependent on a number of important factors, ranging from quality and reliability of LEDs components, to accurate and real measurement of LED fixture performances (not only on LED device, but on the complete fixture), to customer education and acceptance.
- An overview of the market outlook for LEDs in general (Fig.6) and an overview for LED lighting market in particular (Fig.7) were presented.

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