LIGHT-EMITTING DIODE

A light-emitting diode (LED) is a semiconductor light source. LEDs are used as indicator lamps in many devices and are increasingly used for other lighting. Appearing as practical electronic components in 1962, early LEDs emitted low-intensity red light, but modern versions are available across the visible, ultraviolet, and infrared wavelengths, with very high brightness.

An LED is often small in area (less than $1mm^2$), and integrated optical components may be used to shape its radiation pattern. LEDs present many advantages over incandescent light sources including lower energy consumption, longer lifetime, improved physical robustness, smaller size, and faster switching. LEDs powerful enough for room lighting are relatively expensive and require more precise current and heat management than compact fluorescent lamp sources of comparable output.

> In semiconductor physics, the band gap of a semiconductor is always one of two types, a direct band gap or an indirect band gap. The band gap is called "direct" if the momentum of electrons and holes is the same in both the conduction band and the valence band; an electron can directly emit a photon. In an "indirect" gap, a photon cannot be emitted because the electron must pass through an intermediate state and transfer momentum to the crystal lattice.

Physics

The LED consists of a chip of semiconducting material doped with impurities to create a p-n junction. 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 thus its color 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 GaN/InGaN, also use sapphire substrate.

> “N – type” is a semiconductor in which main charge carriers are electrons and “p – type” is a semiconductor in which main charge carriers are holes. (Holes так и переводится – дырки). In other words, “p-type” has abundance of holes and “n-type” has abundance of electrons.

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

Efficiency and operational parameters

One of the key advantages of LED-based lighting sources is high luminous efficiency. White LEDs quickly matched and overtook the efficacy of standard incandescent lighting systems. In 2002, Lumileds made five-watt LEDs available with a luminous efficacy of 18–22 lumens per watt (lm/W). For comparison, a conventional incandescent light bulb of 60–100 watts emits around 15 lm/W, and standard fluorescent lights emit up to 100 lm/W. A recurring problem is that efficacy falls sharply with rising current.
In September 2003, a new type of blue LED was demonstrated by the company Cree Inc. to provide 24 mW at 20 milliamperes (mA). This produced a commercially packaged white light giving 65 lm/W at 20 mA, becoming the brightest white LED commercially available at the time, and more than four times as efficient as standard incandescents. In 2006, they demonstrated a prototype with a record white LED luminous efficacy of 131 lm/W at 20 mA. Nichia Corporation has developed a white LED with luminous efficacy of 150 lm/W at a forward current of 20 mA. Cree's XLamp XM-L LEDs, commercially available in 2011, produce 100 lumens per watt at their full power of 10 watts, and up to 160 lumens/watt at around 2 watts input power.

LED light output rises at lower temperatures, leveling off, depending on type, at around -30 °C.
Because LEDs emit less heat than incandescent bulbs, they are an energy-efficient technology for uses such as in freezers and refrigerators. However, because they emit little heat, ice and snow may build up on the LED luminaire in colder climates.

White light

There are two primary ways of producing white light-emitting diodes (WLEDs), LEDs that generate high-intensity white light. One is to use individual LEDs that emit three primary colors — red, green, and blue — and then mix all the colors to form white light. The other is to use a phosphor material to convert monochromatic light from a blue or UV LED to broad-spectrum white light, much in the same way a fluorescent light bulb works.

1. **RGB systems**

White light can be formed by mixing differently colored lights; the most common method is to use red, green, and blue (RGB). Hence the method is called multi-color white LEDs (sometimes referred to as RGB LEDs). Because these need electronic circuits to control the blending and diffusion of different colors, and because the individual color LEDs typically have slightly different emission patterns (leading to variation of the color depending on direction) even if they are made as a single unit, these are seldom used to produce white lighting. Nevertheless, this method is particularly interesting in many uses because of the flexibility of mixing different colors, and, in principle, this mechanism also has higher quantum efficiency in producing white light.

(emission patterns – характеры излучения)

2. Phosphor-based LEDs

This method involves coating LEDs of one color (mostly blue LEDs made of InGaN) with phosphors of different colors to form white light; the resultant LEDs are called phosphor-based white LEDs. A fraction of the blue light undergoes the Stokes shift being transformed from shorter wavelengths to longer. Depending on the color of the original LED, phosphors of different colors can be employed. If several phosphor layers of distinct colors are applied, the emitted spectrum is broadened, effectively raising the color rendering index (CRI) value of a given LED.

(Stokes shift – стоксов сдвиг, color rendering index (CRI) – индекс цветопередачи)

Phosphor-based LED efficiency losses are due to the heat loss from the Stokes shift and also other phosphor-related degradation issues. Their efficiencies compared to normal LEDs depend on the spectral distribution of the resultant light output and the original wavelength of the LED itself.

(spectral distribution – спектральное распределение, спектр)