
Blue LED - History of LEDs - Isamu Akasaki, Hiroshi Amano, Shuji Nakamura

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White LEDs

There are two primary ways of producing white light-emitting diodes. 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, similar to a fluorescent lamp. The yellow phosphor is cerium-doped YAG crystals suspended in the package or coated on the LED. This YAG phosphor causes white LEDs to appear yellow when off, and the space between the crystals allow some blue light to pass through in LEDs with partial phosphor conversion. Alternatively, white LEDs may use other phosphors like manganese(IV)-doped potassium fluorosilicate (PFS) or other engineered phosphors. PFS assists in red light generation, and is used in conjunction with conventional Ce:YAG phosphor. In LEDs with PFS phosphor, some blue light passes through the phosphors, the Ce:YAG phosphor converts blue light to green and red (yellow) light, and the PFS phosphor converts blue light to red light. The color, emission spectrum or color temperature of white phosphor converted and other phosphor converted LEDs can be controlled by changing the concentration of several phosphors that form a phosphor blend used in an LED package.[97][98][99][100]

The 'whiteness' of the light produced is engineered to suit the human eye. Because of metamerism, it is possible to have quite different spectra that appear white. The appearance of objects illuminated by that light may vary as the spectrum varies. This is the issue of color rendition, quite separate from color temperature. An orange or cyan object could appear with the wrong color and much darker as the LED or phosphor does not emit the wavelength it reflects. The best color rendition LEDs use a mix of phosphors, resulting in less efficiency and better color rendering.[citation]

The first white light-emitting diodes (LEDs) were offered for sale in the autumn of 1996.[101]

Blue LEDs have an active region consisting of one or more InGaN quantum wells sandwiched between thicker layers of GaN, called cladding layers. By varying the relative In/Ga fraction in the InGaN quantum wells, the light emission can in theory be varied from violet to amber.

Aluminium gallium nitride (AlGaIn) of varying Al/Ga fraction can be used to manufacture the cladding and quantum well layers for ultraviolet LEDs, but these devices have not yet reached the level of efficiency and technological maturity of InGaIn/GaN blue/green devices. If unalloyed GaIn is used in this case to form the active quantum well layers, the device emits near-ultraviolet light with a peak wavelength centred around 365 nm. Green LEDs manufactured from the InGaIn/GaN system are far more efficient and brighter than green LEDs produced with non-nitride material systems, but practical devices still exhibit efficiency too low for high-brightness applications.[citation needed]

With AlGaIn and AlGaInN, even shorter wavelengths are achievable. Near-UV emitters at wavelengths around 360–395 nm are already cheap and often encountered, for example, as black light lamp replacements for inspection of anti-counterfeiting UV watermarks in documents and bank notes, and for UV curing. Substantially more expensive, shorter-wavelength diodes are commercially available for wavelengths down to 240 nm.[91] As the photosensitivity of microorganisms approximately matches the absorption spectrum of DNA, with a peak at about 260 nm, UV LED emitting at 250–270 nm are expected in prospective disinfection and sterilization devices. Recent research has shown that commercially available UVA LEDs (365 nm) are already effective disinfection and sterilization devices.[92] UV-C wavelengths were obtained in laboratories using aluminium nitride (210 nm),[93] boron nitride (215 nm)[94][95] and diamond (235 nm).[96]

Other white LEDs

Another method used to produce experimental white light LEDs used no phosphors at all and was based on homoepitaxially grown zinc selenide (ZnSe) on a ZnSe substrate that simultaneously emitted blue light from its active region and yellow light from the substrate.[115]

The 2014 Nobel Prize for physics has been awarded to a trio of scientists in Japan and the US for the invention of blue light emitting diodes (LEDs).

By Jonathan Webb

Science reporter, BBC News

Professors Isamu Akasaki, Hiroshi Amano and Shuji Nakamura made the first blue LEDs in the early 1990s.

This enabled a new generation of bright, energy-efficient white lamps, as well as colour LED screens.

The winners will share prize money of eight million kronor (£0.7m).

They were named at a press conference in Sweden, and join a prestigious list of 196 other Physics laureates recognised since 1901.

Media caption,

Staffan Normark, Royal Swedish Academy of Sciences, announces the physics prize

Prof Nakamura, who was woken up in Japan to receive the news, told the press conference, "It's unbelievable."

Making the announcement, the Nobel jury emphasised the usefulness of the invention, adding that the Nobel Prizes were established to recognise developments that delivered "the greatest benefit to mankind".

"These uses are what would make Alfred Nobel very happy," said Prof Olle Inganäs, a member of the prize committee from Linköping University.

