Large-area organic light-emitting diode technology

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The technology of solid-state lighting and flat panel displays can benefit from advances in organic layer deposition and homogeneous light output.

Displays based on organic light-emitting diodes (OLEDs) have benefited from significant advances that have now made them commercially available. Due to the high efficiency of the technology, OLED-based lighting is expected to capture a promising market share. OLEDs are flat light sources that emit diffuse light from a potentially large active area. They do not need light distribution elements, which translates into significant cost benefits in the production of lighting panels. In contrast, inorganic light-emitting diodes are point sources that do require light distribution components for flat panel lighting. Another advantage of OLEDs is that, because they produce light via relatively low peak brightness over a large area, they do not build up heat in one spot, so do not need cooling elements.

A typical OLED consists of stacks of organic layers of ~100nm thickness inserted between a cathode and an anode. Usually, the substrate is glass, coated with a transparent conductive oxide as anode, followed by the organic stack and the inorganic cathode (see Figure 1).

OLED technology uses materials from two different groups. The first includes materials with low molecular weight called small-molecule (SM) OLEDs, originally developed by the Ching Tang group at the Kodak Laboratories in 1987. The deposition of SM-OLEDs is based on vacuum thermal evaporation. The other group of materials includes polymer-based OLEDs consisting of long polymer organic chains deposited by spin-cast or ink-jet methods. SM-OLEDs achieve higher efficiencies and currently dominate OLED applications.

One of the key advantages of OLED technology is the chemical variability of the organic luminescence, allowing production of virtually any color, including white, by two or three red, green, and blue layers. Other advantages include the use of thin-film technology, allowing large area and low-cost deposition, and the possibility of using thin and even flexible substrates to realize a novel class of lighting and display solutions not achievable with other technologies.

Figure 1. Schematic drawing of an organic light-emitting diode. Al: Aluminium. ITO: Indium tin oxide.

The fabrication of large-emission-area OLEDs for lighting at a reasonable cost is essential for the successful penetration of large markets. Achieving this goal however, requires OLED fabrication improvements. The electrical doping of the charge transport layers of these devices represents an important step in this direction. The organic materials used in OLEDs commonly have very low conductivities resulting in high device voltages. The problem has been addressed by the simultaneous evaporation of two materials with higher conductivities as organic layers, shown to significantly decrease the operating voltage. Devices with very high power efficiency have also been realized by combining electrical doping with highly efficient emitter systems. A typical architecture for such devices is p-i-n stacking, a proprietary technology of Novaled AG.

Besides producing highly-efficient white OLED devices, fabrication technology improvements are also essential to realize functional OLED lighting tiles. One important requirement is the achievement of an homogenous light output. Based on the limiting conductivity of indium tin oxide (ITO), typically 10ohm/square, voltage drops can be related to lighting inhomogeneities. Improved current distributions therefore require

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development to achieve homogeneous large area lighting. One possibility is to use metal support lines, which can lower the effective ITO resistance to less than 1 ohm/square (see Figure 2). Of course, such metal lines also reduce the effective lighting area, but they can fortunately be limited to a maximum of 10–20% of the lighting area.

The combination of highly efficient OLEDs and improved lighting integration technology recently allowed the fabrication of the largest SM-OLED lighting module ever reported, with dimensions of 80 × 20 cm², subdivided in four panels. The OLED active area is 1100 cm², and the light output of 250 lumen could be improved up to 500 lumen in future modules (see Figure 3).

Other production aspects, such as fabrication yield and costs, should also be addressed to achieve a large market penetration. However, the advances summarized above represent important solutions to achieve promising new lighting technology for the future.

**Figure 2.** Metal support line integration reduces overall resistance and improves evenness of the light output.

**Figure 3.** Large area OLED module. Dimensions: 80 × 20 cm². Light output: 250 lumen.

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**References**