EE236: Electronic Devices Lab
Lab No. 1

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1 Pre-Lab: Identifying Cut-in Voltages of LEDs and plotting waveforms: completed and checked by TA

1.1 Aim of the experiment

To study the plots of I_d vs V_d and $ln(I_d)$ vs V_d of a diode and 4 LEDs for estimating their Cut-in voltages.

1.2 Circuit Design

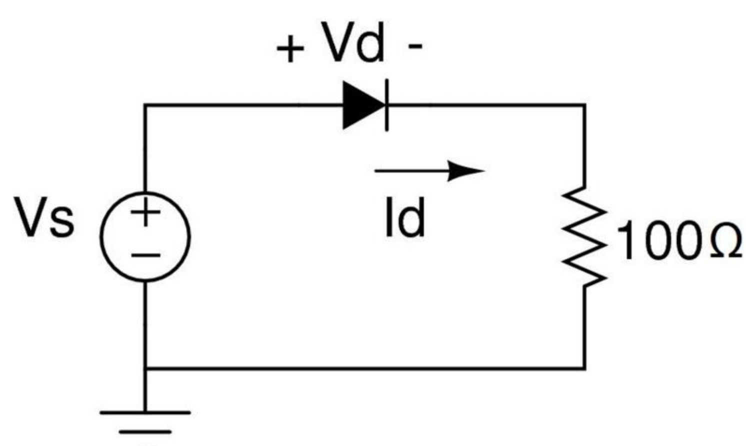

Figure 1: Diode I-V Circuit

1.3 Netlist Code

```
LED I-V Characteristic Plot
.model 1N4007 D ( IS=76.9p RS=42.0m BV=1.00k IBV=5.00u
+ CJO=26.5p M=0.333 N=1.45 TT=4.32u )
.model blue D (IS = 2.659E-20 N = 2.63815 RS = 8.14349)
.model green D (IS = 9.847E-17 N = 2.396 RS = 12.9816)
.model red D (IS = 4.366E-25 N = 1.38167 RS = 3.00014)
.model white D (IS = 1.2853E-15 N = 3.99 RS = 8.12296)

d1 1 2 1N4007
d2 1 3 blue
d3 1 4 green
d4 1 5 red
d5 1 6 white

r1 2 0 100
r2 3 0 100
r3 4 0 100
r4 5 0 100
r5 6 0 100

vin 1 0 dc 0
.dc vin 0.01 5 0.01
.control
run
set color2 = black set
color3 = blue set
color4 = green set
color5 = red set
color6 = yellow

plot (v(2)/100) vs v(1,2) (v(3)/100) vs v(1,3) (v(4)/100) vs v(1,4) (v(5)/100) vs v(1,5) (v(6)/100) vs v(1,6)
plot (log(v(2)/100)) vs v(1,2) (log(v(3)/100)) vs v(1,3) (log(v(4)/100)) vs v(1,4) (log(v(5)/100)) vs v(1,5) (log(v(6)/100)) vs v(1,6)
.endc
.end
```

