LED:A new way to brighten both our homes and our future

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We are using 17 billion kwh out of a total of 37.9 billion kwh supplied in the UK for the whole of the UK every year in terms of lighting. That also represents 10 to 25 percent of residential electricity use in industrialized countries like Britain.

With a 20% shortfall in electricity generation capacity how can we balance the deficit between energy consumption and production? Fortunately since the discovery of LED lighting in the 1960s more and more people consider LED lighting technology as a perfect solution to environmental protection and cost reduction on electricity. However what is a LED? What factors does it have to be considered more successful than other types of lighting systems? And what does it bring to our future?

LED stands for Light Emitting Diode, it is a conducting material made by semi-conductors. If we look at the structure we can see all of the covalent bonds are perfectly bonded to their neighbour atoms, leaving no free electrons (negatively-charged particles) to conduct electric current. There are two types of materials of a semiconductor, N-type and P-type. The N-Type means it has extra negatively charged particles that migrate electrons from a negatively charged area to a positively charged one. While the P-type materials are materials with holes for electrons to jump into. This means electricity can only conduct in one direction, unlike other light bulbs.

When the circuit is open, electrons from the N-type material fill holes from the P-type material along the junction between the layers, forming a depletion zone. Inside a depletion zone all of the holes are filled and nothing (charges nor electrons) are flowing. But once the circuit is completed electrons will move from the negatively charged side to the positively charged side. The holes in the P-type material will also move the other way. Once electrons in the depletion zone have left their holes they start moving. Then the depletion zone disappears. When an electron moves from one hole to another hole, the conduction band will drop which makes the energy level fall from a higher into a lower one, and releases energy in the form of a photon (light).

The amount of photon energy is determined by the energy difference between the top of the valence band and the bottom of the conduction band and this is what we call band gap energy. We can control band gap energy by varying the composition of certain semiconductor alloys. This light emitting mechanism has a much higher energy efficiency since no energy is required to heat up the system, however since not all light photons are able to escape it is estimated about one percent of the photons are turn into heat. Besides efficiency we also need to consider how much light is going to shine on the surface. Since most materials used for making the bulb in LED production have very high refractive indices, light can be easily focused onto the object without being deflected away during infraction.

Most LED related apparatus can be made from a large variety of semimetals; GaN-made LED is the one which many scientists are becoming more interested in. Although GaN was first produced over 30 years ago, it is only in the last ten years that GaN lighting has started to enter real-world applications. Until now high production costs have made GaN-made LED lighting too expensive for wide spread use in homes and offices. However, we cannot underrate its advantages. Its high saturated electron velocity and higher electron mobility makes it able to emit light at a very quick speed and makes electronic apparatus works at very fast speed. Also, in the structure it has a direct band gap which means that it can be used to emit light efficiently.

LED bulbs have a lot of features, for example they normally emits at a specific wavelength which makes it glow in a specific colour. Manufacturers of Christmas lights take advantage of LED bulbs since they do not need to add light filters to get the desired colour of light; this results in lower manufacturing costs. It also means that if we need a white light source from an LED we need to transform it, for example by coating it with phosphor. Its size is incredibly small (smaller than 2 mm^2) and it can be switched on and off in a matter of microseconds making it a favourite option for decorations and an ideal way to transmit signals. Unlike the other energy-saving bulbs it can be dimmed very easily by lowering the forward current. Furthermore, it has an extremely long lifetime since it does not burn out itself. Some reports estimate 35,000 to 50,000 hours of useful life, compared with Fluorescent tubes about 10,000 to 15,000 hours and incandescent light bulbs at 1,000–2,000 hours. Moreover its high shock and water resistances are also very favourable in producing lighting equipment in extreme environments and underwater. Unfortunately, this is counteracted by the high cost of manufacture and using current methods to produce GaN LEDs means that it is as yet uneconomical to produce light bulbs for schools, homes and offices in this way.

Is an LED really a perfectly made product? Like most other things on Earth, no, it isn't. The light emitted by an LED has its own unique wavelength which requires the insertion of plastic lenses, filters and diffusers as well as a d.c transformer otherwise it cannot function properly. Added to this is the burden of increased cost associated with it and more significantly it becomes bulky. Incidentally, it can also lead to light pollution which will be discussed next.

We are now seeing the contribution of LED bulbs towards a low carbon future. Let's take my boarding house as a model. On the first floor there are about twenty conventional 50 Watt light bulbs, by simple calculations the school will be using 1kwh, which is 365kwh per year. What would happen if all of them are replaced by LED light bulbs which only take 5 Watts each?

Then, my annual energy consumption will be only 3.65 kwh! From what we know LED bulbs can save energy by more than 90 percent yet maintain the same lighting quality. This also means that with the installation of the photovoltaic panels we may not even need to pay electric bills on lighting since the manufacture of “homemade” electricity can counteract the energy output easily. Another positive advantage is with the disposal of LEDs being environmentally friendly since they do not contain harmful chemicals like mercury, unlike compact florescent lamps. But it does not mean that they do not cause pollution when in operation as some of the LEDs with high colour temperature actually cause more light pollution than other light sources.

Besides lighting, LEDs can also be used in forms of communication and sensors. As we know the light cycling of it is very quick, it can be used to transmit information in optical fibre and Free Space Optics communications. Domestically it is not hard to see remote controls for TVs which are equipped with LEDs. In addition LEDs can also be used as movement sensors, for example in optical computer mice and Nintendo Wii's sensor bar. Moreover it can also be used as touch-sensing screens of mobiles and computers since it can be functioned as photo emission and detection equipment at the same time.

At the moment, we are still unable to produce LED bulbs that are small enough to fit onto the screen surface. However some of the modern computer or TV screens are using LEDs as backlighting. These changes can bring higher colour saturation (Standard for measuring how well a display reproduces colour purity) compared with conventional monitors, according to National Technical Systems, Inc. Moreover they can be less bulky and can be made thinner and lighter. LED emitting units can also be used for water purification in ponds, hospitals and even baby bottles and toothbrushes by shinning Deep ultra-violet GaN light into the infected areas. This has been proved effective against hospital ‘superbugs’ such as MRSA and C.difficile since ultra-violet radiation can kill harmful pathogens. It can also be used to treat cancer. During the treatment, a light generating circuit and photosensitizer is implanted into the target region such as a tumour. Once an AC electric field is induced in the region it causes the light generating circuit to generate light which can activate a photosensitizing drug and in turn kill off cancer cells by illumination. This new method has very few side effects, and is capable of reducing damage to non-tumour cells. This can be done through endoscopy with fibre-optics with minimal invasion. Unfortunately this technology is still in an experimental stage and only a small proportion of patients are suitable for this kind of treatment. There are still many unsolved obscurities and technical problems that requires further research.

Overall we have made breakthroughs since the invention of the LED, not to mention the fascinating possibility that LEDs can bring to our lives and have taken a large step to a low carbon future. After writing the essay I am especially touched by the message LEDs bring us: That human civilization can grasp the opportunity to balance technological developments and environmental protection to the Earth, our only planet.

Reference:

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Low–cost LEDs May Slash Household Electric Bills within Five Years Science Daily (Jan. 30, 2009)

www.wikipedia.com

How Light Emitting Diodes Work by Tom Harris

Samsung:http://www.photographyblog.com/news/samsung_24_inch_led_backlit_monitor/

http://www.faqs.org/patents/app/20080221630#ixzz0WxcOV4PG

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