OPTOVATE

NEW PACKAGING FOR LED LIGHTING

OPTOVATE LTD
KEY DATA: FACT FILE

Technology
LED optics manufaturing process

Established
2008

Type
IP producer

Location
Oxford

Employees
2

Founders
Jonathan Harrold, Graham Woodgate
The founders are physicists with optics and display backgrounds, they met at Sharp Laboratories of Europe in Oxford during the time of rapid growth in the Liquid Crystal Display (LCD) industry in the early 1990s. In 2001, they co-founded Ocuity Limited, where they developed glasses-free 3D technology which they sold to AU Optronics of Taiwan in 2008.

By bringing together insights from their experience of LCD manufacturing with a deep understanding of micro optics, Optovate have developed a new approach to LED manufacturing which could transform the pace at which LED lighting is adopted.

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A NEW LED PRODUCTION APPROACH

Conventional LED lighting manufacture follows a mainly serial assembly process where an inorganic semiconductor die (typically gallium nitride) is wire bonded in a lead frame and combined with phosphor and optics. The package is then attached to a thermal and electronic backplane with other similar devices - one at a time - in order to make a sufficiently bright lamp. The approach has many parallels with pre-LSI electronics. It occurred therefore to Optovate that they could use their knowledge of highly integrated manufacturing methods from LCDs and micro-optics to provide a scaleable, parallel, fully integrated (LSI-like) solution for LEDs.

LCD ORIGINS

The two founders, Woodgate and Harrold, have a track record of working at the leading edge of micro optics and LCDs. They met at Sharp Laboratories Europe, based in Oxford, and then went on to establish their own company, Ocuity Ltd, where they developed a proprietary autostereoscopic (glasses-free) 3D display system. Ocuity received funding from a consortium of investors, including TTP Ventures and BTG Group, in 2003, before the technology was sold to AU Optronics of Taiwan in 2008.

As a condition of the sale, the founders were 'locked in' for two years while the technology was transferred to AU Optronics. Their strong track record of developing IP for LCD manufacture proved valuable in the transfer to volume production enabling AU Optronics to provide technology that was launched successfully in 3D laptop and TV products.

TIPPING POINT

After the sale of Ocuity, Harrold and Woodgate came to the conclusion that LED lighting was going to be the next promising field, as it seemed to be at the same 'tipping point' that the LCD industry had been at the start of the 1990s. Also, the largest user of white LEDs was the LCD backlight industry, which suggested to them that new movers in LEDs would be from within the LCD industry itself, looking to transition experience and infrastructure in backlights into more general LED lighting. Importantly, this meant that Woodgate and Harrold would be able to leverage their existing contacts in the LCD industry.

NOVEL LED LIGHT ENGINE

The opportunity they saw in the LED lighting market was to make directional light engines thinner and cheaper. Compared to omni-directional lighting, such as light bulbs, or fluorescent troffers that tend to produce flat and uniform illumination, directional lighting uses collimating optics to deliver structure and contrast to projected light patterns – typically achieving results which are aesthetically more pleasing. Halogen down-lighters are a form of directional lighting, but much less efficient.

THINNER OPTICS

The optics to collimate LED light are well known, so their first thought was to look for a way to design thinner optics. They knew from fundamental physics that making the optics thinner implied making the LED chips much smaller and using many more of them in parallel. The problem was that this would require probably more than one hundred times as many devices for the same output of light.

It was also quite counter-intuitive to think of using smaller devices to generate more light, since the industry was taking the different tack of using larger LED chips to achieve higher light output. However, Optovate discovered that if the devices were arranged in an array of many hundreds of sparsely separated micro-LEDs it caused the light output actually to increase. It still left the problem to solve that existing LED packaging approaches - using pick and place and wire bonding - were far too expensive for handling many hundreds of these 'micro-LEDs'; so they had to find another way.

