Science Tech Entrepreneur
Oct. 2009

Cool, super efficient LED lights

Efficient LED stands for light-emitting diode. It emits light by passing a current through a solid chip between the cathode and anode. The chip emits a single or monochromatic light based on two factors, the amount of voltage and the content of the chip. This light that resonates from the chip is extremely concentrated in the visual light spectrum without much infrared spectrum.

A light-emitting diode (LED) is an electronic light source. All early devices emitted low-intensity red light, but modern LEDs are available across the visible, ultraviolet and infra red wavelengths, with very high brightness.

A better lighting option than CFLs

LEDs are based on the semiconductor diode. When the diode is forward biased (switched on), electrons are able to recombine with holes and energy is released in the form of light. This effect is called electroluminescence and the colour of the light is determined by the energy gap of the semiconductor. The LED is usually small in area (less than 1 mm^2) with integrated optical components to shape its radiation pattern and assist in reflection.

LED lighting has been around since the 1960s, but is just now beginning to appear in the residential market for space lighting. At first white LEDs were only possible by "rainbow" groups of three LEDs - red, green, and blue (RGB), by controlling the current to each to yield an overall white light. Each diode is about 1/4 inch in diameter and uses about ten milliamps to operate at about a tenth of a watt. LEDs are small in size, but can be grouped together for higher intensity applications. LED fixtures require a driver which is analogous to the ballast in fluorescent fixtures. The drivers are typically built into the fixture (like fluorescent ballasts) or they are a plug transformer for portable (plug-in) fixtures.

LED Manufacturing Technology

Like a normal diode, the LED consists of a chip of semiconducting material impregnated, or *doped*, with impurities to create a *p-n junction* (p–n junction is a junction formed by joining P(Positive)-type and N(negative)-type semiconductors together in very close contact). As in other diodes, current flows easily from the p-side, or anode, to the n-side, or cathode, but not in the reverse direction. Charge-carriers-electrons and holes—flow into the junction from electrodes with different voltages. When an electron meets a hole, it falls into a lower energy level, and releases energy in the form of a photon.

The wavelength of the light emitted, and therefore its Colour, depends on the band gap energy of the materials forming the *p-n junction*. In silicon or germanium diodes, the electrons and holes recombine by a non-radiative transition which produces no optical emission, because these are indirect band gap materials. The materials used for the LED have a direct band gap with energies corresponding to near-infrared, visible or near-ultraviolet light.

LEDs are usually built on an n-type substrate, with an electrode attached to the p-type layer deposited on its surface. P-type substrates, while less common, occur as well. Many commercial LEDs, especially Gallium nitride /Indium gallium nitride (GaN/InGaN), also use sapphire substrate.

Most materials used for LED production have very high refractive indices. This means that much light will be reflected back in to the material at the material/air surface interface. Therefore Light extraction in such lamps is an important aspect of production, subject to much research and development.

Organic light-emitting diodes (OLEDs)

If the emitting layer material of the LED is an organic compound, it is known as an Organic Light Emitting Diode (OLED). To function as a semiconductor, the organic emitting material must have conjugated pi bonds. The emitting material can be a small organic molecule in a crystalline phase, or a polymer. Polymer materials can be flexible; such LEDs are known as PLEDs or FLEDs.

Compared with regular LEDs, OLEDs are lighter, and polymer LEDs can have the added benefit of being flexible. Some possible future applications of OLEDs could be:

- **Inexpensive, flexible displays**
- **Light sources**
- **Wall decorations**
- **Luminous cloth**

OLEDs have been used to produce visual displays for portable electronic devices such as cell phones, digital cameras, and MP3 players. Larger displays have been demonstrated, but their life expectancy is still far too short (<1,000 hours).Today, OLEDs operate at substantially lower efficiency than inorganic (crystalline) LEDs.

High power LEDs

High power LEDs (HPLED) can be driven at hundreds of mA (vs. tens of mA for other LEDs), some with more than one ampere of current, and give out large amounts of light. Since overheating is destructive, the HPLEDs must be highly efficient to minimize excess heat; furthermore, they are often mounted on a heat sink to allow for heat dissipation. If the heat from a HPLED is not removed, the device will burn out in seconds.

A single HPLED can often replace an incandescent bulb in a flashlight, or be set in an array to form a powerful LED lamp.

