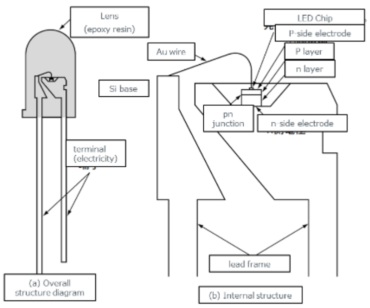
LED Devices

About LED Devices

Recently, a lot of LED products are used in the market for display devices. This application note describes the principle of light-emitting devices that are used for LED products and manufacturing methods and so on.

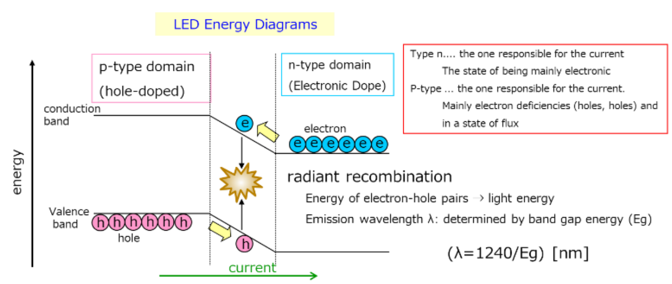
Overview of Light-Emitting Diode (LED)

LED stands for Light Emitting Diode, a semiconductor element which emits light when injecting an electric current into it.



The Principle of LED Light Emission

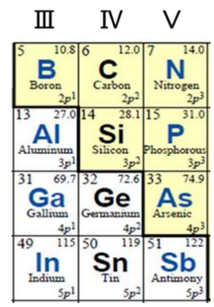
Light-emitting recombination：Emitted by the recombination of holes injected from p-type layer and electrons injected from n-type layer.



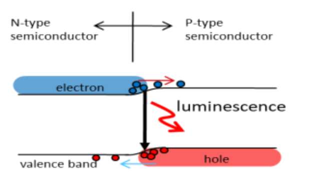
Materials of Light-Emitting Elements

Group Ⅳ (unit element) semiconductors such as Si and Ge are unlikely to emit light when the electron-hole pairs are recombined. On the other hand, III-V compound semiconductors such as GaN, GaAs, and InP tend to emit light when the electron-hole pairs are recombined. Examples of combinations include GaAsP, AlGaAs, GaP, InGaP and InGaAlP. Growing these materials on a given substrate with the crystal planes aligned (epitaxial growth) makes it possible to gain the light-emitting functions.

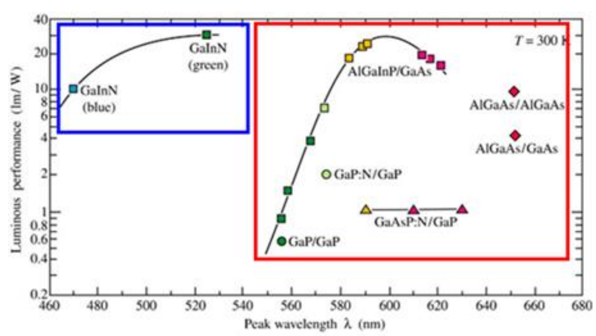
Materials and Emission Wavelengths



Compound semiconductors (consist of Ga, Al, In, P, N, As, etc.) have different emission wavelengths λ depending on their constituent elements and mixed crystal tario. The wavelength is also determined by the band gap energy Eg of the compound semiconductors.



Band Diagram of PN Junction (Forward Bias)



Materials of Light-Emitting Elements

The following table shows the relationship between light-emitting materials and colors. The driving voltage is also roughly determined by the light-emitting colors.

