Semiconductor Device and Quantum Technology

LED

Present by

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Contents:

i)LED

Principle,Construction,working,Application

ii)White LED

Principle,Construction,working,Application

Definition!

LED [Light Emitting Diode] is defined as a PN junction diode which emits visible or invisible light under **Forward Biase** condition.

Note:

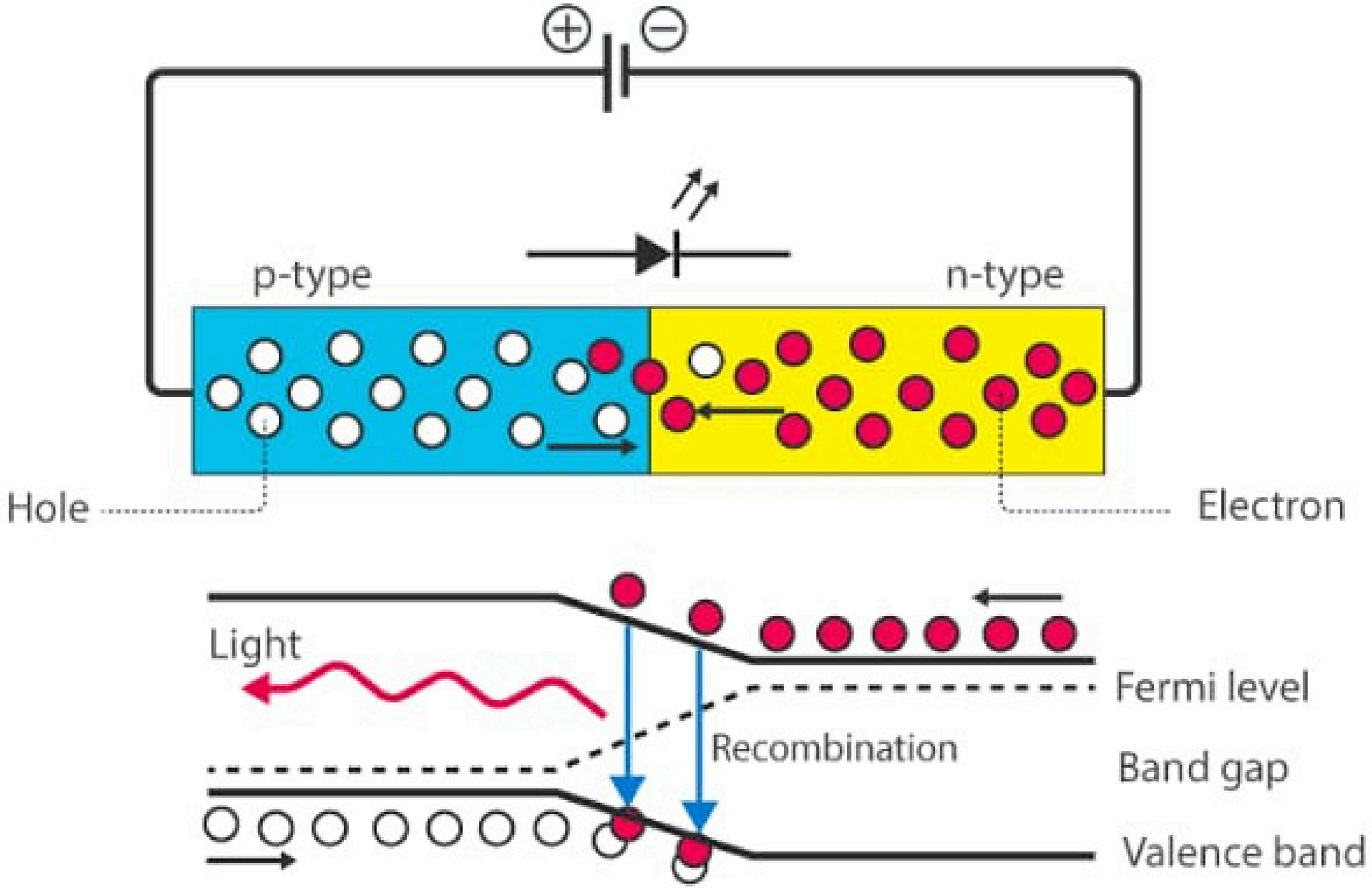
Forward Biase : Positive Terminal is connected to p-type and Negative terminal is connected to n-type,

Principle:

Light Emitting Diode works on the principle of ELECTROLUMINESCENE.