1.4 Simulations and Conclusions (Prelab)

Node 2: 1N4007

Node 3: blue

Node 4: green

Node 5: red

Node 6: white

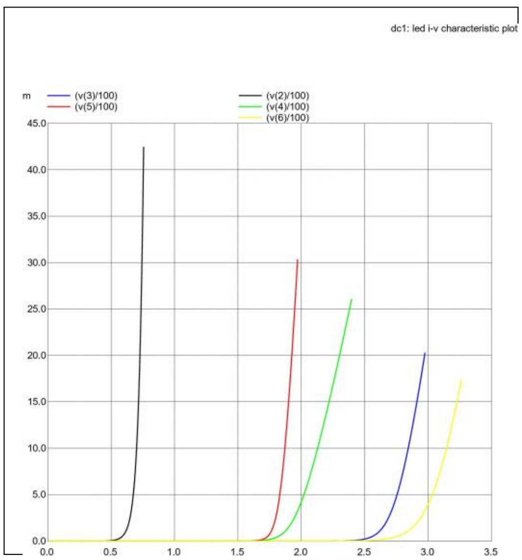

Figure 2: I_D vs V_D Plot

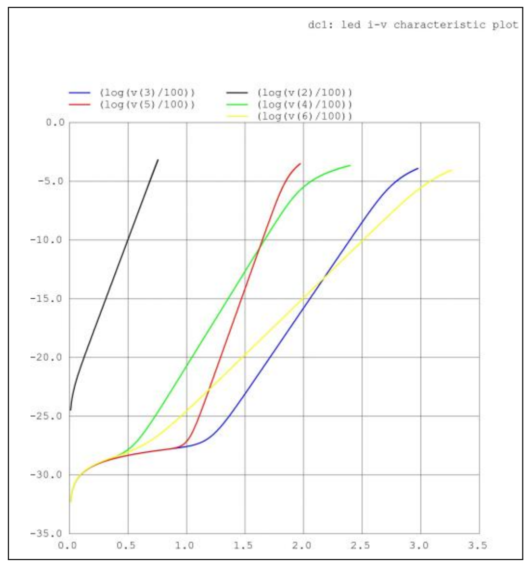

Figure 3: ln(I_D) vs V_D Plot

Cut-in Voltages

- Normal diode = 0.4V
- Blue LED = 2.2V
- Green LED = 1.5V
- Red LED = 1.5V
- White LED = 2.4V

1.5 Discussion

Figure 4: Emission Intensity vs Wavelength of LEDs for different currents

Question:

The two wavelengths in the spectrum of the white LED are due to the direct emission of blue light from the LED chip and the secondary emission of yellow (or broader spectrum) light from the phosphor. This combination of emissions creates the appearance of white light.

Figure 4 presents the spectra of various colored LEDs operating at different current levels. As anticipated, the light emission intensity rises with increasing current due to higher minority carrier injection. It is noteworthy that the white LED exhibits two distinct wavelengths. Why does this occur?

2 Lab Exercise

2.1 Aim

- To analyze the forward bias I/V characteristics of PN junction diodes and estimate the band gap of the semiconductor material used in the diodes.
- To determine the ideality factor, reverse saturation current, and doping densities of various PN junction diodes.

2.2 Important Equations

Band Gap Equation:

$$E_g = \frac{hc}{\lambda} = \frac{1240}{\lambda}$$

where:

- E_g: Band gap of the material in units of electron Volts (eV)
- λ: Emission wavelength in nanometers (nm)

I/V Characteristic of a Forward Biased Diode:

$$I_D = I_{00} e^{-\frac{E_g}{kT}} \left(e^{\frac{qV_D}{\eta kT}} - 1\right)$$

Saturation Current:

$$I_S = I_{00} e^{-\frac{E_g}{kT}}$$

Assuming $qV_D \gg \eta kT$:

$$\ln \frac{I_D}{I_{00}} + \frac{E_g}{kT} = \frac{qV_D}{\eta kT}$$

Assuming the density of states are approximately the same for all semiconductor materials:

$$n_i \propto e^{-\frac{E_g}{2kT}}$$

2.3 Circuit Diagram

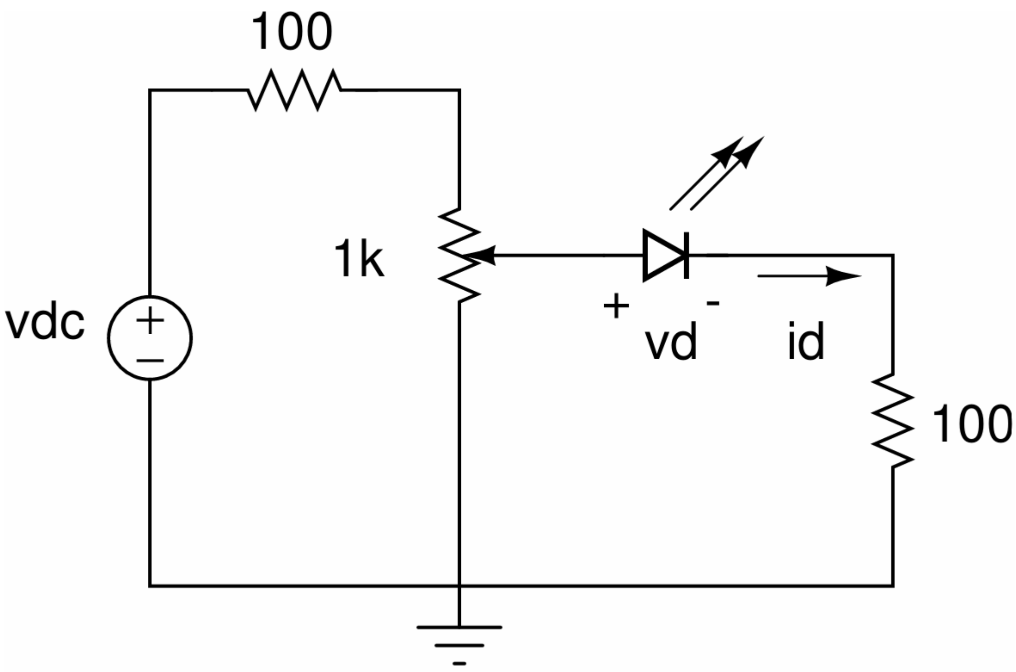

Figure 5: Circuit to measure I/V characteristics of a semiconductor diode

Components used:

- Silicon P-N junction diode 1N914
- LEDs: Red, Green, Blue, and White
- Resistors: 100 Ω (×2)
- Potentiometer: 1 kΩ
- Breadboard, connecting wires