Benefits of LED Lights

LED lamps have many advantages over traditional lighting methods. These include:

- **Efficiency:** LEDs produce more light per watt than incandescent bulbs.
- **Colour:** LEDs can emit light of an intended Colour without the use of Colour filters that traditional lighting methods require. This is more efficient and can lower initial costs.
- **Size:** LEDs can be very small (smaller than 2 mm^2) and are easily populated onto printed circuit boards.
- **On/Off time:** LEDs light up very quickly. A typical red indicator LED will achieve full brightness in microseconds. LEDs used in communications devices can have even faster response times.
- **Cycling:** LEDs are ideal for use in applications that are subject to frequent on-off cycling, unlike fluorescent lamps that burn out more quickly when cycled frequently, or High Intensity Discharge (HID) lamps that require a long time before restarting.
- **Dimming:** LEDs can very easily be dimmed either by Pulse-width modulation or lowering the forward current.
- **Cool light:** In contrast to most light sources, LEDs radiate very little heat in the form of IR that can cause damage to sensitive objects or fabrics. Wasted energy is dispersed as heat through the base of the LED.

- **Slow failure:** LEDs mostly fail by dimming over time, rather than the abrupt burn-out of incandescent bulbs.
- **Lifetime:** LEDs can have a relatively long useful life. One report estimates 35,000 to 50,000 hours of useful life, though time to complete failure may be longer. Fluorescent tubes typically are rated at about 10,000 to 15,000 hours, depending partly on the conditions of use, and incandescent light bulbs at 1,000–2,000 hours.
- **Shock resistance:** LEDs, being solid state components, are difficult to damage with external shock, unlike fluorescent and incandescent bulbs which are fragile.
- **Focus:** The solid package of the LED can be designed to focus its light. Incandescent and fluorescent sources often require an external reflector to collect light and direct it in a usable manner.
- **Toxicity:** LEDs do not contain mercury, unlike fluorescent lamps.

Applications of LEDs

Applications of LEDs are diverse. They are used as low-energy indicators but also for replacements for traditional light sources in general lighting and automotive lighting. The compact size of LEDs has allowed new text and video displays and sensors to be developed, while their high switching rates are useful in communications technology.

The many application of LEDs are very diverse but fall into three major categories: Visual signal application where the light goes more or less directly from the LED to the human eye, to convey a message or meaning. Illumination where LED light is reflected from object to give visual response of these objects. Finally LEDs are also used to generate light for measuring and interacting with processes that do not involve the human visual system.

Indicators and signs

The low energy consumption, low maintenance and small size of modern LEDs has led to applications as status indicators and displays on a variety of equipment and installations. Large area LED displays are used as stadium displays and as dynamic decorative displays. Thin, lightweight message displays are used at airports and railway stations, and as destination displays for trains and buses etc.

The single Colour light is well suited for traffic lights and signals, exit signs, emergency vehicle lighting. Red or yellow LEDs are used in indicator and alpha numeric displays in environments where night vision must be retained: aircraft cockpits, astronomy observatories, and in the field, e.g. night time animal watching and military field use.

Because of their long life and fast switching times, LEDs have been used for automotive high-mounted brake lights and truck and bus brake lights and turn signals for some time, but many high-end vehicles are now starting to use LEDs for their entire rear light clusters. The use of LEDs also has styling advantages because LEDs are capable of forming much thinner lights than incandescent lamps with parabolic reflectors. The significant improvement in the time taken to light up (perhaps 0.5s faster than an incandescent bulb) improves safety by giving drivers more time to react. It has been reported that at normal highway speeds this equal's one car length increased reaction time for the car behind. White LED headlamps are beginning to make an appearance.

Lighting

With the development of high efficiency and high power LEDs it has become possible to incorporate LEDs in lighting and illumination. Replacement light bulbs have been made as well as dedicated fixtures and LED lamps. LEDs are used as street lights and in other architectural lighting where Colour changing is used.

LEDs are also suitable for backlighting for LCD televisions and lightweight laptop displays and light source for Digital Light Processing (DLP) projectors. RGB LEDs increase the Colour gamut by as much as 45%. Screen for TV and computer displays can be made increasingly thin using LEDs for backlighting.

LED Home lighting Programme

Worldwide nearly 2 billion people do not have access to clean and reliable lighting. Half of the population of the Huge and modernizing India do not have access to reliable and clean lighting. Emerging technologies in LEDs offer promise of reliable lighting to the poor and needy.

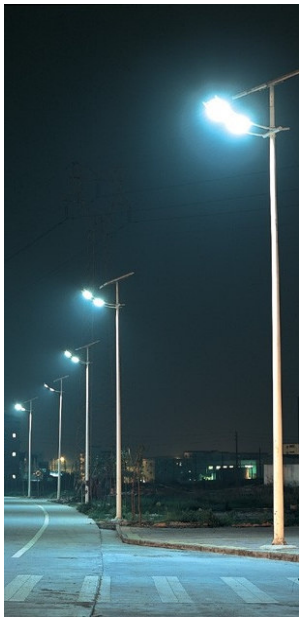
"THRIVE" agency in India started its work in LED Lighting in a small way five years ago. They implemented its LED lighting technology in a remote *lamabdi* tribal habitation in *Nalgonda* district of Andhra Pradesh as proof of concept. Here 33 houses were each provided with 3 such lights each, which were powered by a common apparatus consisting of a 36w Solar panel mounted on one rooftop, a 40 amp. 12V lead acid battery and a charge controller.

