The Economist, Mar 4th 2010

Consumer electronics

Tiny semiconductor crystals, called quantum dots, enable new forms of energy-efficient lighting

HOW many inventions does it take to change a light bulb? More than you might think. Around the world, many people are switching from traditional incandescent bulbs to compact fluorescent (CFL) bulbs, which require less energy to produce a given amount of light, and therefore save money and reduce carbon emissions. But CFLs themselves may soon be overhauled by light emitting diodes (LEDs), which are even more energy efficient and have the further advantage that they come on instantly at full brightness, unlike CFLs, which can take a while to warm up. Advocates of LEDs note that the technology is versatile enough to work in almost any situation, from stadium lighting right down to the tiny light on your phone that flashes to indicate a new message.

But not even LEDs, it seems, are the end of the story. Yet another lighting technology is on the horizon that offers further advantages: even greater power efficiency and softer, warmer light, the colour of which can be precisely controlled. Even though it will be put to rather mundane uses, the technology in question has an exotic name: quantum-dot lighting.

Quantum dots are tiny crystals of semiconducting material just a few tens of atoms, or a few nanometres (billionths of a metre), across. They are typically made using some combination of zinc, cadmium, selenium and sulphur atoms. Their origins go back to work published in 1983 by Louis Brus, then at Bell Labs, in New Jersey, though it was several years before another physicist, Mark Reed at Yale University, described these tiny semiconductor clumps as “quantum dots”. When excited by light or electricity, a quantum dot emits light of a colour determined by the dot’s size and the material from which it is made. Light of a particular colour can therefore be produced by exciting dots of a specific size.

Seth Coe-Sullivan, co-founder and chief technology officer of QD Vision, a start-up spun out of the Massachusetts Institute of Technology, likens a quantum dot to a tuning fork: when it is struck, it oscillates at a specific, fixed frequency, producing a note of a particular pitch (or, in the case of a quantum dot, light of a particular colour). This has immediate applications in general lighting, but quantum dots can also be put to many other uses.

Shine a light

In lighting, quantum dots allow the colour of the light from a light source to be precisely controlled, says Jason Hartlove, the chief executive of Nanosys, based in Palo Alto, California—one of a handful of companies making quantum dots and selling lighting components based on them. The first products to come to market use quantum dots to produce warm, white light from blue LEDs. In essence, quantum dots are used to change the colour of the light. The advantage of this approach is that blue LEDs are the brightest, most energy-efficient kind.

Existing white LEDs are also based on blue ones, the light from which is used to excite a phosphor layer made of yttrium aluminium garnet (YAG). The phosphor absorbs some of the blue light and is “pumped” into an excited state. When it relaxes, the energy it has absorbed is re-emitted as yellowish light. The combination of blue and yellow produces a rough approximation of white light. But it contains less red light than is found in natural light, says Mr Hartlove. As a result, the light seems cold and harsh. The same is true of some kinds of fluorescent lighting, which are also deficient in red light. “The light is not very pleasing to the human eye,” says Dr Coe-Sullivan.

QD Vision’s first product, developed in conjunction with Nexxus Lighting of Charlotte, North Carolina, consists of a film embedded with quantum dots of different sizes in carefully chosen ratios. The film attaches to the front of a bulb containing several blue LEDs, and acts like a phosphor: blue light from the LEDs excites the quantum dots, causing them to emit light in a range of colours which combines to form white light.

This approach has two advantages over using a YAG phosphor: with the right combination of quantum dots, the resulting light can be tuned to be much warmer; and quantum dots convert blue light to white light with an efficiency approaching 100%, so less energy is needed to produce a given amount of white light. The bulb will go on sale this year. It will offer the performance of a 70-watt incandescent bulb but will draw only 11 watts. (A comparable CFL bulb would draw around 15 watts.)

Nanosys is using a similar approach, coating blue LEDs with quantum dots to produce highly efficient white LEDs for use as backlights for the liquid-crystal displays (LCDs) used in computers, mobile phones and televisions. In January the company signed an agreement with the component-manufacturing arm of LG Electronics, which will use its products to produce backlights for mobile-phone displays. Nanosys calls this quantum-dot backlighting technology Quantum Rail. It requires only about half as much energy as the conventional white LEDs used in backlights, which should help extend the battery life of mobile devices, as well as providing richer, more saturated colours.

