EXPERIMENT-1

LIGHT EMITTING DIODES (LED's)

BACKGROUND INFORMATION:

A Light emitting diode (LED) is essentially a pn junction diode. When carriers are injected across a forward-biased junction, it emits incoherent light. Most of the commercial LEDs are realized using a highly doped n and a p Junction.

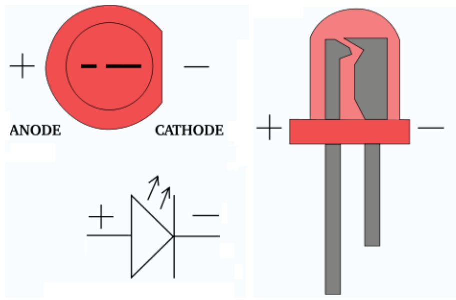
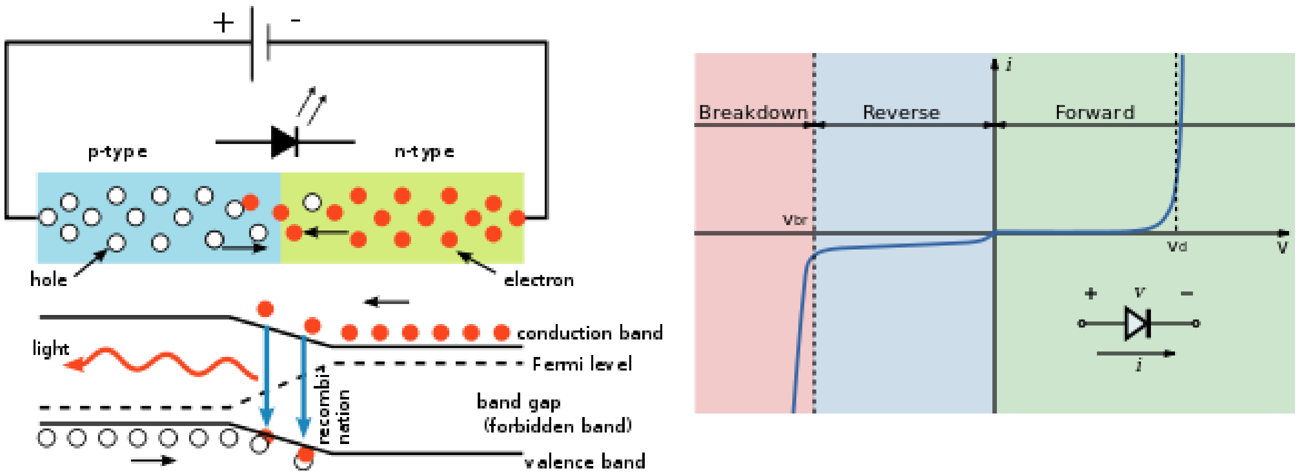


Fig. 5 The schematics of LED

The light output of an LED is the spontaneous emission generated by radiative recombination of electrons and holes in the active region of the diode under forward bias.



(a) (b)

Fig. 6 Operation of an LED under forward bias polarity (a) and I-V characteristics for a diode (b) [*www.wikipedia.org]*

To understand the principle, let's focus on pn junction. The depletion region extends mainly into the p-side. There is a potential barrier from E_c (the energy level of conduction band) on the n-side to the E_c on the p-side, called the built-in voltage, V_0. This potential barrier prevents the excess free electrons on the n+ side from diffusing into the p side.

When a Voltage V is applied across the junction, the built-in potential is reduced from V_0

to $V_0 - V$. This allows the electrons from the n+ side to get injected into the p-side. Since electrons are the minority carriers in the p-side, this process is called minority carrier injection. But the hole injection from the p side to n+ side is very less and so the current is primarily due to the flow of electrons into the p-side.

These electrons injected into the p-side recombine with the holes. This recombination results in spontaneous emission of photons (light). This effect is called injection electroluminescence. These photons should be allowed to escape from the device without being reabsorbed.

An LED emits incoherent, non-directional, and unpolarized spontaneous photons that are not amplified by stimulated emission.

An LED does not have a threshold current. It starts emitting light as soon as an injection current flows across the junction.

The wavelength of the light emitted, and hence the color, depends on the band gap energy of the materials forming the p-n junction. The emitted photon energy is approximately equal to the band gap energy of the semiconductor. The higher the energy gap, the greater the frequency of emitted light. The following equation relates the wavelength and the energy band gap.

$$h\nu = Eg$$

$$hc/\lambda = Eg$$

$$\lambda = hc/ Eg$$

Here c is the speed of light in vacuum and h is Planck's constant given as 6.63×10^{-34} J·s or 4.13566^{-15} eV·s

For example, assume that the energy gap of a given LED is 2 eV. Let’s calculate the radiation wavelength of this Led.

$$\lambda = hc/ Eg = (4.1356610^{-15} \text{ eV·s} \cdot 3 \cdot 10^{8} \text{m/s}) / (2 \text{ eV}) = 0.62 \text{ µm} = 620 \text{ nm}.$$

This led emits red light.