Over a period of time, based on the learning's from the field and after several changes, modifications, and up-gradations, this has been released that current model of this lighting system which comes in a highly robust polymer casing, consists of a modular and state of the art microcontroller based circuitry, and which is capable of providing over 80 hrs of clean and bright light.

This lamp runs on a 6v 4.5 ampere-hour sealed lead acid battery that has to be charged once in a while. This provided an additional livelihood option for rural entrepreneurs, who are provided with charging systems, and for a small amount help in re-charging and maintenance of the lamps.

Since LEDs are small, durable and require little power they are used in hand held devices such as flashlights. LED strobe lights or camera flashes operate at a safe, low voltage, as opposed to the 250+ volts commonly found in xenon flash lamp-based lighting. This is particularly applicable to cameras on mobile phones, where space is at a premium and bulky voltage-increasing circuitry is undesirable. LEDs are used for infrared illumination in night vision applications including security cameras. A ring of LEDs around a video camera, aimed forward into a retro reflective background, allows chroma keying in video productions.

Smart lighting



Light can be used to transmit broadband data, which is already implemented Infra red data association (IrDA) standards using infrared LEDs. Because LEDs can cycle on and off millions of times per second, they can, in effect, become wireless routers for data transport. Lasers can also be modulated in this manner.

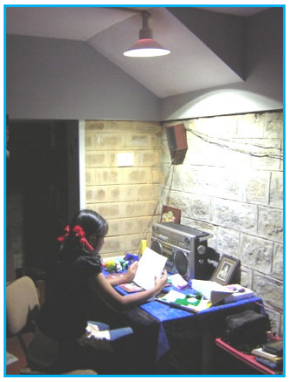
LEDs Lights in the Home

Light-emitting diodes, now making its way into our homes as lighting fixtures. Currently their residential uses are limited, canned lighting being one of the few uses, but this technology is quickly advancing and new such products will be making their way to homes soon.

LED lighting fixtures that can be purchased for residential use. It cost around twice as much as conventional lighting fixtures. These kinds of home lights use little power and often surpass other light sources in energy-efficiency. These kinds of lights do offer more longevity, lasting as long as 50,000 hours. That means that if we have your lights on 8 hours a day, the LEDs should last about 17 years.

Global LED market

The global LED industry clusters in Japan, Europe and Taiwan. Japan ranks first, followed by Taiwan. In China, this industry is dispersed, and thousands of manufacturers are mainly in the downstream to engage in Lamp packaging. The LED downstream market can be divided into three parts, TFT-LCD backlight, lighting and signal or data display, and this backlight is the most significant market. With the improvement of technology, luminescence efficiency and cost reduction in 2009, LED has shown the great strength in the large-size sector.



Market conditions are right for the LED replacement lamp market to accelerate in the next few years, according to a new report from

strategies unlimited. Although the market for LED replacement lamps is still in its early stages of development, lamp revenues are forecast to grow at a compound annual growth rate (CAGR) of 107% through 2013.

The market is in a state of flux as utilities, energy efficiency organizations and customers look for optimum solutions which save energy, minimize the cost of ownership, and give acceptable quality of light.

Future prospects of LED based lamps

We all know Power is a concurrent subject. It is not just in India but the entire world that has failed to make up for the shortage of power.

With energy prices on the rise and natural resources receding, it has become more important to conserve power for the brighter life of our future generation. Small steps at the individual level can really change the way we utilize electricity at homes or even outside. A good supply of light does not necessarily mean the consumption of a great deal of electricity. If the right lamp is selected for the right type of function, it is possible to save electricity.

Till date, we have been used to five basic types of lighting: incandescent, fluorescent, high intensity discharge, low pressure sodium and compact fluorescent lamp (CFL).

Compact fluorescent lamps (CFLs) were considered till date to be the most significant lighting devices for homes but these lights are sensitive to the fluctuation and inconsistent power supply in India. On the other hand, solid-state lighting or light emitting diodes (LED) are rugged, sustains power surges, shocks and vibrations. LEDs are easy to install and have long span of life - 50,000+ hrs (10+ years). The advantages of LED lighting, besides lower power consumption, reduces the worlds carbon footprint and are easily recyclable - thus considerate to be absolute green technology.

With all of these ideas in mind, LEDs do show a promising future in the world of lighting. With improvements in technology, it may be possible to incorporate these lights into almost all lighting applications. They definitely have a number of important advantages.

Raman Gujral

e mail: gujralraman@yahoo.com

Note: The author may have used various references in the preparation of this article. For further details please contact him/her.