Chip materials		formative law	color	Peak Wavelength (nm)	luminosity (mcd)	Driving voltage (V)	band width (eV)
luminous layer	substrate						
GaP(Zn,O)	GaP	liquid phase epitaxy	Red	700	40	2	2.26
Ga0.65Al0.35As(DDH)	GaAlAs	liquid phase epitaxy	Red	660	5,000	1.9	1.9
Ga0.65Al0.35As(DH)	GaAs	liquid phase epitaxy	Red	660	2,500	1.9	1.9
Ga0.65Al0.35As(SH)	GaAs	liquid phase epitaxy	Red	660	1,200	1.8	1.9
GaAs0.35P0.65	GaP	vapor phase growth	Red	635	600	2	1.95
GaAs0155P0.85	GaP		Yellow	585	600	2	2.1
(Al0.05Ga0.96)0.5In0.5P	GaAs	MOCVD	Red	647	6,000	2.1	1.92
(Al0.2Ga0.8)0.5In0.5P	GaAs	MOCVD	Orange	609	10,000	2.1	2.04
(Al0.3Ga0.7)0.5In0.5P	GaAs	MOCVD	Yellow	591	8,000	2.1	2.1
(Al0.45Ga0.55)0.5In0.5P	GaAs	MOCVD	Green	560	1,000	2.1	2.2
GaP(N)	GaP	liquid phase epitaxy	Green	565	1,000	2	2.26
In0.45Ga0.55N	sapphire	MOCVD	Green	520	10,000	3.5	2.38
In0.2Ga0.8N	sapphire	MOCVD	Blue	465	3,000	3.6	2.67
In0.1Ga0.9N	sapphire	MOCVD	violet	405	–	3.7	3.06

Increasing the Brightness of LED Chips

The following approaches are used to increase the brightness of LED elements.

1. Improving the internal emission efficiency

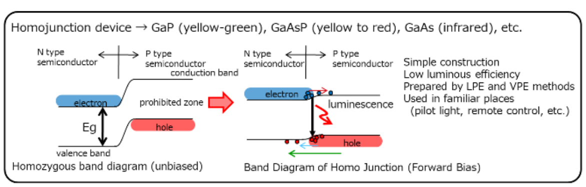
Increase the amount of light emission in the active layer (emission layer). It is necessary to create high quality crystals and structures that improve the recombination efficiency of electrons and holes.

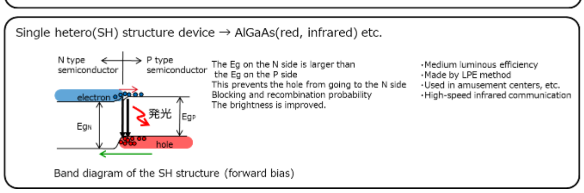
2. Improving the external emission efficiency

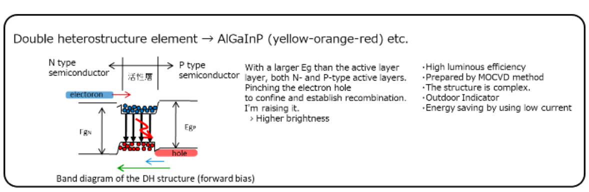
It is necessary to create structures that extract more light from the light-emitting layer to the outside of the LED chips.

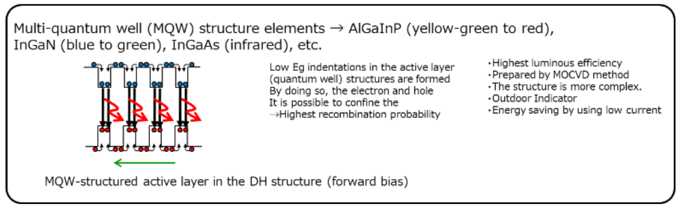
Structure of the light-emitting layer

Typical structures of light-emitting layers are as follows.