LED Materials:

Some common materials for LEDs include InGaN (near UV and blue), GaN (blue and green), AlGaP (green), AlGaInP (green, yellow, and orange), AlAs & GaAs (red and near infrared), InGaAsP (near infrared). The semiconductor material is direct-bandgap to ensure high **quantum efficiency**, often III-V semiconductors.

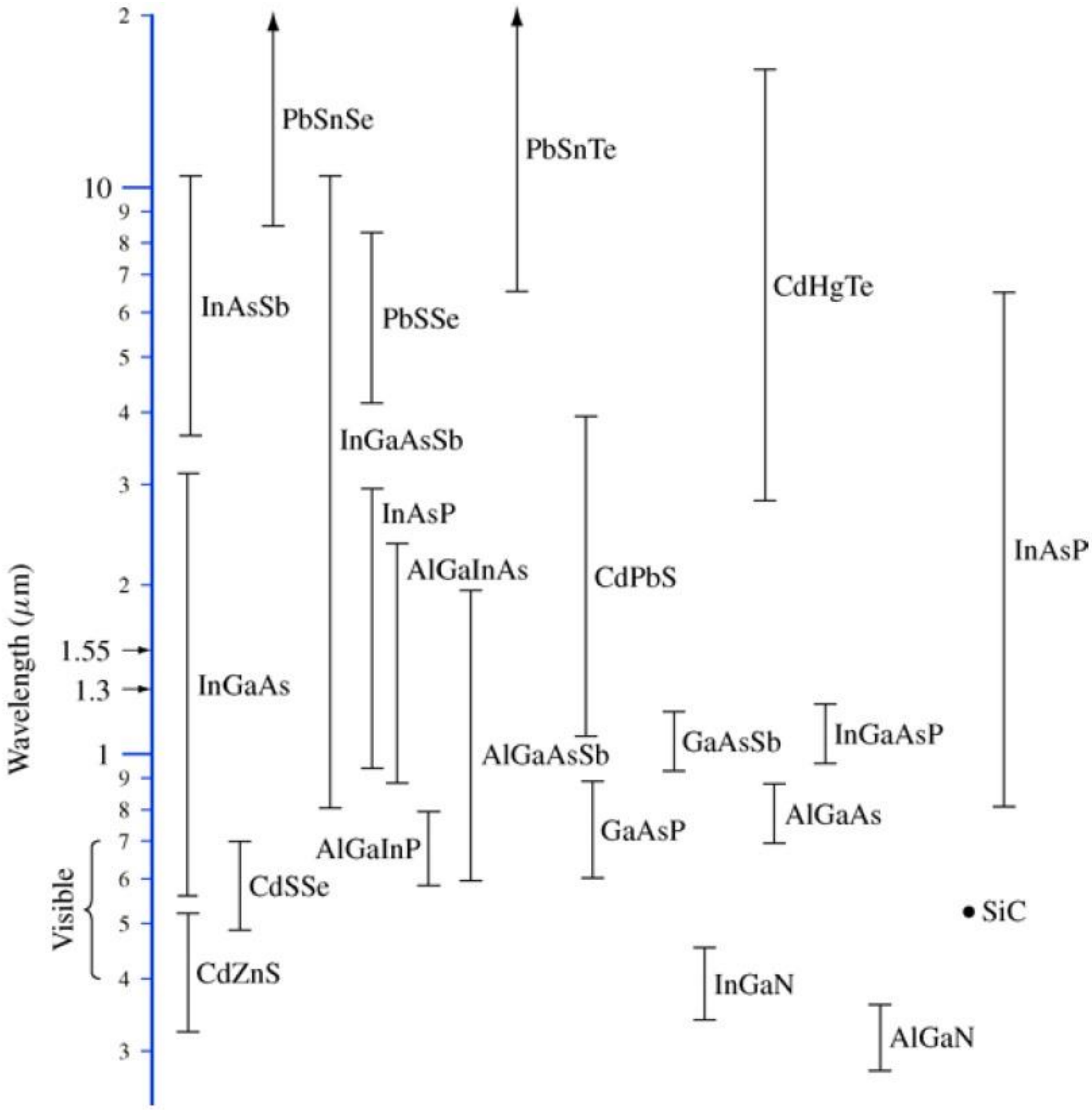


Fig. 7 Some semiconductor materials and their wavelength ranges.

Applications of LEDs

One of the biggest advantages of LEDs over the traditional incandescent light is its high luminous efficacy. That is to say, LEDs can produce more light than can traditional incandescent light bulbs when consuming the same amount of electricity. Due to this advantage, LEDs have been applied to many areas so far. For example, mobile phone backlighting, flashlights, and displays for calculators and many other electronic devices are almost dominated by LEDs now. In some places, traffic lights are also lit using LEDs. Despite all these current applications of LEDs, the lighting methods nowadays in homes and offices are still the traditional light bulbs due to the relatively high initial cost of LED implementations. However, taking into account the fact that prices of LEDs have dropped significantly since their first invention and will continue decreasing, it is very likely that in the future, all lightings in homes and offices will be replaced by LEDs.

