EE236: Experiment 5
Diodes, and Why They are Awesome

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1 Aim of the experiment

- To study I-V characteristics of various diodes under forward bias and estimate the bandgap of the semiconductor material diode is made of.
- To study difference between silicon pn junction diode and Schottky diode through their I-V characteristics.
- To learn about the many applications of diodes and appreciate them.

2 Methods

To perform this experiment, we required the following:

- An easy way to distinguish band gaps of diodes made of different materials.
- A way to calculate bandgap of a given diode.

Hence, we used LEDs (Light Emitting Diodes) because they can be distinguished from their color and bandgap can be estimated from I-V characteristics. Peak emission wavelength of LED is a measure of .

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

E_g: bandgap of material in eV.
λ: wavelength of material in nm.

2.1 Part 1

A voltage divider circuit is implemented using a 1kΩ potentiometer to vary the input voltage of the diode. An ammeter and voltmeter are connected to the diode for measuring I-V characteristics.

2.2 Part 2

A sinusoidal wave (AC) of 2 different P_k-P_k voltage values is provided from the function generator and waveforms are observed on the DSO using the 1N914, BAT85 and 4V7 Zener diode. We could not provide 16V of P_k-P_k voltage because our function generator saturated at around 15.4 Volts.

3 Observations

3.1 Part 1

Voltage	Current
0.05	-0.01
0.1	-0.01
0.2	-0.01
0.3	0
0.4	0.03
0.5	0.04
0.55	0.07
0.56	0.11
0.6	0.27
0.65	0.9
0.69	1.7
0.7	2.01
0.71	2.5
0.75	4.9
0.8	13.4
0.81	14.6

(a) 1N914

Voltage	Current
2	0
2.2	0.001
2.3	0.002
2.4	0.003
2.5	0.004
2.6	0.011
2.64	0.021
2.7	0.073
2.72	0.103
2.8	0.33
2.82	0.4
2.84	0.63
2.92	1.44
2.97	2.65
3.05	5.69
3.11	9.2

(b) Green LED

Voltage	Current
2	0
2.2	0.001
2.5	0.024
2.54	0.034
2.6	0.25
2.7	1.47
2.75	2.22
2.8	4.2
2.85	6.13
2.9	8.3

(a) White LED

Voltage	Current
1.42	0
1.6	0
1.66	0.02
1.72	0.08
1.75	0.25
1.76	0.3
1.8	0.65
1.85	1.27
1.88	1.98
1.89	2.45
1.9	2.83
1.95	5.3

(b) Red LED

Voltage	Current
0.364	13.1
0.357	10.2
0.354	9.3
0.34	7.98
0.325	6.25
0.323	6
0.321	5.4
0.31	3.55
0.285	1.7
0.27	0.97
0.25	0.61
0.24	0.24
0.21	0.09
0.2	0.04
0.19	0.03
0.15	0.01
0.1	0.005
0.07	0.001

(a) BAT85

Voltage	Current
2.51	0.002
2.6	0.005
2.64	0.008
2.65	0.009
2.66	0.01
2.67	0.013
2.69	0.021
2.7	0.026
2.75	0.049
2.83	0.28
2.92	0.8
2.96	1.26
3.04	3.38
3.11	5.76
3.17	8.93

