EE236: Experiment 1
Familiarization with tools

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1 Overview of the experiment

1.1 Aim of the experiment

The aim of this experiment was to understand the I-V characteristics of a pn junction diode and see the difference between the characteristics when the bandgap changed. We also calculated the bandgaps from the characteristics.

1.2 Methods

The steps involved were as follows:
Write a ngspice netlist for the circuit and run the simulation for the 5 different types of diodes.
Create I-V and ln(I)-V plots for each diode on the same plot.
Find the slope of the linear portion in the second plot to find η for the diodes.
Calculate E_g using the emission intensity plots for each diode.
Plot E_g vs V_d.

2 Design

The formulae used for calculating E_g from peak intensity wavelength, η fro derivative of ln(I) vs V plot and the calculation of saturation current have all been provided in the lab sheet, and since they were used as is, I am not mentioning them again.

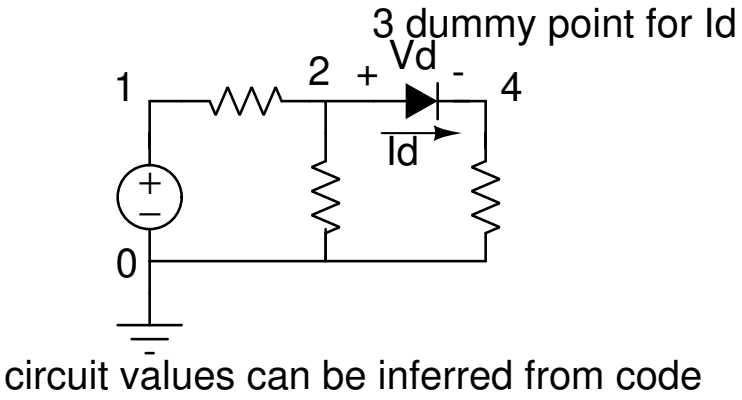


Figure 1: Circuit diagram used

3 Simulation results

3.1 Code snippet

```
19D070052 Sheel Shah Plot 1 for 1N914

.include models/Diode_1N914.txt
v_dc 1 0
r1 1 2 100
r2 2 0 1k
** dummy voltage
v_d 2 3 0
d0 3 4 1N914
r3 4 0 100

.dc v_dc 0.01 5 0.01

.control

run
* plot i(v_d) vs v(3)-v(4)
.endc

.end
```

The same code is used for all diodes with the diode model changed. The exact code can be found in the submission on moodle.

3.2 Simulation results

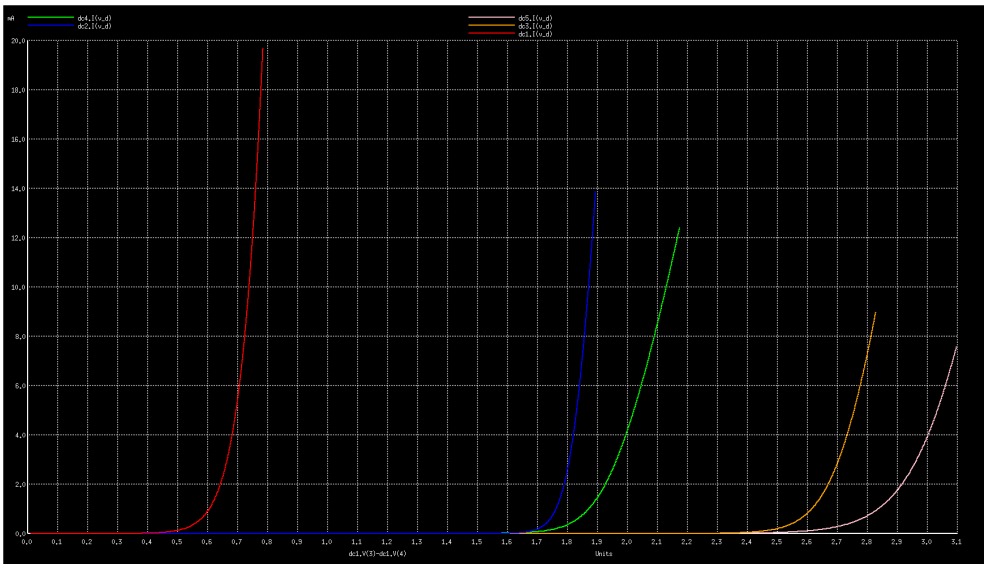


Figure 2: I-V plots: red(dc1): 1N914, blue(dc2): red led, orange(dc3): blue, green(dc4): green led, pink(dc5): white led
The same order is maintained for all following plots and tables