2.4 Observations and Conclusions

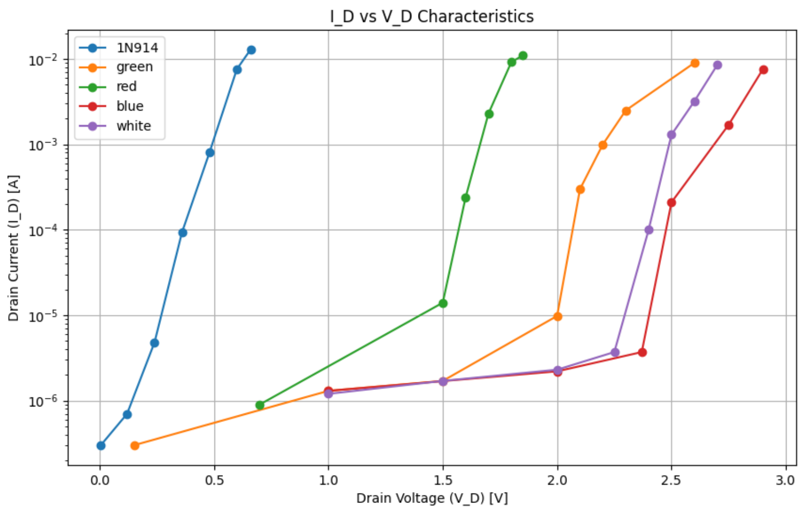

Figure 6: Plot 1 - I_D v/s V_D for all five diodes

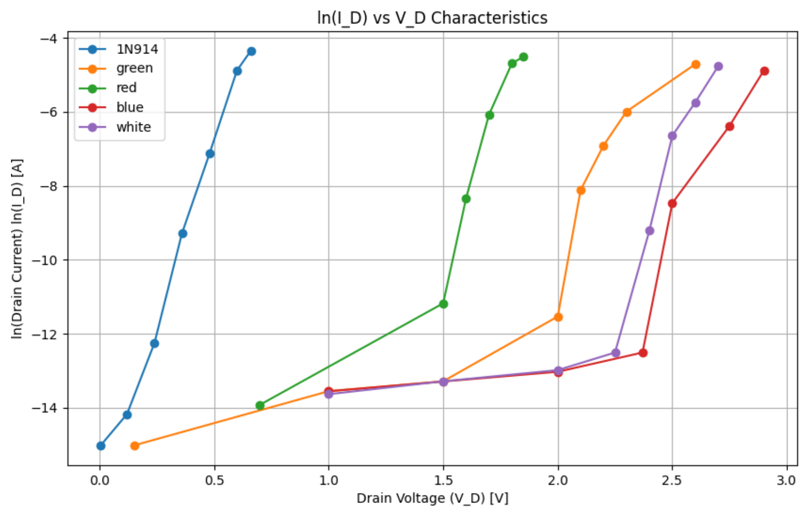

Figure 7: Plot 2 - $ln(I_D)$ v/s V_D for all five diodes

Diode	Slope	Intercept	Ideality Factor	Saturation Current
1N914	17.6417	-15.7956	0.00147	1.3806×10^{-7} A
Red	4.3319	-17.3886	0.00597	2.8068×10^{-8} A
Green	8.1456	-20.5396	0.00318	1.2016×10^{-9} A
Blue	4.3876	-19.6884	0.00590	2.8147×10^{-9} A
White	5.1683	-20.7974	0.00501	9.2855×10^{-10} A

Table 1: Results for each diode

Diode	Band Gap E_g	Cut-in Voltage V_γ	n_i (cm^{-3})	$N_{A,D}$ (cm^{-3})
1N914	1.1 eV	0.7 V	1.45×10^{10}	6.07×10^{15}
Red	1.96 eV	1.9 V	2.48×10^{9}	2.17×10^{16}
Green	2.36 eV	2.2 V	1.42×10^{8}	6.89×10^{16}
Blue	2.72 eV	2.9 V	1.65×10^{7}	6.34×10^{17}
White	2.75 eV	3.2 V	1.21×10^{7}	1.09×10^{18}

Table 2: Band gap E_g, Cut-in Voltage V_γ and Doping densities

Figure 8: Plot 3 - E_g v/s V_γ for all five diodes

Questions Solved

$$I_D = I_{00} e^{-\frac{E_g}{kT}} \quad e^{\frac{qV_D}{\eta kT}} - 1 \tag{1}$$

$$\ln \frac{I_D}{I_{00}} + \frac{E_g}{kT} = \frac{qV_D}{\eta kT} \tag{2}$$

- **-** Are equations 1 and 2 valid across the entire range of \(V_D \)? Yes, the equations appear to hold true over the entire range of \(V_D \) (0-3V), as observed from the plots.
-
- - Examine the relationship between \(V_\gamma \) and \(E_g \) by selecting a current \(I_D \) of 50 µA and 5 mA, and observe how the non-ideality of the I/V characteristics affects the experiment. The non-ideality factor (\(\eta \)) influences the cut-in voltage. A higher \(\eta \) will result in a higher \(V_\gamma \) for the same \(I_D \) compared to an ideal diode (\(\eta = 1 \)). This factor indicates the deviation from ideal diode behavior and can be affected by practical factors like recombination and series resistance within the diode. Therefore, both \(I_D \) and \(\eta \) will impact the measured \(V_\gamma \), and observing these variations provides insight into the non-ideal characteristics of diodes in real-world scenarios.State some applications of all the diodes that you used today

1. 1N914 Diode: Optimal for general rectification, switching, and signal processing tasks.
2. Red LED: Ideal for use in indicators, displays, and decorative lighting.
3. Green LED: Well-suited for indicators, traffic signals, and display technology.
4. Blue LED: Commonly used in high-intensity lighting, displays, and UV applications.
5. White LED: Perfect for general illumination, automotive lighting, and display backlighting.

2.5 Experiment completion status

Completion status: **100% and checked by TA**