

III • Executive Summary



OLED Lighting – ready for takeoff

The increasing viability of OLED as a source of light has led to an increasing number of commercial companies expressing confidence in this new solid-state lighting technology. Whereas in the flat panel display market, OLED technology is seen as an evolutionary replacement for LCD technology, the unique technical features of OLEDs as regards lighting applications are expected to result in a fundamental change.

OLEDs are thin area light sources that emit uniform diffuse light. White OLEDs display very high color rendering properties and this results in a very pleasing and comfortable light. Furthermore, they are fully dimmable, can be switched on and off without any time delay, and already exhibit impressive energy efficiencies and operating lifetimes. There is currently no other lighting technology that can deliver a mirror-like appearance or full transparency in the off-state.

Evidence that commercial interest in this sector is increasing comes via new product-level announcements from companies engaged in OLED lighting technology and a surprisingly strong presence of lighting products and concepts at recent design and lighting exhibitions. At present, the OLED lighting industry is very young and technology driven, contrasting the lighting industry which is very experienced in delivering end-user solutions.

The successful conversion of market interest into commercial products requires a high level of financial investment in the OLED lighting industry. This in turn requires confidence in the growth potential of the market for its lighting products and services. In the scheme of any self-fulfilling prophecy, connecting those two self-serving ends is the means to success.

Against this background there is a need to move the discussion beyond technology and onto the application level. There is also a need to reset short term expectations, which appear to be infected with visions of fully flexible and extremely cheap lighting. This should be achieved by demonstrating that OLED lighting is already a viable, exciting and unrivalled lighting technology.

Design

OLEDs are thin area light sources emitting uniform diffuse light. This technology enables lighting capability to be directly embedded in architectural materials, such as metal and glass. OLEDs do not require light distribution optics - OLED lighting is pure lighting.

Conventional lighting schemes use linear and point sources, not only occupying a volume of space, but also not producing uniform illumination and needing to be combined with optical light management fixtures. OLED lighting offers designers a new lighting design platform that enables the total integration of lighting and architectural materials – something that is not possible today. In addition, both on-state and off-state can be utilized for decorative impact.

Transparent OLED panels made on glass substrates will be able to function as windows during the day and light up after dark, either mimicking natural light or providing attractive interior lighting. Furthermore, they could also function as privacy shields in homes or offices during the day.

OLEDs made directly on metal substrates such as steel, mean that it is now possible to introduce lighting into a widely used architectural product without comprising surface integrity. In addition, such OLEDs demonstrate very good heat dissipation and are therefore ideally suited for high brightness lighting applications. The use of metal plates as substrates offers a route to fully flexible and robust products.

To date, rigid glass and metal substrates have been used to make reliable OLEDs. However, research is being carried out with plastics and thin metal substrates to make flexible OLED lighting and it should reach industrialization level in due course.

Technology

OLED devices consist of a substrate material, metallic electrodes and functional organic materials that are environmentally safe. Furthermore, they do not contain mercury and are made on a variety of substrates which can be opaque or transparent, rigid or flexible, giving rise to different product features and performance levels.

The organic semiconductor materials are molecular, carbon based substances that form extremely thin amorphous layers, typically consisting of separate charge conduction layers and light emission layers that are deposited in a predefined order and referred to as an OLED stack. Upon the application of a low voltage across the OLED, charge carriers are injected from the electrodes into the organic layers. On reaching the emission layer, which is the middle layer of the OLED, the charge carriers recombine and produce light of a predefined color.

The further development of OLED lighting technology is dependent on enhancing the performance and stability of the OLED stack. Electrical improvements, for example reducing the driving voltage, can be realized by doping techniques. Phosphorescent emitter materials are more efficient than fluorescent and improving blue emitter lifetime is the subject of intensive research. Advances in optical engineering contribute to the increased extraction of light and thus higher efficiency.

One hurdle that the commercialization of OLED lighting faces is the cost of manufacturing. Currently, the high efficacy OLED devices are fabricated using vacuum evaporation equipment. This has a high capital cost but with a high throughput, the manufacturing cost can be reasonable. Roll-to-roll manufacturing and solution processing techniques such as ink jet printing have been proposed and represent further possibilities of achieving cost reduction.