Note:

Electroluminescence: an optical phenomenon, and electrical phenomenon where a material emits light in response to an electric current passed through it.


p-type
n-type
Hole
Electron
Light
Recombination
Fermi level
Band gap
Valence band

LED Materials:

Condition for LED materials:

*Energy Gap greater than or equal to about 2eV are required to obtain visible radiation.

*Both p and n types must exist with low resistivities.

*Efficient radiative pathways must be present.

Semiconductor Diode:

* Gallium arsenide[GaAs]
*Gallium phosphide[GaP]
*Gallium arsenide phosphide[GaAsP]
*Gallium aluminium arsenide[GaAlAs]

Working:

When the diode is forward biased, the minority electrons are sent from p → n while the minority holes are sent from n → p.

At the junction boundary, the concentration of minority carriers increases.

The excess minority carriers at the junction recombine with the majority charges carriers

Working:

During recombination process,energy is relased in the form of light(radiative) or heat (non-radiative).

Thus, Light radiation from LED is caused by recombination of holes and electrons that are injected into junction by Forward bias voltage

Energy of emitted photon of LED with wavelength ‘λ’ is given by,

Energy of a photon

We can measure the energy of a photon using Einstein’s equation:

$$E = hf = \frac{hc}{\lambda}$$

h = 6.63×10^{-34} Js → Planck constant

f = frequency of photon/electromagnetic radiation

c = 3×10^{8} m/s → speed of light in a vacuum

λ = wavelength of photon/electromagnetic radiation

CONCEPT OF REVERSE VOLTAGE:

* LEDs have low reverse voltage rating (i,e) Maximum reverse voltage rating of 3V.

*If reverse voltage is applied greater than this limit, LED may be destroyed.

*To protect from damage, connect a rectifier diode in parallel with LED.

Semiconductor material	Wavelength	Colour
GaAs	850 – 940 nm	Infra-red
GaAsP	630 – 660 nm	Red
GaAsP	605 – 620 nm	Amber
GaAsP:N	585 – 595 nm	Yellow
AlGaP	550 – 570 nm	Green
SiC	430 – 505 nm	Blue
GaInN	450 nm	White

Si is not an LED material.

Applications:

- Used in Indicator Lamps on the front panel of the scientific and laboratory equipments.
- Seven Segment Displays
- Traffic signals,Emergency vehicle lighting etc.
- Remote control of television air-conditioner.

Points to Ponder:

›The warm-up time required is low. So, Switching speed is high.

[warm-up time: time require to attain highest performances]

› LED works when the p-n junction is forward biased

›The reverse breakdown voltages of LEDs are very low

› LED is heavily doped.

› LED has lower output Power.

Numerical Problems:

1)Calculate the wavelength of the radiation by a LED made up of GaAs with band gap energy 1.43eV. **Ans**: 868nm

2) Determine the material of the LED if the energy band gap of the material is 4.14x10^-17J.

Ans:SiC

Reasoning:

3)Why we avoid to use Silicon and Germanium for LED making ,instead we are using Gallium?

Ans: E for Si 1.1eV

E for Ge 0.7eV


EASY
EASY
ALMOST IMPOSSIBLE

Why there is a separate preparation for WHITE LEDs?

WHITE LEDs:

- Semiconductor device that produce white light [GaInN].
- Typically,constructed using a combination of different material and techniques.

Principle:

› White LED also works on the principle of Electroluminescence.

› In the case of white LEDs,a combination of blue and phosphors is to be done.

Methods :

- **Wavelength Conversion**
- Colour Mixing
- Homo Epitaxial ZnSe

Construction:

It consist of ,

i) Substrate: LED chip is usally mounted on a substrate which provides mechanical support and helps to dissipate heat.

ii)LED chip: It is made up of a semiconductor material,GaN doped with indium.This chip emits blue or UV light when a currect passes through it

iii)Phosphor Layer: It absorbs blue or UV and re-emits it as a broader spectrum of light.