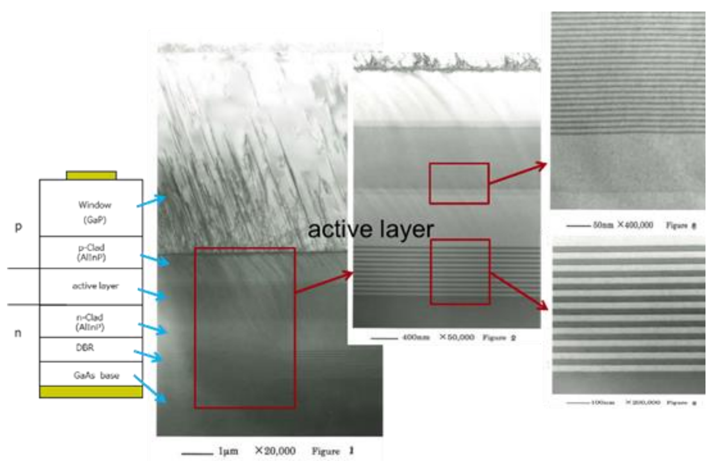
Crystal Growth Methods

The following is a list of growth methods used to make LED light-emitting layers.

Crystal Growth Method	Film Thickness Control	Film Deposition Rate	mass production	Other
LPE : Liquid Phase Epitaxial	× A few um ~10+ um	◎	◎	Old school. For low luminous intensity models It still applies today.
CVD : Chemical Vapor Deposition	△ sub-um ~A few um.	○	○	For low luminous intensity models It still applies today.
MBE : Molecular Beam Epitaxy	◎ Å level	×	×	For Research and Development
ALE : Atomic Layer Epitaxy	◎ Å level	×	×	For Research and Development
MOCVD : Metal-Organic Chemical Vapor Deposition	○ Several Å ~nm	○	○	Widely applicable to mass production has been production system

TEM observation of the crystal structure of an epitaxial film (AlGaInP system)

The structure of the AlGaInP element by transmission electron microscope (TEM) is shown below.



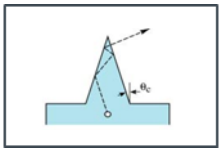
Increasing the Brightness of LED Chips (Improvement of the External Emission Efficiency)

One way to increase the brightness of LED chips is to improve its external emission efficiency. This is done by extracting more light from the LED light-emitting layer to the outside of the chips.

The following methods are used to achieve that.

(a) Provide a reflective layer on the substrate to prevent the light from being absorbed. (e.g. DBR layer)

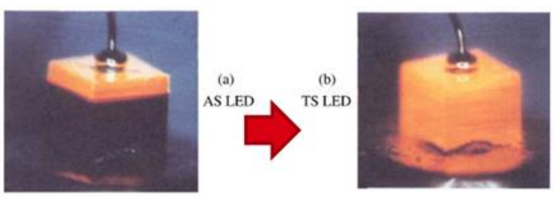
(b) Unevenness on the element surface is provided to prevent total reflection on the element surface.



(c) A transparent conductive film is provided on the surface of the element to expand the current.

(d) Change the current path not to be emitted directly under the element electrode as much as possible.

(e) Thicken the epi-layer to increase the amount of light extraction from the element sides.



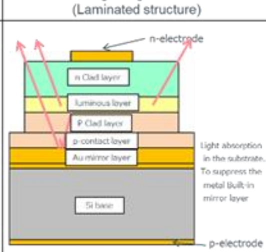
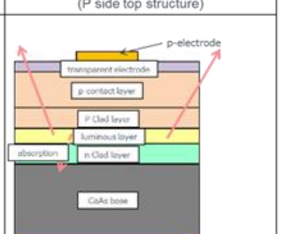
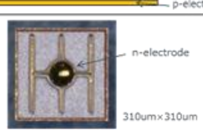
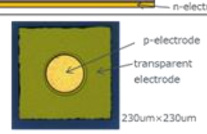
(f) Change the substrate material from a light-absorbing material to a transparent material.

(g) Make the chip size larger.

(f) Make the electrode size smaller.

