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2014
Development of high brightness light emitting diodes (LEDs) for large screen displays of outdoor use (Stanley, Toshiba, Nichia)

~ Discrete Semiconductor/Others ~

The discovery by H.J. Round in 1907 that SiC crystals emit light when voltage was applied is thought to be the origin of the light emitting diode (LED). However, it is said that the practical LED was fabricated in 1962 when N. Holonyak Jr., known as the "Father of LEDs", succeeded in developing the GaAsP red LED[(1)]. At that time, crystals grown by the liquid-phase crystal growth technology had many defects and the luminous efficiency was only 0.01%, which was far from practical use.

In 1969, Jun-ichi Nishizawa invented the vapor pressure controlled temperature difference method, which had been able to obtain high quality compound semiconductor crystals, resulting in the realization of high brightness red and green LEDs [(2)]. Stanley Electric commercialized GaAs red LED with 60 mcd brightness in 1976 and GaP green LED with 80 mcd brightness in 1979. It was started to install LEDs in indicators of such various electronic equipment as calculator.

From the 1980s, it became possible to produce green LEDs with a brightness of 100 mcd using GaP crystals and red LEDs with a brightness of over 1 cd using GaAsP and GaAlAs crystals, which were used for outdoor information displays, traffic signals, and automotive high-mounted stop lamps[(3)].

It became possible to grow high-quality ternary and quaternary compound semiconductors with precisely controlled composition and thickness by the MOCVD method using organometallic compounds, invented by H.M. Monasevit in 1968[(4)] and LEDs with complex structures were developed. By optimally selecting the composition ratio of the crystal, InGaAlP can change emitting light from red to green holding the same lattice constant as that of the GaAs substrate. In 1991, Toshiba started mass production of InGaAlP high-brightness LEDs by using the MOCVD method, and commercialized red LEDs with a brightness of 5 cd and green LEDs with a brightness of 2 cd[(5)]. As shown in Fig. 1, in addition to the light-emitting area of the double heterojunction (DH) structure, a Distributed Bragg Reflector (DBR) which was made up of several layers of two different materials with different refractive indices at a thickness of 1/4 of the light wavelength, was provided to have a reflective effect. Light radiating toward the substrate side was reflected upward. In addition, a current diffusion layer and a current blocking layer were provided in order to make the entire chip surface emit light.

In 1993, Nichia Corporation developed and started mass production of InGaN blue LEDs with brightness exceeding 1 cd[(6)].

As the results, LEDs emitting three primary colors of light (Red, Green, and Blue: RGB) necessary for full-color displays with the brightness of 5000 cd/m^2 and more required for daytime outdoor use became available. Afterward, large screen full-color LED displays have widely been installed for stadium scoreboards, sports facilities etc. from around 1995 (7).

Thanks to advances in packaging and other technologies, in the 2010s, ultra-large screen outdoor LED displays with a width of over 100 meters have been realized(8)(9)(10)(11).

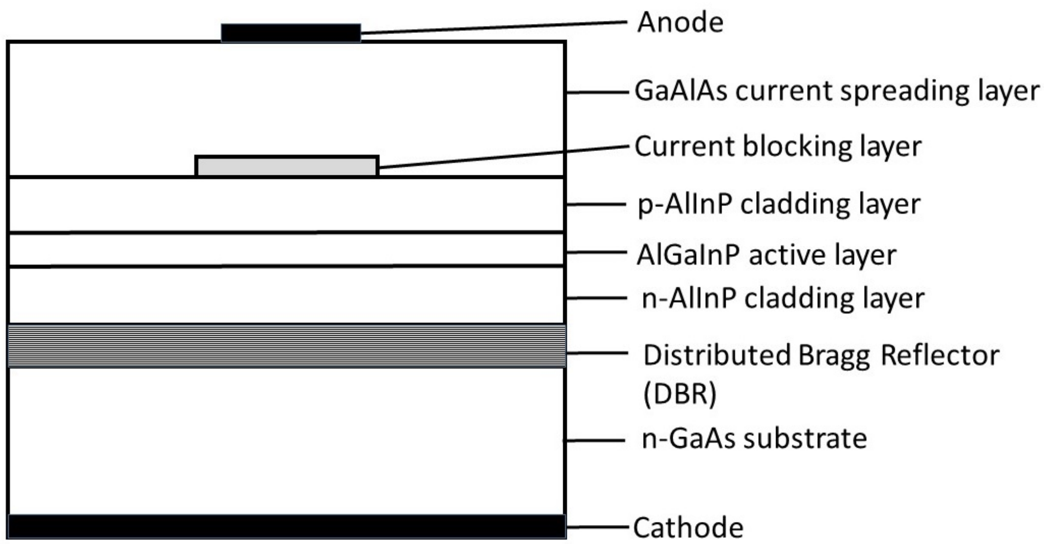

Figure 1 Cross-sectional view of an InGaAlP/GaAs visible light-emitting diode

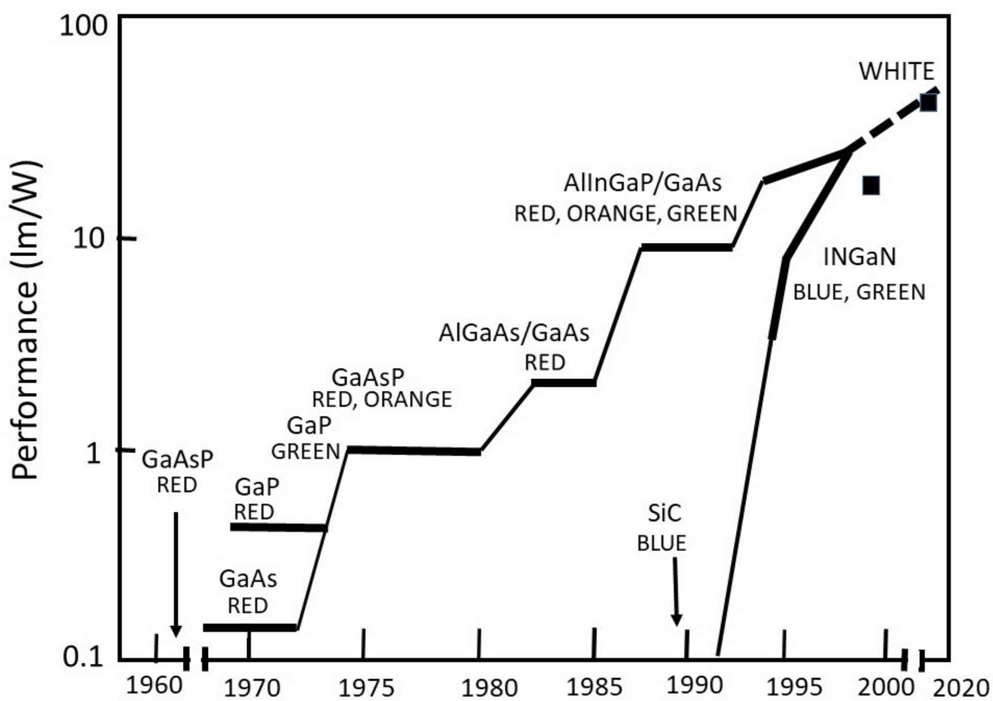

Figure 2 Brief History of LED Development

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