LCD INSIGHT

The insight they had to solve this came about from combining their experience in the LCD industry of electrode-on-glass (TFT substrate) and of optics-on-glass (colour filter substrate)

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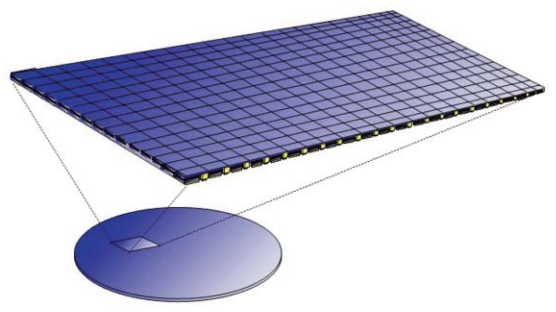
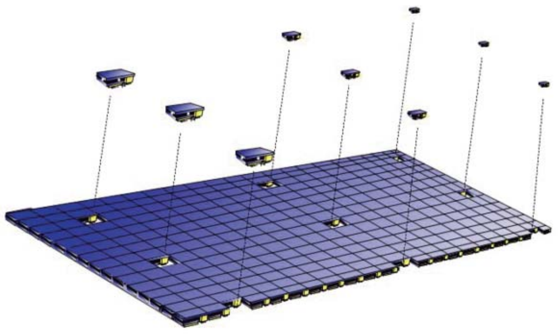
SCALE PROCESS MANUFACTURING STEPS

1x1mm high power LED → 10 x 10 array of 100μm micro-LEDs.

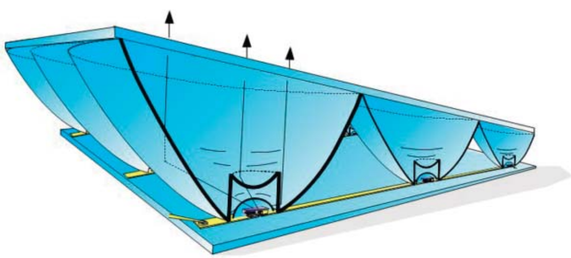


STEP ONE
Standard GaN epitaxy and wafer processing.



STEP TWO
Extract micro-LEDs in parallel and place a whole group in one operation.

STEP THREE
Mount onto lithographic electrical / thermal substrate.



STEP FOUR
Attach micro-optic array.

technologies, together with the wafer scale (gallium nitride) lithographic processes of the LED industry. They found that in particular 0.1mm x 0.1mm square micro-LEDs on a 2mm pitch worked well for this; whereas conventional devices used 1x1mm LEDs on a 20mm pitch.

PATTERNED LASER LIFT OFF

The next challenge was how to remove these sparse arrays of micro-LEDs from the GaN wafer - otherwise 99.75% of the wafer area would be wasted by not using the wafer area between the extracted chips. They realised this could be solved by using a 'lift off' process to transfer the GaN micro-LEDs in parallel to what Optovate calls a glass 'mothersheet' substrate containing electrodes and heat management layers. To do this they developed a proprietary process, which they call 'Patterned Laser Lift Off' (PLLO). This is able to remove arrays of many thousands of micro-LEDs from a GaN epitaxial wafer to the mothersheet while at the same time preserving the original lithographically-defined positions of the micro-LEDs.

MANUFACTURING BENEFITS

By using the same lithographic technique for the electrodes they found it possible to connect the array without the need for wire-bonding of all the numerous separate connections. This simple transfer method 'makes a vital difference' they say, bearing in mind the yield and reliability issues that would otherwise have to be overcome for sequentially bonded devices in such large numbers.

The micro-LEDs are sampled from across the wafer area, so that the total output of the light engine is a statistical average of total wafer area rather than sampled from a small area of the wafer – something that can reduce the need to separate the LEDs from a

