by Stuart Cherry Images: Philips. Illustration: Roland Blokhuizen

OLED windows are transparent during the day but can light up the room at night.

Thinking outside the **bulb**

Ever seen a window that gives natural-looking daylight in the middle of the night? Or a glowing ceiling that evenly lights your workspace without glare or flicker? Well you could soon, thanks to a revolutionary new lighting technology that may also slash your electricity bills and carbon emissions.

The organic light emitting diode (OLED) is not just another lighting technology. And it's not another version of the chip-based LED. It's something fundamentally different. For a start, OLEDs aren't bulbs or point sources, but thin, glowing sheets that produce diffuse, constant light of almost any color.

You're unlikely to ever see OLED bulbs in the shops. Rather, OLEDs are all-in-one lighting systems or luminaires – complete with built-in reflectors and diffusers for directed yet gentle light. This makes OLEDs ideal for applications that evenly illuminate a wide area – something current lighting options don't easily cover. By contrast, their chip-based cousins, LEDs, are perfect for spotlight effects and as replacements for traditional bulbs.

Unique effects

Although the technology is still in development and very few products are currently available, lighting designers are already excited about the never-before-seen applications that OLEDs enable. Renowned German lighting designer Ingo Maurer, one of the first to use OLEDs in the industrial arena, is fascinated by how different they are from traditional light sources.

"OLEDs have a completely different look. They don't require large sockets or external reflectors for directing light," he says. "They are very light, allowing me to realize some long-standing visions of mine." These include a coffee table that appears to float magically in the air, and a suspended light fitting he describes as like "a flock of extraterrestrial beings, hovering and moving in the passing wind."

Jeff Gerwing of the US-based SmithGroup is equally excited: "For lighting designers, OLEDs present amazing new opportunities. In fact, OLEDs could revolutionize how we use light to shape architecture. The sky's the limit!"

For example, being very thin (typically less than two millimeters), OLEDs can be embedded into surfaces like walls, table tops or ceilings. Ambient lighting could then become an integral part of a building's look and feel – giving it real 'hidden lighting' without intrusive fittings.

Look and feel

Because of their small size, OLEDs have the potential to be embedded into objects and surfaces of almost any shape. Like most lighting technologies, the light-emitting part needs to be protected from the environment. Incandescent and fluorescent lamps use glass bulbs and tubes. For OLEDs, you need a protective substrate, and currently glass is the best option. But since OLED technology isn't tied to a certain form, designers have an almost limitless scope to create new scenes and features.

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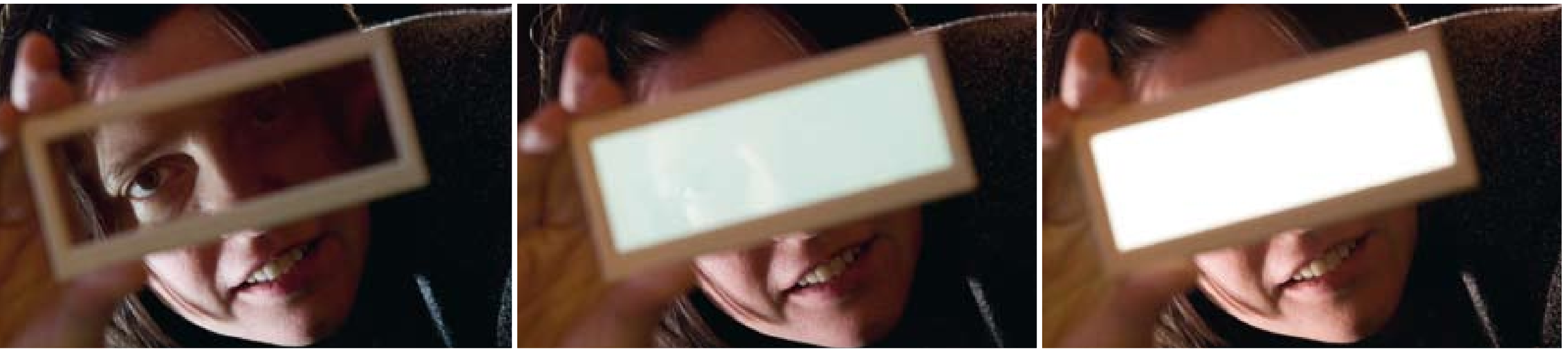


Transparent OLEDs can turn normal windows, which let natural sunlight in during the day, into diffuse indoor lighting sources at night.

Looking ahead, plastic substrates are being developed that could potentially replace glass by providing the same level of protection against moisture and air but with less constraints. When these become available, OLEDs could become curved, moldable and even flexible. Users could reshape light sources to suit their mood – or fold them up and carry them in their pockets.

Perhaps most intriguingly, OLEDs could one day be made using completely clear substrates, light-emitting materials and electrodes. These transparent OLEDs would enable glowing mirrors, or even windows that let natural sunlight through during the day and deliver pleasant, diffuse indoor lighting when the sun goes down – the options are almost limitless. "For a lighting designer, this is really exciting," Gerwing says.

Green lighting

It's not just OLEDs' design possibilities that excite potential users. The technology could also dramatically cut lighting's environmental impact. Like their chip-based cousins, OLEDs directly convert electricity into light via 'electroluminescence'. So both technologies have the potential to be extremely energy efficient. In fact, OLEDs could be as much as ten times more efficient than standard incandescent bulbs and around three times more efficient than today's energy-saving compact fluorescents (CFLs).

