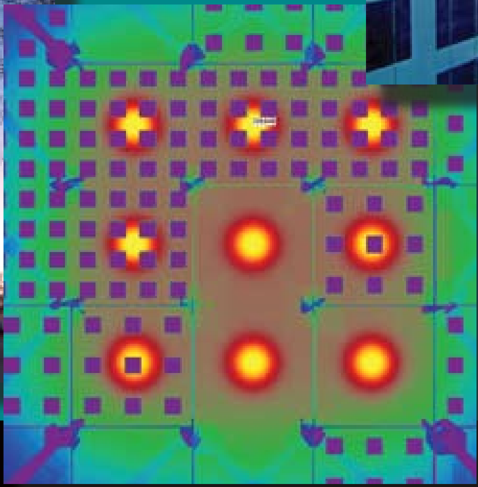
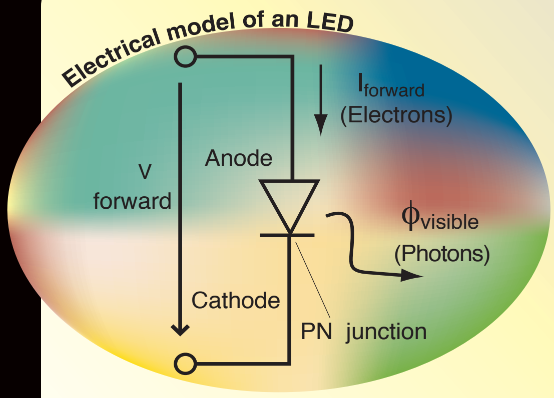


Color LEDs are already widely used for displays, automotive lighting, and decoration for appealing yet efficient light. Last summer at the Beijing Olympic opening ceremony, an enormous LED display opened like an ancient Chinese painting scroll and served as a movie screen. *Image of Zero Energy Media Wall, Beijing, China, courtesy by Simone Giostra & Partners and Arup.*

LEDs lighting the way

While energy production and distribution have always been a challenge, today it is increasingly urgent to reduce power consumption — and lighting is no exception. Light-emitting diodes or *LED*s provide an alternative to conventional lighting for consuming less power, lower thermal dissipation, and longer life. In fact, LED products are already spurring evolution in lighting, and it is anticipated that power LEDs will lead the way in combining high intensity and efficiency. So what is the structure of LEDs, and how do they emit light?



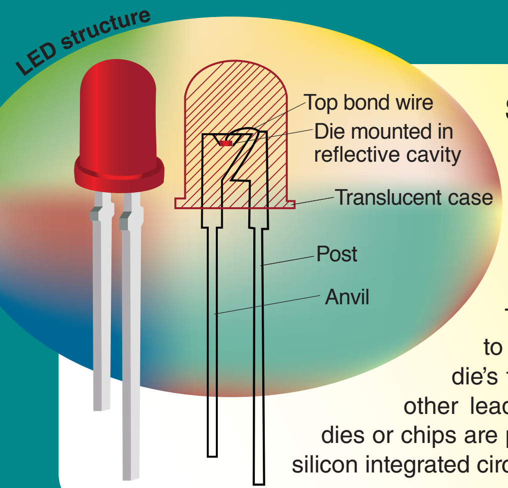
The electrical module of LED emitting light wavelength varies, primarily with the semiconductor materials used, because the bandgap energy varies with different semiconductors.

How LEDs emit light

All ICs, including LEDs, are basically sourced from P-N junctions. A P-N junction is made of N and P-type semiconductors doped with different impurity.

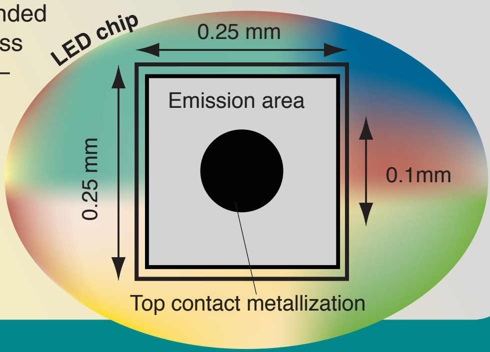
See the tic-tac-toe-looking image, above: Free electrons and holes, initially intended to meet across a junction, result in a depletion zone. The zone blocks charge flow (or current) — and so, a suitably directed voltage is needed by the two ends of the P-N junction (forward bias) to overcome blocking force. (The wrong direction makes the depletion zone wider.)

An LED is a P-N junction semiconductor diode that emits photons when forward-biased, and it occurs when minority carriers recombine with carriers of the opposite type in a diode's bandgap.



Structure of an LED

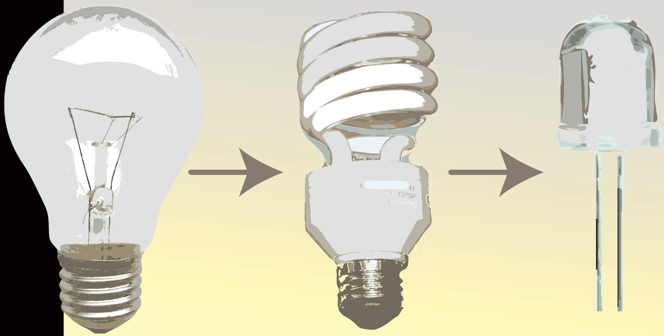
LEDs are composed of a die, a lead frame to hold the die, and encapsulation epoxy, which surrounds and protects the die and disperses light. The die is bonded with conductive epoxy into a recess in one half of the lead frame — called the anvil due to its shape. The recess in the anvil is shaped to project the radiated light. The die's top contact is wire bonded to the other lead frame terminal, the post. LED dies or chips are processed in wafer form similar to silicon integrated circuits, and broken into dice.