Advantages of using LED's

- LEDs produce more light per watt
- LEDs work under low voltage.
- They have small size but can produce high intensity illumination
- LEDs can emit light of an intended color without the use of color filters
- The solid package of an LED can be designed to focus its light
- LEDs have an extremely long life span
- LEDs light up very quickly. Therefore they can be used in fast optical switching.
- LEDs can be very small and are easily populated onto printed circuit boards

REFERENCES

1. Course Notes of Rhode Island University.
2. Course Notes of Penn State University.
3. Betty Lise Anderson and Richard L. Anderson, "Fundamentals of Semiconductor Devices", McGraw-Hill, 2004.

Experiment-1: LIGHT EMITTING DIODES

AIM: To determine characteristics of LEDs.

EQUIPMENT

Power Supply

Oscilloscope

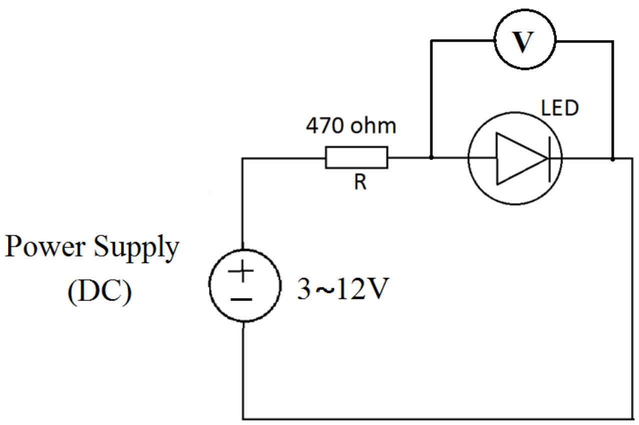
Voltmeter, Ampermeter

Red, Green and Yellow clear Leds

Red, Green and Yellow diffused Leds

Procedure: Use both clear and diffused LED's from the same manufacturer.

Construct the circuit one on the breadboard using a 470 Ω resistor for R.



Complete the following Tables for setting the voltage source from 3V to 12V. Use a digital multimeter set ONLY TO MEASURE DC VOLTAGE.

Table 1 –DC operation of Diffused RED LED

DC Voltage Supply	3V	4V	5V	6V	7V	8V	9V	10V	11V	12V
Voltage across R										
Voltage across LED										
Now **CALCULATE** the following										
Current through R										
Power in LED										

Table 2 –DC operation of Diffused GREEN LED

DC Voltage Supply	3V	4V	5V	6V	7V	8V	9V	10V	11V	12V
Voltage across R										
Voltage across LED										
Now **CALCULATE** the following										
Current through R										
Power in LED										

Table 3 –DC operation of Diffused YELLOW LED

DC Voltage Supply	3V	4V	5V	6V	7V	8V	9V	10V	11V	12V
Voltage across R										
Voltage across LED										
Now **CALCULATE** the following										
Current through R										
Power in LED										

Table 4 –DC operation of Clear RED LED

DC Voltage Supply	3V	4V	5V	6V	7V	8V	9V	10V	11V	12V
Voltage across R										
Voltage across LED										
Now **CALCULATE** the following										

Current through R						
Power in LED						

Table 5 –DC operation of Clear GREEN LED

DC Voltage Supply	3V	4V	5V	6V	7V	8V	9V	10V	11V	12V
Voltage across R										
Voltage across LED										
Now **CALCULATE** the following										
Current through R										
Power in LED										

Table 6 –DC operation of Clear YELLOW LED

DC Voltage Supply	3V	4V	5V	6V	7V	8V	9V	10V	11V	12V
Voltage across R										
Voltage across LED										
Now **CALCULATE** the following										
Current through R										
Power in LED										

Place a RED DIFFUSED LED right next to a RED CLEAR LED. Use a 470Ω resistor with each LED and connect them to a supply voltage of 12V.

Use a piece of paper to cover the top part of each of the two LEDs. Which LED burns brighter? Use direct observation to draw a conclusion.

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Which LED would cover a larger area? Again use direct observation.

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By transferring the obtained data to Matlab software, *sketch* an I-V curve for each LED (the x and y axes should be represented by the voltage and current of the LED, respectively).

Sketch, on a single graph paper, a bar graph showing the **LED type to Power** change for each of the voltage settings. Group the different colours and voltages together. **12 LEDs must feature** on the x-axis with RED next to RED and so forth. Use different colours to indicate the three various LEDs.

Include a table in the final report, as an annexure, illustrating the different peak wavelengths, typical luminous intensities and viewing angles for the six different LED's above. Refer to the data sheets for the information. The LED numbers are given in Annexure 1 and the relevant web sites are given in Annexure 2.

Remember that the first letter of the LED number often indicates the manufacturer's name.

Conclusion:

Evaluate the overall efficiency of the clear and diffused LED's in the 5V DC operation.

A number of LEDs need to be connected in series across a 12V DC power supply. No series resistors may be used. Conclude which LEDs you would use to make up this series combination.

Conclude why the RED clear LED draws more current than the other LED's in the 5V operation.

Contrast the diffused RED LED with the clear RED LED (12V) as OBSERVED in this practical.

Justify appropriate applications for diffused and clear LED's.

Reference: Course notes of Vaal University of Technology