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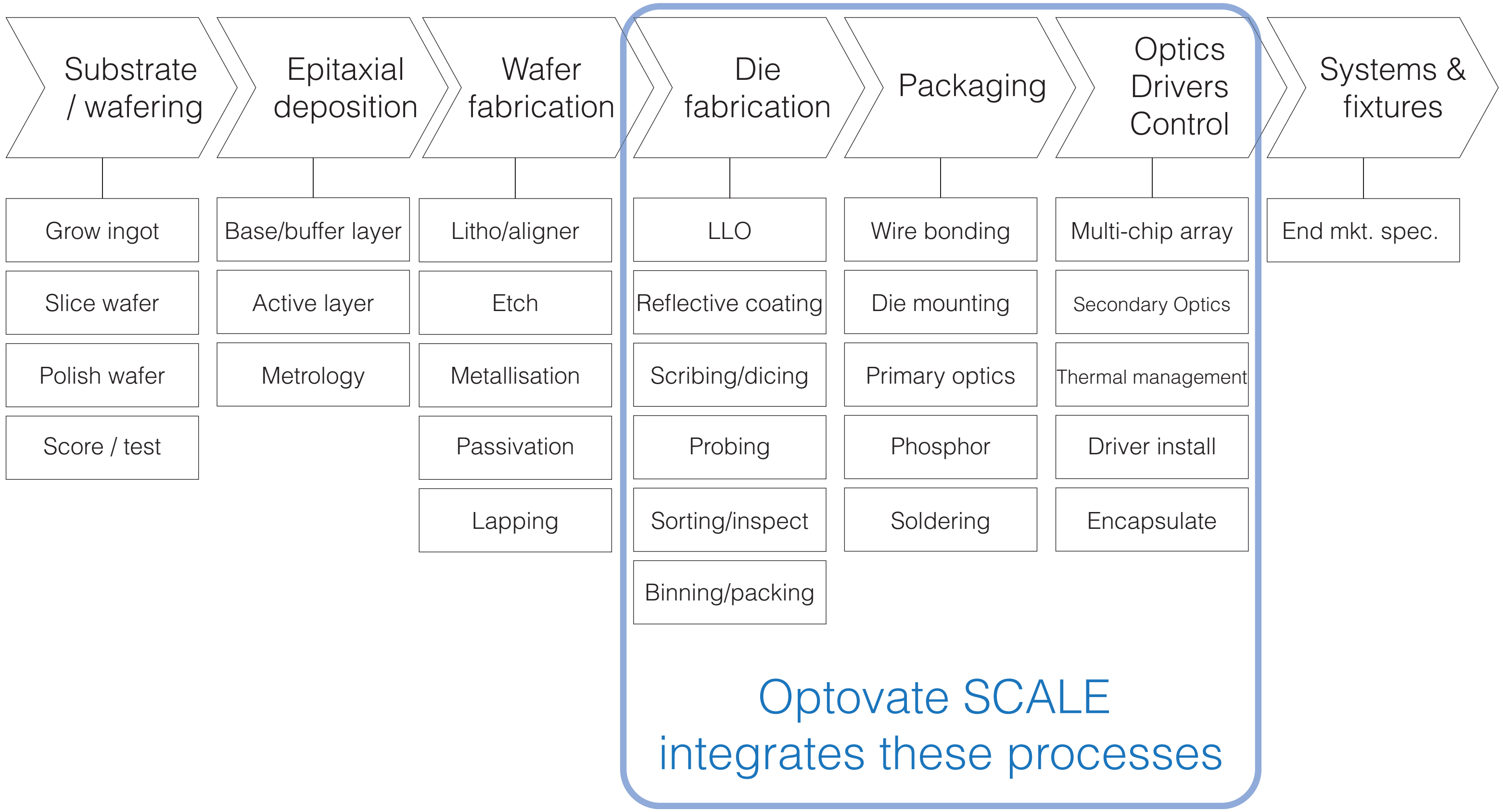
wafer in to separate wavelength “bins”. As a result, they found the quality of light output for each device is increased.

Another advantage of the process is that it is possible to align a single very large array of individual collimating optics on a second glass substrate to the micro-LEDs on the mothersheet in a single step. This they say gives ‘tremendous cost savings’, as well as helping to achieve the targeted thinness of the optics.



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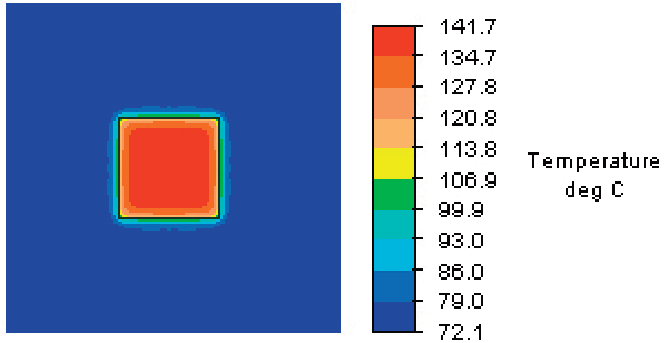
GLASS SUBSTRATE

Optovate's process can be used with large area, inexpensive, glass substrates of more than 1000mm x1000mm which can be cut to the required lamp size using the same methods as the LCD industry uses to cut different size panels from a mother glass sheet. It means that manufacturers can use existing (or obsolescent) LCD manufacturing lines to manufacture the LED lights, thereby reducing capital costs significantly. The transfer and lift off process is also quicker, so it shortens the production cycle and increases productivity.