(b) Blue LED

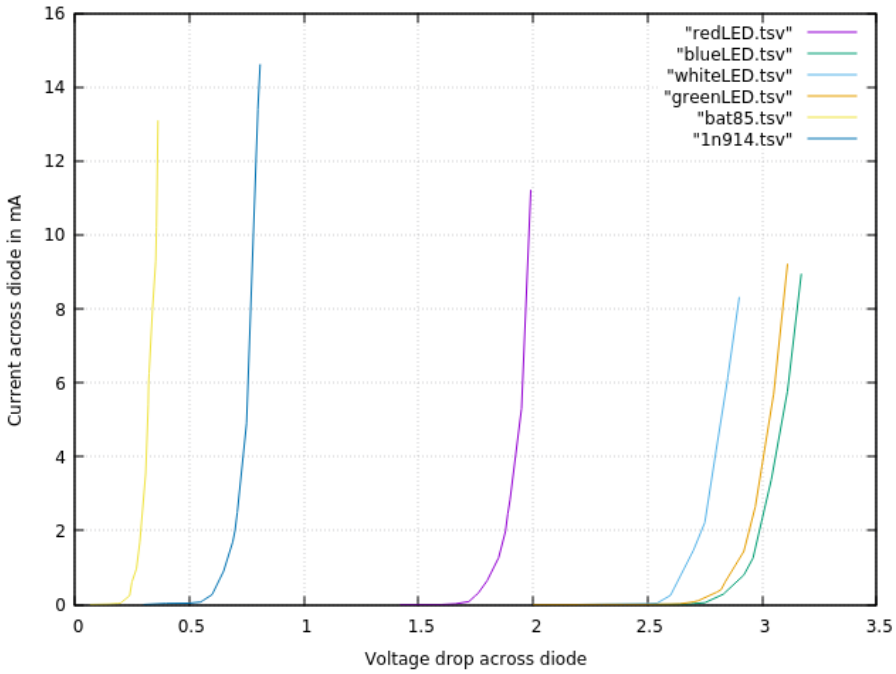


Figure 1: $I - V$ characteristic plot

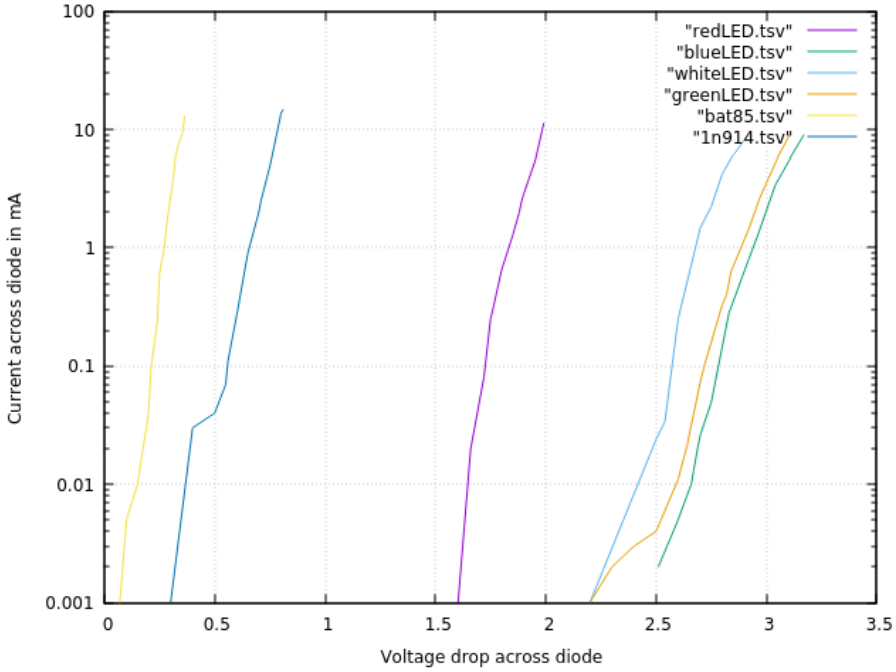
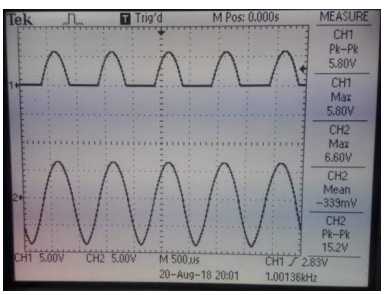
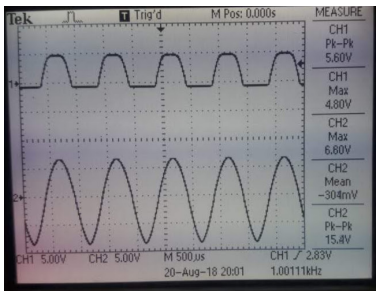