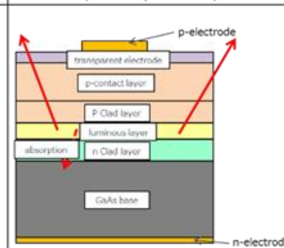
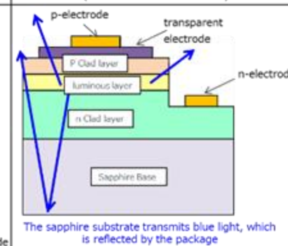
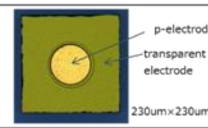
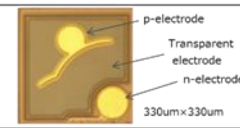
Comparison of AlGaInP LED Structures

The following table shows the difference in structures between normal-brightness type and high-brightness type (laminated structure) of AlGaInP LED elements.

	Red High Brightness LED (Laminated structure)	Red Regular Brightness LED (P side top structure)
elemental structure (Cross-sectional diagram)		
External appearance of the upper surface of the element		

Comparison of the Structures of Red and Blue Devices

The difference in structure between red (InGaAlP) and blue (InGaN) elements is shown below.

	Red Regular Brightness LED (P side top structure)	Blue, Green LED (2-wire basic structure)
elemental structure (Cross-sectional diagram)		
External appearance of the upper surface of the element		

Notes

1) The information contained herein is subject to change without notice.

2) Before you use our Products, please contact our sales representative and verify the latest specifications :

3) Although ROHM is continuously working to improve product reliability and quality, semiconductors can break down and malfunction due to various factors.
Therefore, in order to prevent personal injury or fire arising from failure, please take safety measures such as complying with the derating characteristics, implementing redundant and fire prevention designs, and utilizing backups and fail-safe procedures. ROHM shall have no responsibility for any damages arising out of the use of our Poducts beyond the rating specified by ROHM.

4) Examples of application circuits, circuit constants and any other information contained herein are provided only to illustrate the standard usage and operations of the Products. The peripheral conditions must be taken into account when designing circuits for mass production.

5) The technical information specified herein is intended only to show the typical functions of and examples of application circuits for the Products. ROHM does not grant you, explicitly or implicitly, any license to use or exercise intellectual property or other rights held by ROHM or any other parties. ROHM shall have no responsibility whatsoever for any dispute arising out of the use of such technical information.

6) The Products specified in this document are not designed to be radiation tolerant.

7) For use of our Products in applications requiring a high degree of reliability (as exemplified below), please contact and consult with a ROHM representative : transportation equipment (i.e. cars, ships, trains), primary communication equipment, traffic lights, fire/crime prevention, safety equipment, medical systems, servers, solar cells, and power transmission systems.

8) Do not use our Products in applications requiring extremely high reliability, such as aerospace equipment, nuclear power control systems, and submarine repeaters.

9) ROHM shall have no responsibility for any damages or injury arising from non-compliance with the recommended usage conditions and specifications contained herein.

10) ROHM has used reasonable care to ensure the accuracy of the information contained in this document. However, ROHM does not warrants that such information is error-free, and ROHM shall have no responsibility for any damages arising from any inaccuracy or misprint of such information.

11) Please use the Products in accordance with any applicable environmental laws and regulations, such as the RoHS Directive. For more details, including RoHS compatibility, please contact a ROHM sales office. ROHM shall have no responsibility for any damages or losses resulting non-compliance with any applicable laws or regulations.

12) When providing our Products and technologies contained in this document to other countries, you must abide by the procedures and provisions stipulated in all applicable export laws and regulations, including without limitation the US Export Administration Regulations and the Foreign Exchange and Foreign Trade Act.

13) This document, in part or in whole, may not be reprinted or reproduced without prior consent of ROHM.

Thank you for your accessing to ROHM product informations.
More detail product informations and catalogs are available, please contact us.

ROHM Customer Support System

http://www.rohm.com/contact/