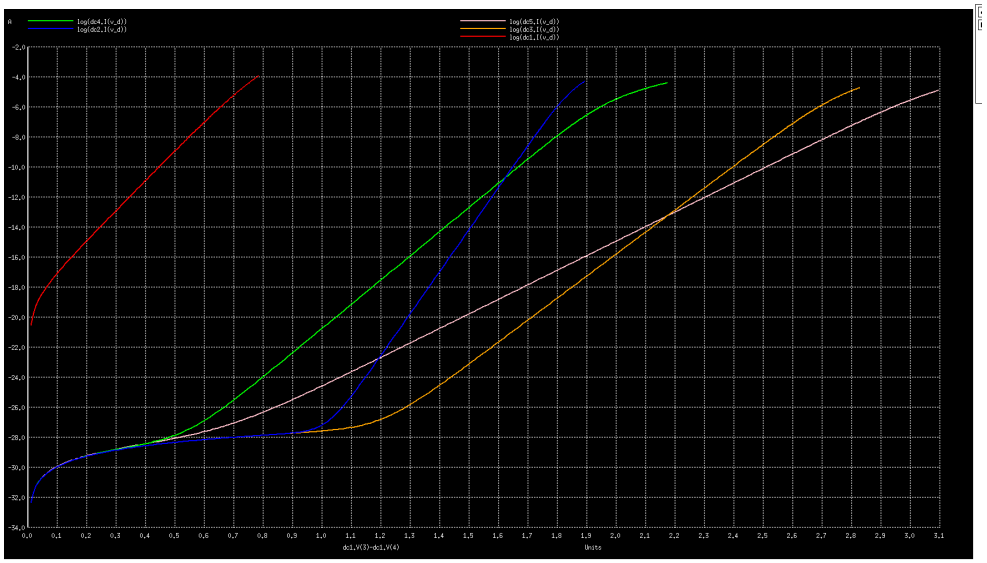


Figure 3: ln(I) vs V graphs

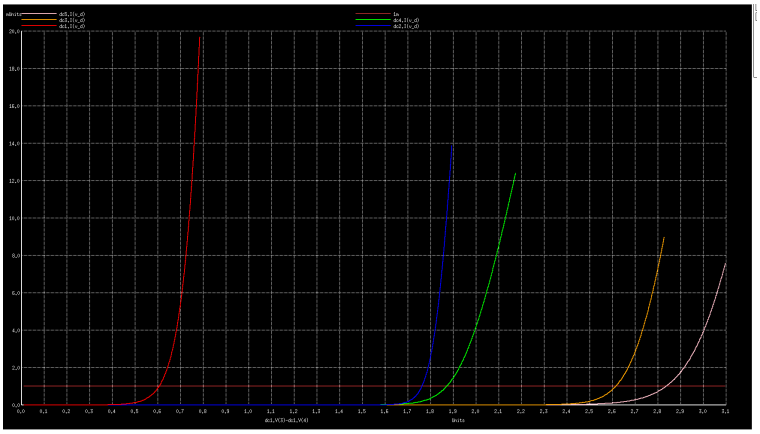
```
x0 = 0.19434, y0 = -15.037    x1 = 0.618868, y
1 = -6.66667
dx = 0.424528, dy = 8.37037
dy/dx = 19.7169    dx/dy = 0.050718

x0 = 1.15283, y0 = -24.037    x1 = 1.56226, y1
 = -12.4074
dx = 0.409434, dy = 11.6296
dy/dx = 28.4042    dx/dy = 0.0352061

x0 = 1.51887, y0 = -22.963    x1 = 2.08868, y1
 = -14.5926
dx = 0.569811, dy = 8.37037
dy/dx = 14.6897    dx/dy = 0.0680748

x0 = 0.960377, y0 = -21.2963    x1 = 1.50566,
y1 = -12.5556
dx = 0.545283, dy = 8.74074
dy/dx = 16.0297    dx/dy = 0.0623841

x0 = 1.28868, y0 = -21.9259    x1 = 2.06226, y
1 = -14.3333
dx = 0.773585, dy = 7.59259
dy/dx = 9.81481    dx/dy = 0.101887
```

```
ngspice 23 -> eta1 = x/19.7169
ngspice 24 -> eta2 = x/28.4042
ngspice 25 -> eta3 = x/14.6897
ngspice 26 -> eta4 = x/16.0297
ngspice 27 -> eta5 = x/9.81481
```

Figure 4: Calculation of slope from ln(I) vs V graph, and using that to calculate the respective ηs

4 Experimental results

For reference: dc1 = 1N914, dc2 = red, dc3 = blue, dc4 = green, dc5 = white



```
x0 = 0.609434, y0 = 0.000988506

x0 = 1.76415, y0 = 0.000988506

x0 = 1.87358, y0 = 0.000965517

x0 = 2.61698, y0 = 0.00103448

x0 = 2.84151, y0 = 0.000965517
```

Figure 5: Plot for V_d calculation and the values seen

```
ngspice 28 -> eg3 = 1240/450
ngspice 29 -> eg4 = 1240/520
ngspice 30 -> eg5 = 1240/450
ngspice 31 -> eg2 = 1240/630
ngspice 32 -> eg1 = 1.1
```

Figure 6: Calculation of E_g

Table 1: η and I_s values

Diode no.	η	I_s(A)
dc1	1.95	1.70e-19
dc2	1.37	1.08e-19
dc3	2.49	2.44e-11
dc4	2.59	9.02e-16
dc5	3.96	5.72e-20

5 Experiment completion status

I was able to complete all parts of the experiment.

Table 2: V_d values in Volts

Diode no.	V_d (for I_d = 1mA)	V_d (for I_d = 50uA)	V_d (for I_d = 5mA)
dc1	0.61	0.56	0.69
dc2	1.76	1.66	1.84
dc3	2.62	2.51	2.75
dc4	1.87	1.68	2.00
dc5	2.84	2.77	3.12

6 Questions for reflection

6.1 Q1

We see two peaks in the spectrum implying that white is made u of two wavelengths. On comparing we see that it is the wavelength of blue and green i.e 450 and 520 nm respectively.
Since the intensity of blue is higher, we use its wavelength (450 nm) for calculation of E_g as 2.76eV.

6.2 Q2

Equation 2 of lab sheet is always valid, but equation 3 uses the approximation $qV_d >> kT$ and hence won't work when the assumption fails (i.e small V_d)

6.3 Q3

At small Id, recombination current becomes significant and hence our formulae aren't applicable. Whereas for large Id, the depletion region also causes voltage drop which was earlier ignored. Hence when we deviate from Id = 1mA, the linearity of the E_g vs V_d plot worsens.