Figure 2: $log(I)$-V characteristic plot

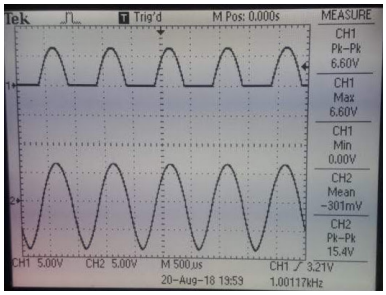
3.2 Part 2



(a) Waveform for 1N914

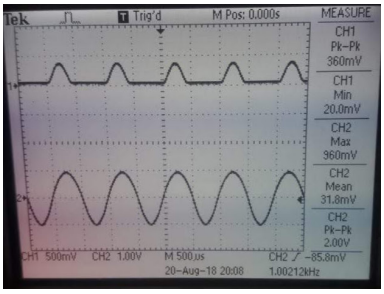


(b) Waveform for 4V7 Zener Diode

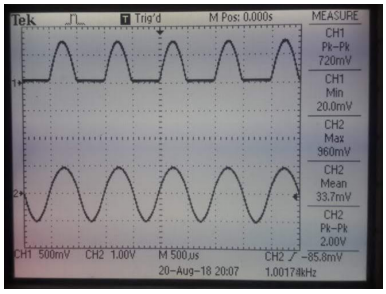


(c) Waveform for BAT85

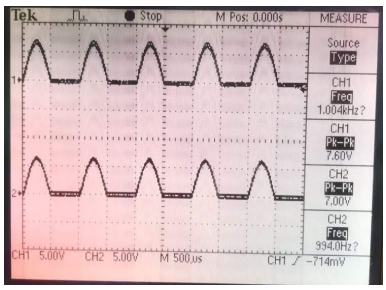
Figure 3: P_k-P_k Voltage = 16V



(a) Waveform for 1N914



(b) Waveform for BAT85



(c) BAT85 vs 1N914

Figure 4: P_k-P_k Voltage = 2V

4 Inference

4.1 Part 1

On fitting $f(x) = mx + c$ on the logarithmic I-V curves, and using the approximate form of diode equation(assumin $qV >> kT$) i.e.
$log(\frac{I_D}{I_0 0}) + \frac{E_g}{kT} = \frac{qV_D}{\eta kT}$, we get $m = \frac{q}{\eta kT}$. And hence, $\eta = \frac{q}{kTm}$ where $\frac{q}{kT} = 38.65V^{-1}$. So Ideality Factor $\eta = \frac{38.65}{m}$.

Diode	m	c	η
1n914	18	-11.95	2.15
bat85	33.3	-9.26	1.16
redLED	18.3	-33.73	2.11
blueLED	13.94	-41.4	2.77
whiteLED	14.07	-38.25	2.75
greenLED	11.06	-32.2	3.49

Table 1: Linear Regression Data

Diode	λ	E_g in eV	E_γ
1N914		1.1	0.66
White	4.50	2.76	2.72
Blue	4.60	2.70	2.97
Red	6.25	1.99	1.84
Green	5.30	2.34	2.91

Table 2: Bandgap of Diode

Diode	$1mA$	$0.5mA$	$5mA$
1N914	0.66	0.62	0.75
BAT85	0.27	0.25	0.32
redLED	1.84	1.80	1.93
blueLED	2.96	2.92	3.085
whiteLED	2.71	2.66	2.83
greenLED	2.91	2.84	3.05

Table 3: Values of E_γ for different I_D in eV

4.2 Part 2

The 1N914 and BAT85 act as half wave rectifiers and clip down the voltage. Unsurprisingly, Schottky diode has higher peak voltage due to it being a metal semiconductor junction. And again unsurprisingly, Zener diode in reverse bias limits the voltage around 4.7V.

Yes we can predict Zener Diode's output by the fact that it will limit voltage at 4.7V and will be a have wave rectifier because it is a diode.

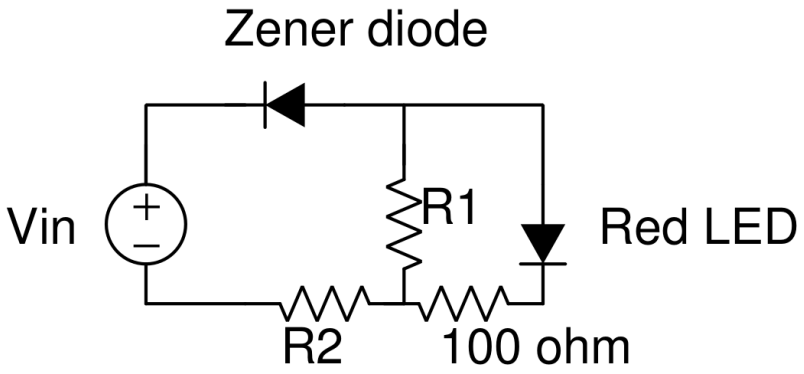
Diodes can be used as rectifiers, for clipper/clamper circuits, logic gates, voltage regulator, visual indicator, home lighting, and there are a lot of other applications as well. Schottky diode is used for fast operation circuits.

Schottky and Si pn junction diode can be differentiated by their resistance in forward bias. Schottky has lower resistance. Zener can be identified by applying reverse bias voltage and checking if it saturates.

Schottky diode has less cutting voltage than pn junction diode as well as a lower resistance. Hence its I-V curve will be below Si diode in forward bias and above it in reverse bias.

5 Advanced component

We use a potentiometer to implement a voltage divider and use a zener diode to 'absorb'4.7V and rest 1.3V is supplied to Red LED and the resistors. We adjust the pot such that LED glows just above 6V.



6 Reflection questions