EE236: Lab 1
Diode Transients &
C-V Characteristics of Schottky Diode

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1 Aim of the experiment

1. To measure and compare the Reverse Recovery Times (RRT) of a P-N Junction diode (1N4007) and a Schottky diode (1N5822).
2. To measure C-V characteristics of a Schottky diode and extract its built-in potential and doping density.

2 Design & Working

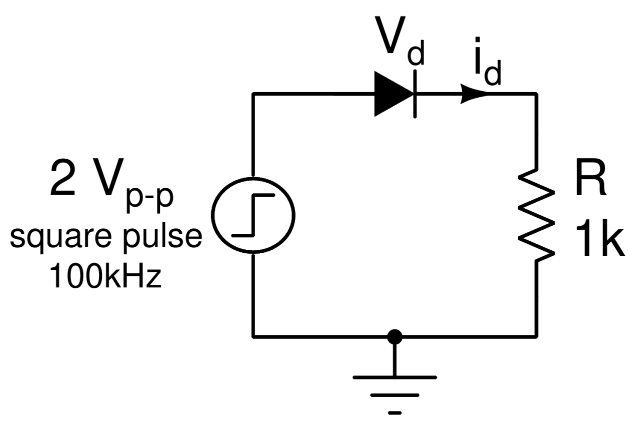

Fig. Circuit to measure Reverse Recovery Time

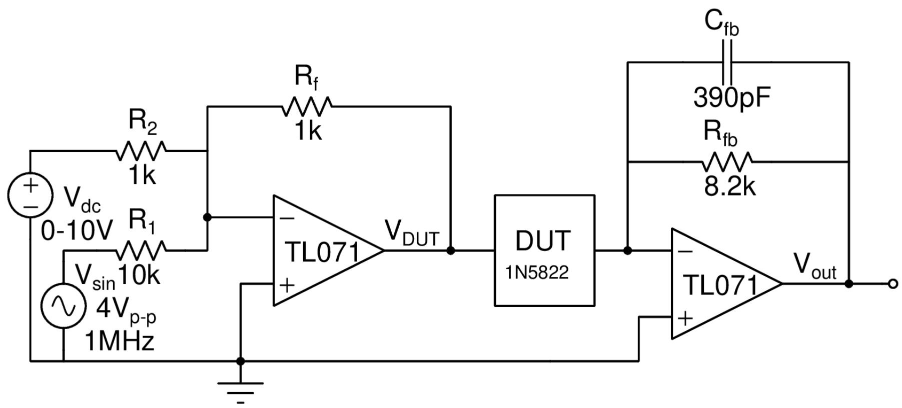

Fig. Circuit to measure Schottky C-V Characteristics

3 Simulation

3.1 Code Snippet

3.1.1 1N4007 Diode

```
Reverse Recovery Time for 1N4007

.include 1N4007.txt
Vp 1 0 pulse(-1 1 0ns 1ns 1ns 1ms 2ms)
Vdummy 1 2 dc 0
Rd 2 3 100
D 3 0 1N4007
.tran 10ns 3.01ms 2.99ms
.control
run
plot i(Vdummy)
plot v(3)
meas tran tstart MIN_AT i(Vdummy)
meas tran tstop MAX_AT i(Vdummy) from=tstart
print tstop - tstart
.endc
.end
```

3.1.2 BAT85 Diode

```
Reverse Recovery Time for BAT85

.include BAT85.txt
Vp 1 0 pulse(-1 1 0ns 1ns 1ns 1ms 2ms)
Vdummy 1 2 dc 0
Rd 2 3 100
X 3 0 BAT85
.tran 10ns 3.00001ms 2.99999ms
.control
run
plot i(Vdummy)
plot v(3)
meas tran tstart MIN_AT i(Vdummy)
meas tran tstop MAX_AT i(Vdummy) from=tstart
print tstop - tstart
.endc
.end
.end
```

3.2 Simulation Results

3.2.1 1N4007 Diode

Given below is the plot for I_D waveform for the 1N4007 diode with a 1kHz input pulse, obtained from the transient analysis of the circuit:

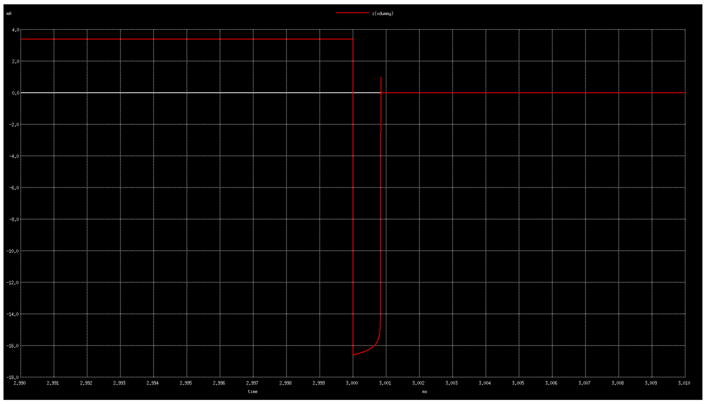

Fig. I_D plot for 1N4007 Diode at 1kHz

Given below is the plot for I_D waveform for the 1N4007 diode with a 10kHz input pulse, obtained from the transient analysis of the circuit:

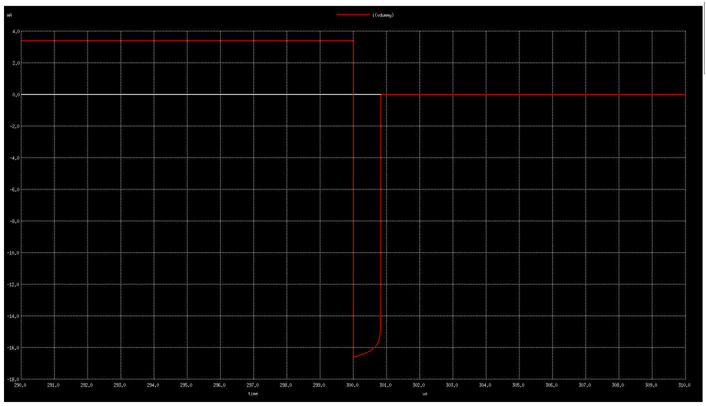

Fig. I_D plot for 1N4007 Diode at 10kHz

Given below is the plot for I_D waveform for the 1N4007 diode with a 100kHz input pulse, obtained from the transient analysis of the circuit:

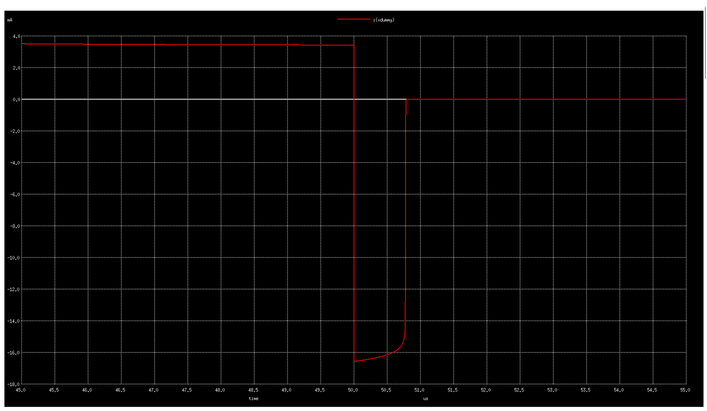

Fig. I_D plot for 1N4007 Diode at 100kHz

3.2.2 BAT85 Diode

Given below is the plot for I_D waveform for the BAT85 diode with a 1kHz input pulse, obtained from the transient analysis of the circuit:

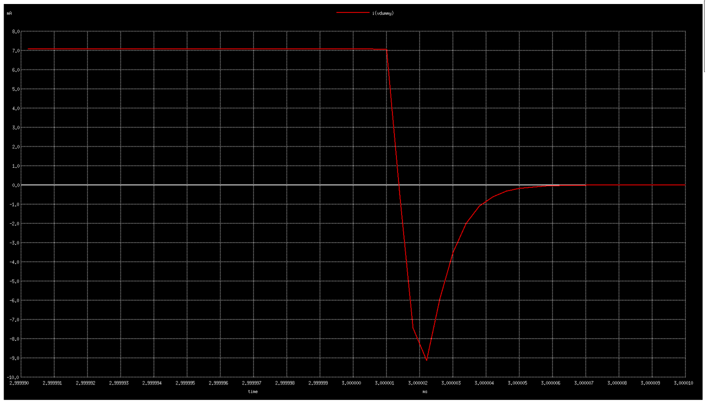

Fig. I_D plot for BAT85 Diode at 1kHz

Given below is the plot for I_D waveform for the BAT85 diode with a 10kHz input pulse, obtained from the transient analysis of the circuit:

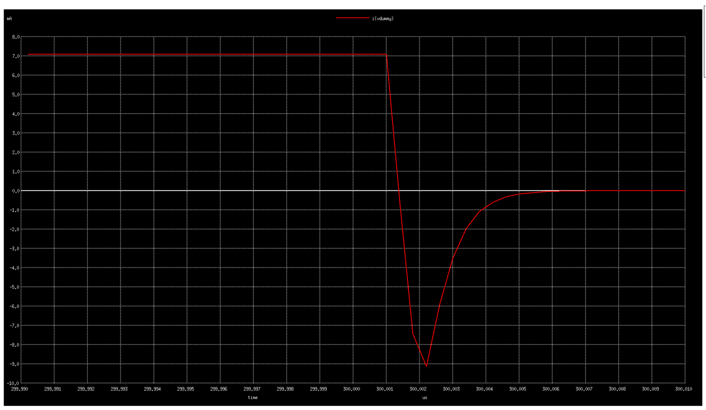

Fig. I_D plot for BAT85 Diode at 10kHz

Given below is the plot for I_D waveform for the BAT85 diode with a 100kHz input pulse, obtained from the transient analysis of the circuit:

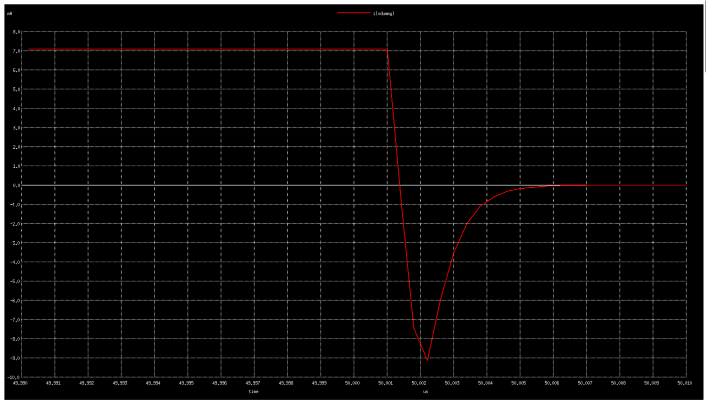

Fig. I_D plot for BAT85 Diode at 100kHz

Given below are the measured readings using the above simulations for RRT for 1N4007 and BAT85 diodes at various frequencies:

Frequency	RRT of PN	RRT of Schottky
$1k$	$0.84\mu s$	$8ns$
$10k$	$9.99\mu s$	$7.8ns$
$100k$	$4.99\mu s$	$7.8ns$

4 Experimental Results

Given below are the measured readings using the above simulations for RRT for 1N4007 and BAT85 diodes at various frequencies:

Frequency	RRT of PN	RRT of Schottky
$10k$	$1.8\mu s$	$150ns$
$100k$	$0.8\mu s$	$125ns$
$1M$	$100ns$	$110ns$
$10M$	-	-

The capacitance of a Schottky diode can be represented by:

$$\frac{1}{C^2} = \frac{2(V_{bi}-V_i)}{q\epsilon_s\epsilon_o S^2 N_d}$$

The above equation represents a straight line. N_d can be calculated using the slope whereas V_{bi} can be calculated using the intercept.
For measurement of Schottky diode, the AC gain from V_{dut} to V_{out} is given by,

$$\left|\frac{V_{out}}{V_{dut}}\right| = \frac{C_{dut}}{C_{fb}} \frac{1}{\sqrt{1+\frac{1}{(\omega R_{fb} C_{fb})^2}}}$$

Given below are my observations for the experiment:

V_{dc} (in V)	$Vout$	V_{dut}	C_{dut}
0	$40mV$	$32mV$	$487.5pF$
0.5	$48mV$	$60mV$	$312.0pF$
1	$32mV$	$40mV$	$312.0pF$
1.5	$32mV$	$24mV$	$520.0pF$
2	$32mV$	$24mV$	$520.0pF$
3	$32mV$	$24mV$	$520.0pF$
4	$40mV$	$24mV$	$520.0pF$
5	$32mV$	$24mV$	$520.0pF$
6	$32mV$	$24mV$	$520.0pF$
7	$32mV$	$24mV$	$520.0pF$
8	$32mV$	$24mV$	$520.0pF$
9	$32mV$	$24mV$	$520.0pF$
10	$32mV$	$24mV$	$520.0pF$

Given below are the required plots based on the above readings:

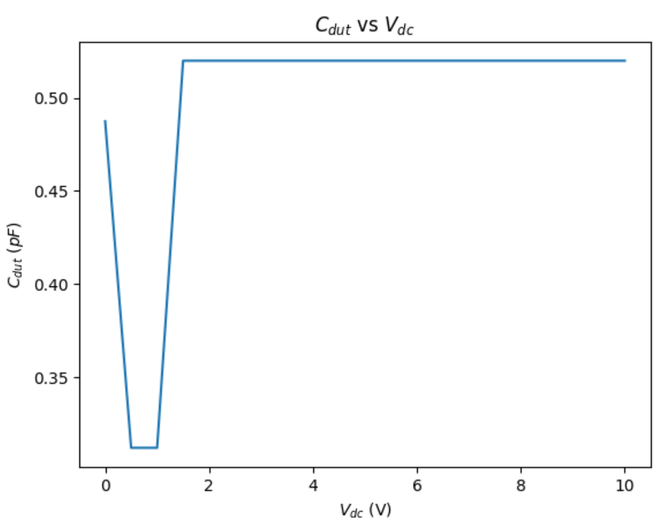

Fig. C_{dut} vs V_{dc} Plot for the Schottky diode

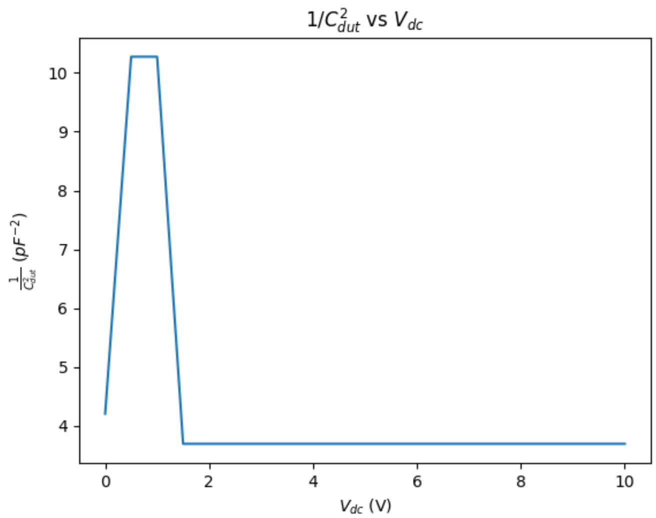

Fig. $\frac{1}{C_{dut}^2}$ vs V_{dc} Plot for the Schottky diode

Using the above, I get the value for built-in potential (V_{bi}) to be around 0.3V. The area (S) can be calculated using the following equation:

$$I_{rev} = SA^*T^2e^{-V_{bi}/V_t}$$

Using the above equation, I got the value for S to be $4.145 \times 10^{-8} cm^2$
To find the doping density, we can use the below formula:

$$Slope = -\frac{2}{q\epsilon_s\epsilon_0 S^2 N_d}$$

Using this we get the value for doping density to be $5.414 \times 10^{20} cm^{-3}$

5 Simulation Exercise

5.1 Code Snippet

5.1.1 1N4007 Diode

```
Bridge Rectifier using 1N4007

.include 1N4007.txt
```

```
d1 dummy1 2 1N4007
d2 0 1 1N4007
d3 dummy3 2 1N4007
d4 0 3 1N4007
Rl 2 0 1k
Vd1 1 dummy1 dc 0
Vd2 3 dummy3 dc 0
Vin 1 3 sin(0 5 50 0 0)
.tran 0.1m 100m
.control
run
plot v(2) v(1,3)
plot v(2) vs v(1,3)
.endc
.end
```

