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1993

Release of the world's first commercial indium-gallium-nitride / gallium-nitride blue LED with high brightness (Nichia Corporation)

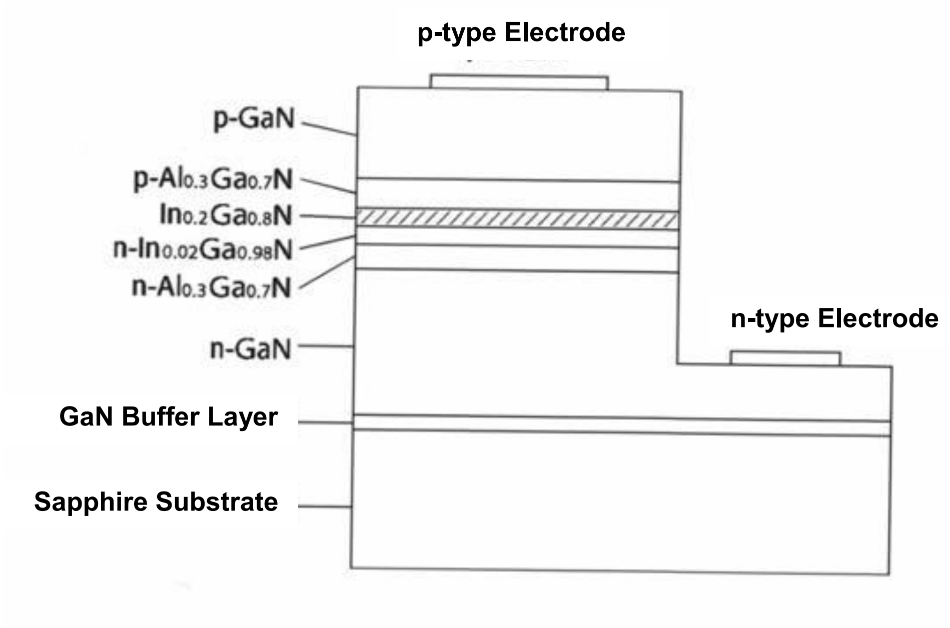
~ Discrete Semiconductor/Others ~

For realizing a blue LED, it is necessary to form a p-n junction with a semiconductor material having a band gap of about 2.6 eV. The materials were studied such as ZeSe of II-VI family, GaN based semiconductor of III-V group, and SiC of IV-IV group. Among them, SiC had poor luminous efficiency due to its indirect transition, ZeSe was severely deteriorated, and it was difficult to form a GaN thin crystal film. For these reasons, the development of blue LED was most delayed among the three primary colors (RGB).
The first light emission of a GaN LED was observed in the MIS structure in 1971, but since the improvement of the defective GaN crystal did not progress and the p-type GaN could not be made, many researchers backed away in the late 1970s. Akasaki and Amano et al. of Nagoya University continued research vigorously from this time, and succeeded in the development of p-n junction blue LED first in the world in 1989, by reducing crystal defects by adopting an AlN buffer layer and realizing p-type GaN layer by irradiating a Zn-doped layer with an electron beam. However, the emission was weak and it did not reach practical use.

Nakamura et al. of Nichia devised a two-flow MOCVD apparatus that horizontally fed a material gas containing a Ga compound to a heated sapphire substrate and vertically introduced nitrogen and hydrogen gases to the substrate. This is later referred to as the 404 patent (Patent No. 2628404). By using this technique and adopting an amorphous GaN buffer layer, high quality GaN and InGaN single crystals could be obtained. They also discovered that Mg was activated and p-type GaN was obtained by heat treatment of Mg-doped GaN in a hydrogen-free atmosphere, and they also clarified its mechanism.
By realizing the high quality InGaN crystal and p-type GaN, they developed a homo-junction blue LED with the luminous efficiency of 0.18% in 1991, and a double heterojunction LED using InGaN as the light emitting layer with the luminous efficiency of 2.7% and commercialized it in 1993 for the first time in the world. After that, the InGaN quantum well structure was adopted for the light emitting layer, and the luminous efficiency of 9.2% was achieved.

Nakamura et al. further succeeded in the room temperature CW oscillating of the blue semiconductor laser which adopted the InGaN multiple quantum well structure of 20 periods in the light emitting layer and the GaN/AlGaN superlattice structure in the cladding layer. In 1999, Nichia started the sales of blue semiconductor laser for the first time in the world.

With this invention of a series of LED technologies, a large-sized full color display device, and a long life, high brightness, low power white light source became widely spread. Akasaki, Amano, and Nakamura received the 2014 Nobel Prize in Physics.



Cross sectional structure of single quantum well blue LED (2)

References:

(1) D. Steigerwald, s. Rudaz, H. Liu, R. Kern, W. Goetz, & R. Fletcher, "III-V nitride semiconductors for high-performance blue and green light-emitting devices", JOM, Vol. 49, No. 9, pp. 18-23, (1997)
http://www.tms.org/pubs/journals/jom/9709/steigerwald-9709.html

(2) Fujifilm Science Imaging Systems Application Note, No. 9 (Sep. 1997)

(3) The Nobel Prize in Physics 2014
http://www.nobelprize.org/nobel_prizes/physics/laureates/2014/

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