Working:

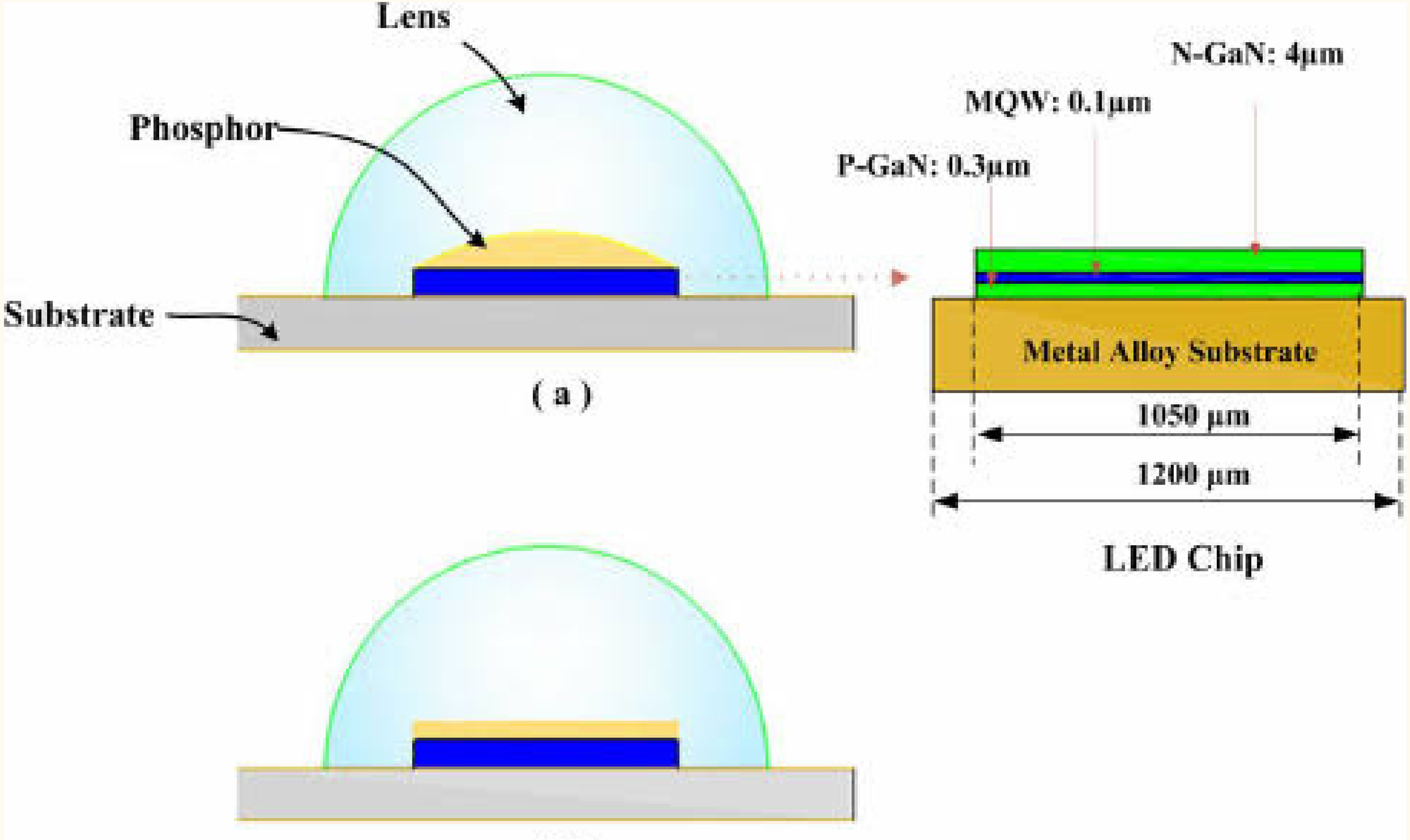
When a forward voltage is applied across the LED, electron and holes recombine within the semiconductor material.

In the case of blue LED chip,recombination take place in Gallium Nitride layer,resulting the emission of blue light.

Working:

- Blue light interacts with the phosphor layer,where some of the energy is absorbed by the phosphor material.

- The absorbed energy causes the phosphor to re-emit light, which combines with the remaining blue light to produce a white light output.


Lens
Phosphor
Substrate
(a)
N-GaN: 4μm
MQW: 0.1μm
P-GaN: 0.3μm
Metal Alloy Substrate
1050 μm
1200 μm
LED Chip

Application of White LEDs:

White LEDs play a vitol role in almost all light application .

- **Street Light**-Offers better energy efficiency and visibility.
- **Flashlights and lamps**-Offers high brightness and low power consumption
- **Headlights,Tailights in vehicle**-energy efficiency and compact size

References

01 Semionductor Optoelectonic Devices
Pallab Bhattacharya

02 Semiconductor
P.K.Palanisamy

03 Principles of Electronis
V.K.Mehta

Thank you!

Practice makes Perfect

NOTICE: Objective of this seminar is to provide basic understanding of LEDs only.For Deep learning put your best foot forward