As lighting currently consumes about 19% of the world's electricity, technologies such as LEDs and OLEDs could significantly reduce global energy consumption and fossil fuel usage. That, in turn, would slash carbon dioxide emissions. What's more, unlike CFLs, OLEDs don't contain mercury or other environmentally sensitive materials, and can be easily and safely disposed of at the end of their life. Nor do they suffer other issues sometimes associated with current energy-saving lamps: they are instant-on, don't flicker, can be dimmed and emit a crisp, clear color.

A technology on the rise

OLEDs are clearly a globally important technology. Consequently, they are attracting attention from research groups around the world. In line with its goal to reduce CO_2 emissions by 20% by 2020, the European Union has partially funded two public-private research projects focused on OLED technology through its Research Framework Programme.

The first was the recently concluded OLLA project. The 24-member consortium behind the project was made up of universities, research institutes and companies including Philips. Covering the whole value chain, the project laid the technology foundations for OLED devices and investigated materials, manufacturing techniques, device technologies and application requirements.

Efficiency was a key project objective given that previous OLEDs had limitations in this area. A light source's efficiency is often expressed in terms of its 'luminous efficacy' – the amount of light (in lumens) emitted for a given input power (usually in watts).

In June 2008, the project announced it had achieved an impressive feat: a white-light prototype with a luminous efficacy of 50.7 lumens per watt (lm/W) and an initial brightness of 1000 candelas per square meter, with a lifetime above 10,000 hours. This is comparable to today's CFLs but is just the beginning for OLEDs.

A worthy goal

On September 1, 2008, the baton passed to the OLED100.eu project, focusing on devices and applications. According to OLED100.eu project manager Stefan Grabowski of Philips Research, the key aims are "twice the efficiency, ten times the operational lifetime and a factor-of-ten increase in panel size to one square meter."

Project members believe these ambitious goals are achievable with current light-emitting materials. Grabowski predicts that optimizing the OLED device structure and the way light is channeled could double the luminous efficacy.

In achieving its 100 lm/W goal, the OLED100.eu project will take OLED efficiency past that of fluorescent tubes – currently the most efficient commercial white light source. But the project team has even bigger dreams, as Philips Lighting's Dietrich Bertram, a member of both the OLLA and OLED100.eu projects, explains. "Energy prices won't fall, so we'll keep pushing efficiency as long as it's commercially worthwhile. Nobody knows what the limit is, but 150 lm/W should be possible." With the technology developing rapidly, new performance records are constantly being reported. But since different groups often use different reporting standards, it's hard to keep track of progress and compare products. In a move to hasten market uptake, the OLED100.eu project is working on exactly this: a set of industry-recognized standards.

Coming soon?

So when should we see OLEDs lighting up our homes and workplaces? Bertram believes it won't be too long. "OLEDs will have an impact on the general lighting market within eight to ten years," he predicts. "But we should see some of these new, breakthrough applications appearing within three to five years."

As yet, no one dares to say what those first OLED applications will look like. In fact, the OLED100.eu project team is keen to hear ideas and suggestions from potential users. But one thing is certain: it won't be a boring old bulb.

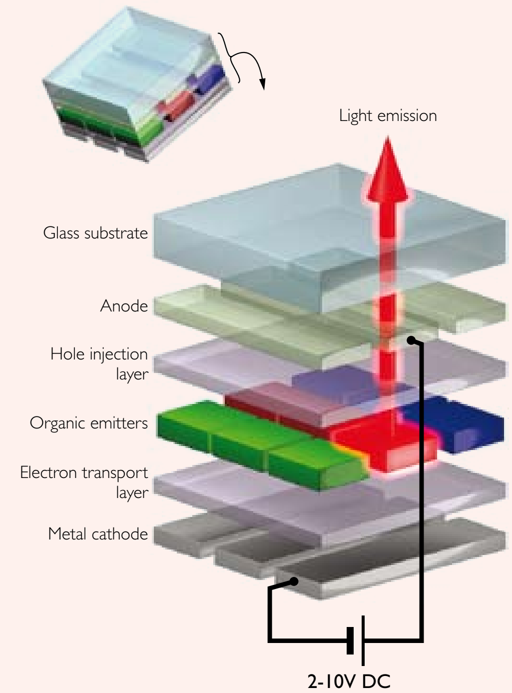
More

Making OLEDs glow

Cut through an OLED and it looks like a tiny multi-layer sandwich. There is a thin cathode, typically aluminum, on the bottom and an anode made from a transparent oxide, such as indium tin oxide, on the top. The filling consists of layers of organic semiconductors.

Just like chip-based LEDs, OLEDs produce light through electroluminescence. When a voltage is applied across the electrodes, electrons are injected into the semiconductor layer near the cathode and removed at the anode – leaving behind positively charged 'holes'. The electrons and the holes travel through the semiconductor layer until they meet and re-combine, emitting a photon of light. The energy of the photon, and hence the color of the light emitted, varies for different semiconductors.

As the process directly converts electricity into light, electroluminescence is inherently more efficient than incandescent bulbs where a wire is heated until it glows, leaving as much as 90% of the energy consumed to be diffused as heat. Careful device design can increase efficiency even further, either by improving the 'electron-hole' process or by ensuring more of the light produced leaves the device in the optimal direction. This latter process is known as 'light outcoupling'.



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