Chip size of visible-signal LEDs range from 0.18 to 0.36 sq. mm. Infrared or IR LEDs can be larger to handle peak powers, and high-power LEDs are larger still.

Lighting's holy grail: White light

Approximating white sunshine is the ultimate goal of much artifical lighting. White LEDs may soon replace incandescent and fluorescent lamps, as they match the coloring of these old technologies, but with better efficiency.



Blue lighting has been key in the development of white LED manufacturing. The first blue LED was produced in RCA Laboratories in 1971 after experimentation with doping and materials. However, it had poor output, so it wasn't until the 1990s that blue LEDs achieved the efficiency and technological maturity required for commercialization.

Today, primary-color LEDs mix red, green, and blue to produce white light, mainly for custom low-volume applications. Di, tri, and tetrachromatic multi-colored white LEDs vary in color stability, color rendering capability, and luminous efficacy. Dichromatic white LEDs have the best luminous efficiency, but the least accurate color rendering. Tetrachromatic white LEDs exhibit excellent color rendering, but often shine dimly. Trichromatic white LEDs are in between, having both good luminous efficiency and fair color rendering capability.

Making white light with LEDs

Original source	Inspired material/ phosphor	Principle
Blue LED	InGaN/YAG	Blue light from InGaN + yellow light from YAG inspired by the blue light = white light
Blue LED	InGaN/ Phosphor	White light from RGB Phosphor inspired by the blue light from InGaN
Blue LED	ZnSe	Blue light from the layer + yellow light from ZnSe substrate = white light
Ultraviolet LED	InGaN/Phosphor	White light from RGB Phosphor inspired by ultraviolet light from InGaN
Blue, yellow/ green LED	InGaN GaP	Encapsulating two chips of complementary color to build white LED
Blue, Green, Red LED	InGaN AlInGaP	Encapsulating three chips respectively emitting RGB light to build white LED
Multi-color LED	InGaN GaP AlInGaP	Encapsulating multiple chips falling in the whole visible spectrum to build white LED

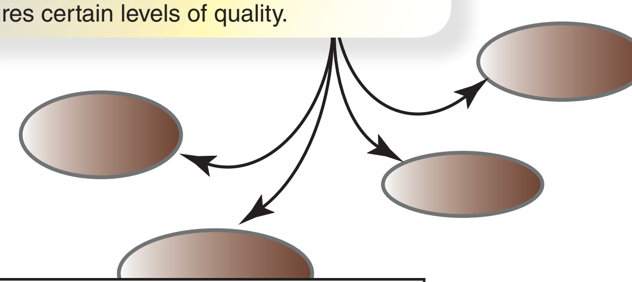
There are different methods for producing white LED light. White LEDs exhibit lower power consumption, longer life, higher brightness, and may be the next primary lighting source.

Another alternative is **phosphors** that convert blue or UV LED to broad-spectrum white light. Phosphor LEDs are more easily manufactured, good for high-volume applications — but have lower quantum efficiency versus RGB units and phosphor-related degradation issues. Blue-based white LEDs involve coating blue LED with phosphor of a different color. The biggest challenge here is Stokes energy loss. Near-ultraviolet emitting LEDs are made with mixed coatings of high-efficiency europium-based red and blue emitting phosphors, plus green emitting copper and aluminum doped zinc sulfide — ZnS:Cu, Al. The Stokes shift is larger, but color rendering is better. Yet another white LED technology is based on homoepitaxially-grown zinc selenide, which simultaneously emits blue light from an active region and yellow light from a substrate.

Green engineering

Pick a bin: Grading LEDs

Binning is used to grade and classify power LED products. Essentially, it subdivides the huge variety of LEDs into grades based on luminous flux, forward voltage, dominating wavelength, and correlated color temperature. For manufacturers and end users, binning reduces cost and ensures certain levels of quality.



Producing color LED

Materials	Color
AlGaAs	Red and infrared
AlGaP	Green
AlGaInP	Orange-red, orange, yellow, green
GaAsP	Red, orange-red, orange, and yellow
GaP	Red, yellow and green
GaN	Green, pure green (or emerald green), and blue; also white (if with AlGaN Quantum Barrier)
InGaN	Near ultraviolet, bluish-green, blue
SiC as substrate	Blue (under development)
ZnSe	Blue
AlN, AlGaN, AlGaInN	Near to far ultraviolet

LED development began with infrared and red light emitting devices made from gallium arsenide. Advances in materials science have made it possible to produce many colors of light. These colors can be generated from various materials, made up from a small group of semiconductive elements.

Brushing Up *information provided by Newark and the Premier Farnell Global Technical Center. For more information on LEDs, visit electronicsdesignworld.com, click on U.S. portal, and then the Technology First publication link on the left navigation menu.*