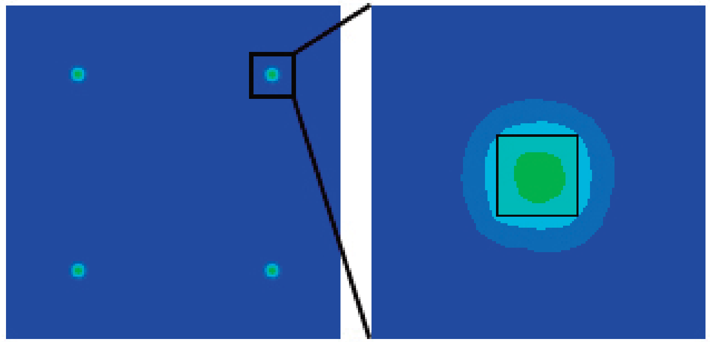
Optovate's slimline Micro LED array compared with a standard LED lamp

HEAT TRANSFER

The cost of the heat sink has become the single most expensive component in an LED lighting unit, expected to account for over 50% of the total light engine cost. The configuration of sparse micro-LEDs on the mothersheet significantly improves heat transfer - Optovate likens it to spreading out the embers of a fire.



Standard LED 1x1mm LED, 1x1W



SCALE 0.1x0.1 micro-LED array, 100x0.01W

SCALE has ~50% like-for-like junction temperature compared to equivalent 1x1m device

Historically, glass has been considered unacceptable for use as a substrate for an LED due to its relatively low thermal conductivity. Optovate have been able to use glass because they have exploited a process for thinning the glass, making use of a standard mass production process in the LCD industry, which delivers significantly improved heat extraction. Optovate say these twin insights have made it possible to reduce by half the size of the heat sink and therefore also the cost.

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LIGHT MANAGEMENT

The multi-LED array mothersheet configuration enables the light emitted to be tailored to suit the particular requirement for power, directionality, light quality, and operating voltage. It can be used for example to minimise glare. Here it is not usually possible to look directly at a directional light due to its very strong glare. The SCALE process however makes it possible to reduce or remove the appearance of glare by incorporating inside a SCALE light engine, a low-cost camera that can analyse the position of the observer's eyes and make sure the light directed towards them is switched off, while still sending light elsewhere. This opens up the opportunity for completely new types of lighting environments: it would, for example, be possible to place a light on a wall (rather than the ceiling) which could be shining around a person, rather than at them, and therefore not dazzle them.

PATENTS

The core patent for the SCALE technology is already granted in the UK (GB2,463,989). This covers the extraction and placement of an array of micro-LEDs from a wafer so that the whole semiconductor growth wafer can be used and aligned with an optical array for mothersheet processing. This patent is pending in other key territories with a wide portfolio of supporting patents also pending.

BUSINESS APPROACH

Optovate are preparing to engage actively with potential licensees. While they were licensing their technology at Ocuity they built up a strong network of contacts in the electronics sector. They have also built up valuable IP management skills. This is reinforced by the fact that between them Harrold and Woodgate have authored around 100 patents, many of which have already been exploited in high volume consumer products.

Licensees will receive demonstrators of the Proof of Concept to show how the SCALE process works, while Optovate will provide technical support to ensure a successful transfer through to volume production, a process with which they are now familiar. Their optical system skills are in very short supply, they add, since the community of leading optics innovators is very small.

CONFIDENCE

Harrold and Woodgate believe firmly that the lighting industry will come to recognise that their approach is the inevitable way forward as the limits of LED efficiency are reached over the next two to five years while the system cost-down pressures will remain for many more years. With patents about to grant in key territories, they are ramping engagement with key manufacturers. The stage may be set for a repeat of the successful model at Ocuity. ■

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