The committee chair, Prof Per Delsing, from Chalmers University of Technology in Gothenburg, emphasised the winners' dedication.

"What's fascinating is that a lot of big companies really tried to do this and they failed," he said. "But these guys persisted and they tried and tried again - and eventually they actually succeeded."

Image caption,
Professors Akasaki, Amano and Nakamura made the first blue LEDs in the early 1990s

Although red and green LEDs had been around for many years, blue LEDs were a long-standing challenge for scientists in both academia and industry.

Without them, the three colours could not be mixed to produce the white light we now see in LED-based computer and TV screens. Furthermore, the high-energy blue light could be used to excite phosphorus and directly produce white light - the basis of the next generation of light bulb.

Today, blue LEDs are found in people's pockets around the world, inside the lights and screens of smartphones.

White LED lamps, meanwhile, deliver light to many offices and households. They use much less energy than both incandescent and fluorescent lamps.

That improvement arises because LEDs convert electricity directly into photons of light, instead of the wasteful mixture of heat and light generated inside traditional, incandescent bulbs. Those bulbs use current to heat a wire filament until it glows, while the gas discharge inside fluorescent lamps also produces both heat and light.

Inside an LED, current is applied to a sandwich of semiconductor materials, which emit a particular wavelength of light depending on the chemical make-up of those materials.

Gallium nitride was the key ingredient used by the Nobel laureates in their ground-breaking blue LEDs. Growing big enough crystals of this compound was the stumbling block that stopped many other researchers - but Profs Akasaki and Amano, working at Nagoya University in Japan, managed to grow them in 1986 on a specially-designed scaffold made partly from sapphire.

Four years later Prof Nakamura made a similar breakthrough, while he was working at the chemical company Nichia. Instead of a special substrate, he used a clever manipulation of temperature to boost the growth of the all-important crystals.

History of LEDs

Light-emitting diode is an electric component that emits light when connected to direct current. It works on electroluminescent principle and can emit light in visible specter as well as in infrared and ultraviolet. They have characteristically low energy consumption, small size, longer lifetime and faster switching than incandescence lamps and because of that, they have a wide palette of applicability.

In 1907, British experimenter in Marconi labs Henry Joseph Round noticed for the first time that when a potential of 10volts is applied to carborundum (silicon carbide) crystal, it emits yellowish light. However, first to investigate it and to propose a working theory was Oleg Vladimirovich Losev from Russia. In 1927, Oleg published a paper "Luminous carborundum detector and detection effect and oscillations with crystals".

For decades no progress was made for different reasons. Rubin Braunstein that worked at Radio Corporation of America, reported in 1955 that some simple diodes emit infrared light when connected to a current. In 1961, Gary Pittman and Bob Biard from Texas Instruments found that that gallium-arsenide diode emits infrared light every time it is connected to current. The same year they received patent for infrared LED. Nick Holonyak Jr., employed in General Electric, developed in 1962 first light-emitting diode that emitted light in the visible part of the frequency range. It was a red LED. In 1972, M. George Craford, who was a graduate student of Holonyak, invented the first yellow LED and a brighter red LED. Thomas P. Pearsall developed high brightness light-emitting diode in 1976, for use with fiber optics in telecommunications. Shuji Nakamura of Nichia Corporation made first blue LED in 1979 but it was too expensive for commercial use until 1994. Light emitting diodes can now be made in one or in more colors.

At first Light-emitting diodes were very expensive, some US\$200 per piece. Because of that, they were used as indicators only in highly professional laboratory equipment. Fairchild Semiconductors succeeded in 1970s to reduce cost of individual LED to 5 cents by using planar process in production of semiconductor chips for light emitting diodes. By using innovative methods of packaging and a planar process of chip production, Fairchild made LED into a commercial product with variety of uses.

LED with visible light is used as a replacement for incandescent and neon lights, as elements in seven-segment displays, in large RGB screen displays, in semaphores and other visual signals, in calculators, watches and in flashlights. Infrared LEDs are used in units for remote control in TVs, DVDs and other places that need wireless control.

Advantages of Light emitting diodes are many, but they also have their flaws. Advantages are that they emit more light per watt than incandescent lamps, they are much smaller, their on/off time is much shorter than of the other types of electric light sources (they are quick), their lifetime is much longer and they are much more difficult to damage. Their flaws are high price per lumen, high dependence of the outside temperature and easy overheating if the outside temperature is too high and there is no heat sink. Despite their flaws, LEDs are finding their place in the human use and are here to stay.