Filtronic and Bookham face some tough decisions

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LED LIGHTING

Lumileds innovation drives market penetration

Tuned in; turned on

Syntune develops fabless strategy as demand soars for tunable lasers.

Spanish fever

GaAs grabs the attention as the mobile industry descends on Barcelona.
Evolutionary new chip design targets lighting systems

Philips Lumileds has combined its thin-film structure with a flip-chip design. The result, say Oleg Shcherchin and Decai Sun, is a highly efficient device for lighting applications that delivers a better performance than vertically injected LEDs.

The performance of commercial white-light LEDs has rocketed over the past few months. Competition has fueled the creation of novel device architectures with improved photon-extraction efficiencies, which have in turn increased the chip’s brightness and output power. This has opened up the range of applications for these devices, and brought their characteristics more closely in line with the requirements for widespread deployment in solid-state lighting.

Among the many LEDs available today for these applications is an InGaN/GaN flip-chip (FC) design by Philips Lumileds, which features in our company’s Luxeon products. We have now built on this success by uniting it with a thin-film (TF) structure to create a higher-performance thin-film flip-chip (TFFC) LED (see figure 1a).

This device combines the manufacturing merits of both approaches, and is produced by taking an FC-LED chip that has an anode and cathode on the same side and bonding it to a submount or package using gold interconnects (see figure 1b). An excimer laser removes the sapphire substrate before photo-electro-chemical etching of the top GaN layer roughens the chip’s surface with an ultraviolet lamp and a dilute potassium hydroxide solution, which disrupts wave-guiding in the high refractive index epilayer. This increases light output and dramatically boosts the LED’s efficiency, which has in turn increased the chip’s brightness and output power. This has opened up the range of applications for these devices, and brought their characteristics more closely in line with the requirements for widespread deployment in solid-state lighting.

The problems of vertical structures are particularly irksome in the tightly packed chip architecture, which eliminates the loss in light output caused by wires and reduces the distance to the primary optic. Vertical thin-film chips (VTF) require a wire bond to create a higher-performance thin-film flip-chip (TFFC) LED (see figure 1a).

Our 425 nm blue LED has a maximum external quantum efficiency (EQE) of 61% and a wall-plug efficiency (WPE) of 44%, and at 2000 mA its output rises to nearly 2 W. This efficiency is among the highest ever reported for blue devices at these current densities. The encapsulated white-light TFFC LED, which incorporates a YAG:Ce phosphor, has a peak luminous efficacy of 147 lm/W at 10 mA. At 350 mA it delivers 88 lm/W and at 1000 mA it produces 56 lm/W (see figure 5). These efficiencies are far higher than those produced by halogen sources, which typically emit 25 lm/W, and will enable manufacturers of lighting systems to deliver greater electrical efficiencies.

Lumiance mapping across the surface of one of our non-encapsulated 1 mm x 1 mm white LED chips reveals a peak lumiance of 58.8 Mnit (Med/m²) and an average surface brightness of 50 Mnit (figure 6). This brightness makes the chip a strong contender for projection displays and automotive headlights. The average brightness of LEDs, which is delivered at a luminous efficacy of 40 lm/W, is much higher than that of a halogen source (15–30 Mnit at ~30 lm/W) and not far behind the average effective brightness of high-intensity discharge lamps (60–80 Mnit at ~100 lm/W).
Our devices also have a significant advantage over these two alternatives: a relatively uniform, tightly controlled emission surface. This eases the design of secondary optics and boosts utilization efficiency, advantages that are particularly attractive for automotive forward lighting. In fact, programs are now underway to install devices in production cars. Monochromatic LEDs, which have a very high surface brightness, are also reaching the point where they can compete directly with ultrahigh-pressure projection bulbs because they do not require color filtering.

Reliability, another key parameter for commercial success, has been examined with in-house high-temperature reliability testing using direct current conditions and a 1 A drive current. Light output power drifted by at just a few percent during a 1000 h white-light LED chip test at 110 °C and a 7000 h blue-light device test at 85 °C.

We have also combined this TFFC design with other technologies developed by Philips Lumileds to produce a 1 mm × 1 mm demonstration chip that delivers 115 lm/W at 350 mA, 61 lm/W at 2 A and a maximum light output of 502 lm. This LED has a correlated color temperature of 4685 K, which is lower than that of many chips produced by our competitors and closer to the wishes of our customers.

**Product roll-out**

The various technologies that feature in this record-breaking chip will be united in our products over the next 12–18 months. However, in the meantime customers will be able to purchase our first TFFC LEDs, which offer an unmatched combination of performance and versatility. These devices, which will be launched this spring, will deliver a reliable, high light output and brightness, and will be suitable for use in various lighting systems from projection to general lighting. We expect that this device platform will provide LED customers with a greater value than ever before, and establish a sound basis to proliferate solid-state lighting.

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**About the authors**

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