5.1.2 BAT85 Diode

```
Bridge Rectifier using BAT85

.include BAT85.txt
x1 dummy1 2 BAT85
x2 0 1 BAT85
x3 dummy3 2 BAT85
x4 0 3 BAT85
Rl 2 0 1k
Vd1 1 dummy1 dc 0
Vd2 3 dummy3 dc 0
Vin 1 3 sin(0 5 50 0 0)
.tran 0.1m 100m
.control
run
plot v(2) v(1,3)
plot v(2) vs v(1,3)
.endc
.end
```

5.2 Simulation Results

Given below are the plots for 1N4007 Diode:

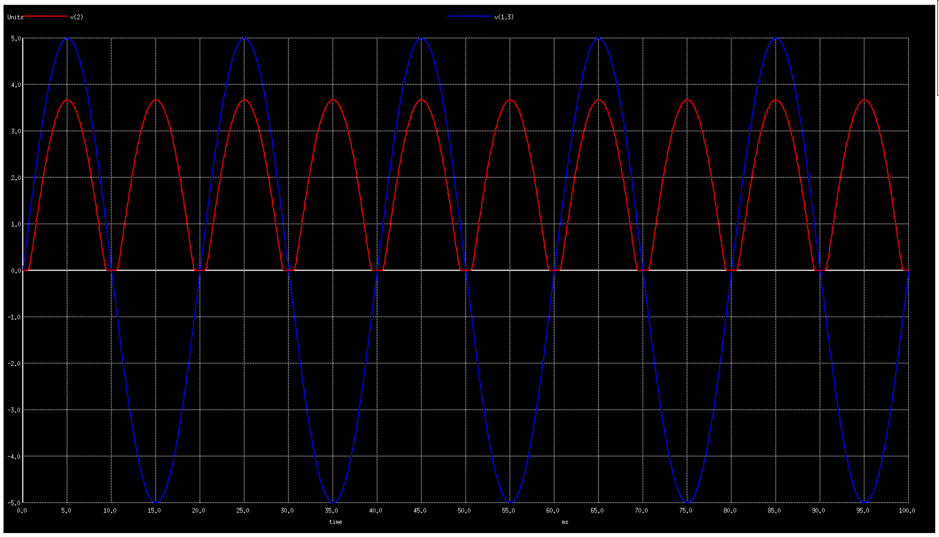

Fig. V_{out} vs V_{in} plot for the 1N4007 diode

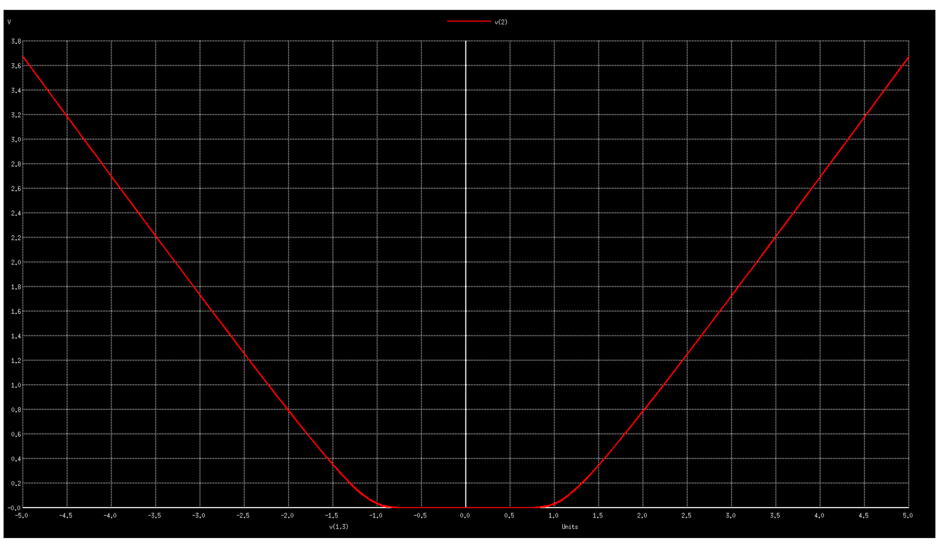

Fig. Transfer characteristics for the 1N4007 diode

Given below are the plots for 1N4007 Diode:

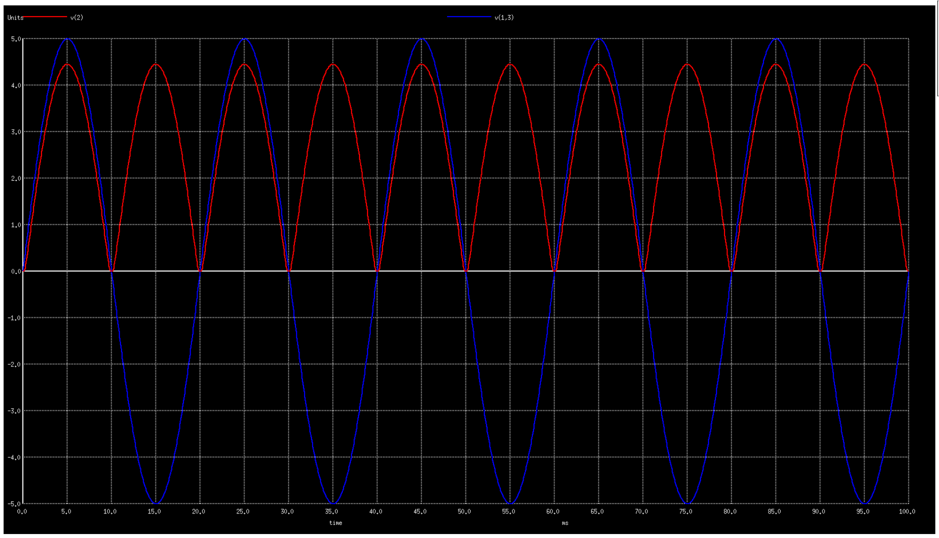

Fig. V_{out} vs V_{in} plot for the BAT85 diode

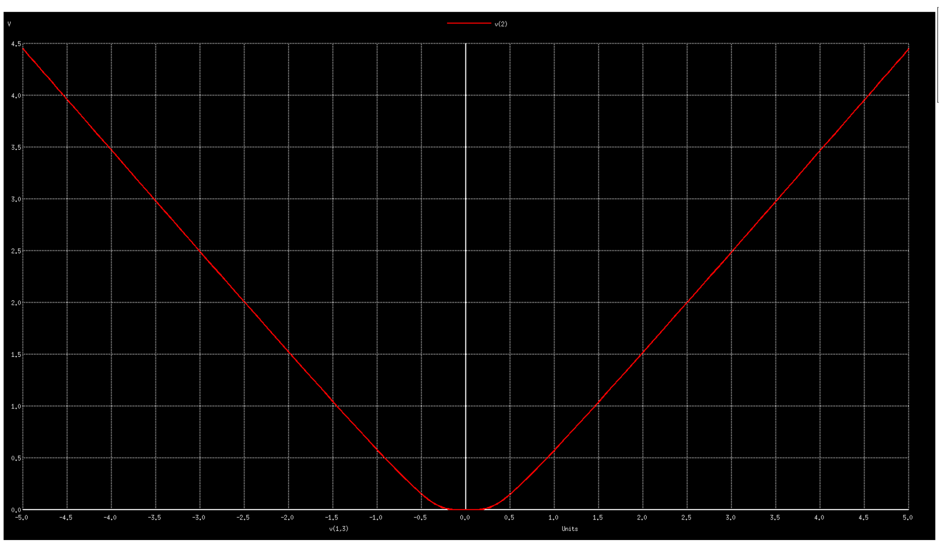

Fig. Transfer characteristics for the BAT85 diode

In these plots we can observe that the drop in V_{out} compared to the V_{in} is much less for the BAT85 diode as compared to the 1N4007 diode, due to the smaller voltage drop for BAT85.
Similarly, in the tranfer-characteristics plot, we can observe that the region of 0 slope is much smaller for the BAT85 diode, which again implies smaller forward voltage drop for the Schottky diode.

From these observations we can deduce that the **Schottky diode** is a better device for rectification due to its **small forward bias voltage drop**.