Exhibit III.2: OLED lighting panels

Source: Novaled AG

Roadmap

Looking back at a number of innovations which gave rise to new industries and markets, the time between initial key technology development and market breakthrough has tended to be approximately 20 to 30 years. The OLED diode was invented in 1987 by Kodak and the first lighting products appeared from 2005-2007 thanks to Ingo Maurer. Consequently, on paper, OLED lighting appears to be well timed for a breakthrough and evidence on the ground supports this viewpoint.

A number of companies such as Osram, Philips and Panasonic have already demonstrated application-ready lighting modules. Based on product-level data, luminous efficacy is in the range 10-25lm/W. On this measure alone OLED is competitive with some other lighting technologies at both lamp and system level. Lifetimes are also entering the required area for specific products, especially where continuous operation is less of a constraint.

Lighting operating in the range from 25lm/W to 50lm/W is of interest for the broader lighting market. This efficacy range is above that of incandescent and halogen light sources and in the operating range of typical CFL and LED-based luminaires. Current state-of-the-art white OLEDs report efficiencies in the range of 30-50 lm/W combined with lifetimes of 10,000 hours or more.

Such funded programs as OLED100.eu or those coordinated by the DoE in USA and NEDO in Japan are supporting product development efforts with ambitious roadmaps. The OLED100.eu project has a final efficacy target for OLED lighting of 100 lumens per watt (lm/W), a lifetime of 100,000 hours and a relatively low cost of €100/m².

Market

The fledgling OLED lighting industry is now entering a phase in which the underlying technology is mature enough to move beyond futuristic visions and ready to envisage real world applications. Key market drivers include design, energy efficiency and sustainability. OLED lighting scores highly in terms of sustainability due to the small amount of materials used and the thin form factor. This results in less packaging and the inherently long lifetime reduces the disposal of materials.

OLED is a disruptive lighting technology as it brings a different and unique value proposition to the existing lighting market. In addition, full integration of light source and luminaire is possible. And from a technology viewpoint, an OLED light source is closer to being a finished lighting product than other light sources and thus creates entry points for new players in the lighting market.

However, there are significant market challenges to overcome. OLED lighting is an area lighting technology that is not applicable in every lighting situation. It is effective at a system level and therefore directly comparing an OLED to an LED makes no sense. Market education and

responding to the resulting feedback will play an important part of the OLED lighting industry activity.

The lighting industry is highly standardized and has existing product labeling and building codes. The relationships and specification processes involved in lighting the built environment are highly complex. OLED lighting can be integrated into non-lighting products, e.g. flat glass or metal sheeting, which are commonly used construction materials. Those products need to be developed and the interaction between lighting and lighting surfaces will need to be defined.



Exhibit III.3: Novaled desk lamp “Victory” in use setting

Source: Novaled AG

Rethinking Lighting

There is already criticism being directed at OLED lighting technology. Some of it is typical criticism that applies to any new technology, e.g. it is too expensive. However, much of it is borne of the experience with LED, e.g. there are no standards. Further criticism questions the promotion of OLED as a general lighting technology, e.g. lumen output is too low.

OLED performance can be defined and measured according to the existing rules of lighting (lifetime, efficacy, power, lumen output). However, OLEDs have new characteristics that are outside existing parameter boundaries (active area, homogeneity, off-state finish, brightness) and should be part of any discussion between the OLED producer and luminaire designer.

Lighting designers may have to adhere to hard technical and economic specifications, such as efficiency and cost of the hardware. Although of growing importance are soft application factors which determine the total effectiveness or value of the lighting system to the users in the given environment.

OLED lighting requires a fresh start and should be approached with a “Think Luminaire” mindset from the outset. Due to the surface nature of OLED lighting many new functional and design options can be created. Tight integration of the end application needs with the technological capability of the OLED is essential in a way never before considered for lighting.

OLED lighting will reinvigorate the use of lighting in existing applications and extend the reach of lighting into new areas. Specific demands for thin, high quality, area light are already evident in automotive and medical markets and a desire for embedded large area lighting exists. OLED lighting can prove to be a transforming lighting technology with the power to open up a whole new market for decorative and low maintenance lighting in the construction industry.

Product Design

The earliest complete luminaire products were those of Ingo Maurer: Flying Future in 2005 and Early Future in 2007. Philips Lighting announced their MirrorWall in 2009, offering the opportunity to purchase or rent this OLED installation piece. For the most part, commercial OLED products are restricted to small size OLED devices like those offered by the major lighting companies, such as Philips’ Lumiblade or Osram’ Orbeos. However, they send an important signal to observers: OLED lighting is in the industrialization phase and interaction with the lighting community is desired.