The Economist, Mar 19th 2009

A brilliant new approach

Light-emitting diodes will transform the business of illumination, especially with new production breakthroughs

"INCANDESCENT" might well describe the rage of those who prefer traditional light bulbs to their low-energy alternatives. This week, the European Commission formally adopted new regulations that will phase such bulbs out in Europe by 2012. America will do so by 2014. Some countries, such as Australia, Brazil and Switzerland, have got rid of them already. When a voluntary agreement came into force in Britain, at the start of the year, people rushed out to buy the last 100-watt light bulbs. Next to go are lower-wattage bulbs.

But what will replace the light bulb? Although obtaining illumination by incandescence (ie, heating something up) goes back to prehistory, it was not until 1879 that Thomas Edison demonstrated a practical example that used a wire filament encased in glass. Modern bulbs, the descendants of that demonstration, are cheap (around 50 cents) but inefficient, because only about 5% of the energy they use is turned into light and the rest is wasted as heat. A typical bulb also has to be replaced every 1,000 hours or so.

Without changing light fittings, the cheapest direct replacement for an incandescent bulb at the moment is a compact fluorescent light (CFL). These use up to 75% less power and last ten times longer, but they cost around $3 each. That price puts some people off, which explains part of the hoarding of incandescent bulbs. But others object not to the price but to the quality of the light, which has a different spectrum from the one they are used to. CFL bulbs can also be slow to reach maximum illumination. And some people worry that they may be bad for the health. Fluorescent lights use electricity to excite mercury vapour. This produces ultraviolet light that causes a phosphor coating inside the bulb to glow. The lights can flicker, which could set off epileptic fits, and badly made ones might leak ultraviolet radiation, and may thus pose a cancer risk. There are also concerns about the disposal of the toxic mercury.

Light-years

The most promising alternatives are light-emitting diodes (LEDs). An LED is made from two layers of semiconductor, an "n-type" with an excess of negatively charged electrons, and a positive "p-type" which has an abundance of "holes" where electrons should be but aren't. When a current is applied across the sandwich, the electrons and holes team up at the junction of the two materials and release energy in the form of light. The colour depends on the properties of the semiconductor, and these can be tuned to produce light that is similar to natural daylight but with virtually no ultraviolet or heat.

Light-emitting diodes have progressed from simple red indicators on electronic products to become torches, streetlights and car headlights. Now the first mains-voltage LEDs designed as direct replacements for incandescent bulbs are arriving on the market. Some, such as the Philips Master LED range, promise energy savings of up to 80% and a working life of 45,000 hours. But they are not cheap: around £40 ($56) in Britain.

Even so, LEDs can still be economical. Only a quarter of lighting is domestic. Businesses and public organisations are more aware of running costs than householders are—and besides the electricity bill they also have to pay people to change bulbs that have failed. For the bulbs to be embraced by households, though, LED costs will need to come down.

Manufacturing efficiencies, as always, will help. But the biggest cost reduction will come from breakthroughs like that recently made by the Centre for Gallium Nitride at Cambridge University, England. Gallium nitride is a semiconductor used to create bright-blue LEDs. These can be made to emit white light by coating the device with a phosphor compound that absorbs part of the blue light and re-emits it as yellow. When combined with the rest of the blue this forms a cool, white light. Most of the white LEDs now on the market are based on gallium nitride.

At present these LEDs are made in machines similar to those used to make silicon chips, by depositing layers of gallium nitride on sapphire-based wafers. Sapphire is robust enough to withstand a process that first heats it to 1,000°C and then cools it to room temperature without causing cracks and other defects. It is, however, quite expensive. What Colin Humphreys and his colleagues at Cambridge have come up with is a reliable way to deposit gallium nitride on much cheaper silicon wafers, which they estimate could cut production costs to a tenth of what they are at the moment.

Because the atomic lattice structure of gallium nitride is better matched to sapphire than it is to silicon, making LEDs on silicon without distortions has proved extremely tricky. The technique used at Cambridge involves depositing additional layers of gallium nitride-based materials, one as a "compression layer" to provide greater resilience and another as an ultra-thin mask that increases the accuracy of fabrication. The important measure of success is the internal quantum efficiency, which shows just how good an LED is at making light. A gallium nitride LED on sapphire has a typical internal quantum efficiency of around 70%. In the past year, Dr Humphreys's team has improved its silicon-based ones from 15% to 45%.

They will get better still, reckons Dr Humphreys. Yet even at this early stage he thinks gallium nitride-on-silicon LEDs would make commercial sense. Besides the lower cost of silicon, the process could also use larger and more economical six-inch (15cm) wafers and be carried out with more common fabrication equipment.

A number of companies are working with Dr Humphreys to commercialise the process. The techniques employed might also help to improve LEDs that produce white light by mixing red, green and blue emitters. These can be modified to produce different colours of light, too, but they have not taken off quickly because they can be hard to package. It is also difficult to maintain consistent outputs from the different LEDs so light from the devices tends to drift into off-white hues.

Developments like the use of cheap silicon make the case for switching to LED lighting even more compelling. About 20% of the world's electricity is used for lighting. America's Department of Energy thinks that, with LEDs, this could be cut in half by 2025, saving more than 130 new power stations in America alone.

Low-cost LEDs would also bring light to new areas. Philips, for instance, is planning to launch a small solar-powered LED reading light for Africa, where an estimated 500m people live without electricity. The simplest version, which it hopes to sell for less than $15, is designed to allow children to do their homework in the evenings without a candle or smoky kerosene lamp. Bringing down the cost of LEDs this way really will let in the light.