This trick of stimulating quantum dots using light in order to get them to emit light of their own is called photoluminescence. Solutions of quantum dots in chloroform glow vividly when illuminated with ultraviolet light, turning light that is imperceptible to human eyes into bright colours. But quantum dots can also be made to glow using direct electrical stimulation —a phenomenon called electroluminescence. The problem is that this latter approach is currently much less energy-efficient, says Dr Coe-Sullivan. Provided this problem can be overcome, however, it should be possible to manufacture quantum dots in large, flexible sheets, opening up many new possibilities in lighting. The first electroluminescent products are likely to be light bulbs, which will probably be available from around 2012, he says. But the technology would also make possible glowing wallpaper that emits light directly, and could be used to make new kinds of signage and displays.

Dots on display

A quantum-dot display would work by arranging quantum dots that emit red, green and blue light in a grid-like pattern, and getting those dots to emit light directly. LCD displays, by contrast, filter light from a backlight through an array of tiny coloured filters and liquid-crystal shutters. This approach works well enough to have made LCDs the dominant display technology, but only a small fraction of the light (typically 10-20%) from the backlight passes through the display. An “emissive” display that emits light directly could therefore be five to ten times more energy-efficient.

One type of emissive display that already exists is based on organic light-emitting diodes (OLEDs). These displays offer deep blacks and high contrast ratios (because no light is emitted from the display in black areas), and are lighter and thinner than LCDs. But the organic materials have a limited lifetime and the technology is expensive to scale up. As a result OLED displays are used in some mobile phones and small televisions, but they have not caught on widely. Researchers have already built experimental displays that combine quantum dots with the underpinnings of OLED displays. Such QD-LED displays may well dethrone LCDs as the dominant display technology in a decade or so. They would offer the benefits of OLED technology, including deep blacks and low power consumption, but with a much longer lifetime, says Mr Hartlove.

Such considerations are likely to become more important in the next few years, says Michael Edelman, the chief executive of Nanoco Technologies, based in Manchester, England, which also produces components based on quantum dots. California has introduced legislation to reduce the power consumption of televisions and computer displays by 33% by 2011 and 50% by 2013, he says, and other parts of the world are likely to follow suit. As a result, manufacturers are actively looking for new ways to reduce the energy consumption of their displays. Quantum dots can help, first by making backlights more efficient and then, potentially, in the form of quantum-dot displays.

But this will mean making quantum dots in much larger quantities, says Mr Edelman. So far, demand for quantum dots has been relatively small: they are used in medical imaging, for example, as a form of highly stable and extremely bright dye. (Cells or molecules of interest that are tagged with quantum dots, sometimes coated with polymers to reduce their toxicity, glow brightly when illuminated.) The volume of quantum dots required is minuscule, however: they are made in batches of a few milligrams at a time.

In order to meet the growing demands of the display market, by contrast, around three tonnes of quantum dots will be needed each year by 2012, Mr Edelman predicts. Moreover, environmental regulations such as the European Union’s Restriction on Hazardous Substances directive are encouraging manufacturers to move away from heavy metals such as cadmium, which is commonly used in quantum dots. Accordingly, Nanoco has spent the past five years devising ways to mass-produce cadmium-free quantum dots. “The performance is now as good as, if not better than, cadmium products,” says Mr Edelman.

Quantum dots are still a technology in their infancy. Researchers are also investigating their use in solar panels, where they could turn light into electricity, instead of the other way around, or make existing solar panels more efficient by enabling them to harvest more of the solar spectrum. Most bizarre of all is the use of quantum dots to build quantum computers, which operate in a fundamentally different way to traditional computers, with each quantum bit, or qubit, able to exist in multiple states simultaneously, rather than storing a straightforward one or zero. Such outlandish possibilities aside, however, it seems likely that quantum dots could become widespread in the next few years in banal household devices such as light bulbs, televisions and mobile phones. It is often said of new technologies that their future looks bright, but in the case of quantum dots that is no exaggeration—it is the literal truth.

A quantum leap for lighting

Approximate Equivalence	75 Watt Incandescent
Base Type	E26, GU24
Average Wattage	18-20 Watts
Power Factor	> .92
Voltage	120 VAC (60Hz)
Color Temp (ANSI)	Natural White (5000K) Warm White (3000K) Inc. Warm White (2700K)

http://www.arraylighting.com/