EE 236: Experiment 6 - Schottky Diode I-V Characterization and Transient Analysis

Keshav Samdani

22b3952

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1 Aim of experiment

- To plot the forward and reverse bias I/V characteristics of 2 fabricated metal-semiconductor junction diodes (one Schottky contact and another Ohmic contact) using a probe station.
- To plot the forward and reverse bias I/V characteristics of a given packaged Schottky diode.
- To obtain and compare the reverse recovery times of a regular PN junction diode and a Schottky diode.

2 Components Required

- Fabricated Samples (10^{15} cm^{-3} and 10^{19} cm^{-3} doped)
- Probe Station
- 1N5822 Schottky Diode
- 1N4007 PN Junction Diode
- Resistors - 100Ω ($\times 2$)
- Potentiometer - 1kΩ
- Breadboard and connecting wires

3 Experimental Setup

The experimental setup consisted of two main parts:

1. Probe station setup for characterizing fabricated samples.
2. Breadboard circuit for characterizing packaged diodes and measuring reverse recovery time.

4 Procedure

4.1 Part 1: Fabricated Samples Characterization

1. Performed I-V characterization (both forward and reverse) of the fabricated diode samples with doping concentrations of 10^{15} cm^{-3} and 10^{19} cm^{-3} using the probe station.
2. Recorded voltage and current measurements for both samples.
3. Plotted I-V characteristics for both samples.

4.2 Part 2a: Packaged Schottky Diode Characterization

1. Set up the circuit for I-V characterization of the 1N5822 Schottky diode.
2. Measured and recorded forward and reverse I-V characteristics.
3. Plotted the I-V characteristics of the Schottky diode.

4.3 Part 2b: Reverse Recovery Time Measurement

1. Set up the circuit for reverse recovery time measurement.
2. Applied a square wave of 2V peak-to-peak amplitude at 100 kHz.
3. Measured and recorded the reverse recovery time for both the PN junction diode (1N4007) and the Schottky diode (1N5822).

5 Results and Analysis:-

5.1 Part 1: Fabricated Samples Characterization

Table 1: I-V Characteristics of Fabricated Samples

Sample 1 (10^{15} cm^{-3})		Sample 2 (10^{19} cm^{-3})	
V (V)	I (mA)	V (V)	I (mA)
-4.64	-0.006	-4.5	-0.049
-3.85	-0.005	-4.0	-0.0425
-3.0	-0.004	-3.5	-0.0369
-2.3	-0.003	-2.5	-0.0242
-1.57	-0.002	-2.0	-0.0176
-1.15	-0.001	-1.5	-0.0119
0	0	-1.0	-0.0054
0.1	0.002	-0.5	-0.001
0.2	0.045	0	0
0.25	0.15	0.5	0.0001
0.28	0.558	1.0	0.0002
0.3	1.05	1.5	0.0003
0.35	2.82	2.0	0.0003
0.4	6.29	2.5	0.0004
0.45	10.39	3.5	0.0005
0.5	14.05	4.5	0.0006
0.56	21.2	4.57	0.0006

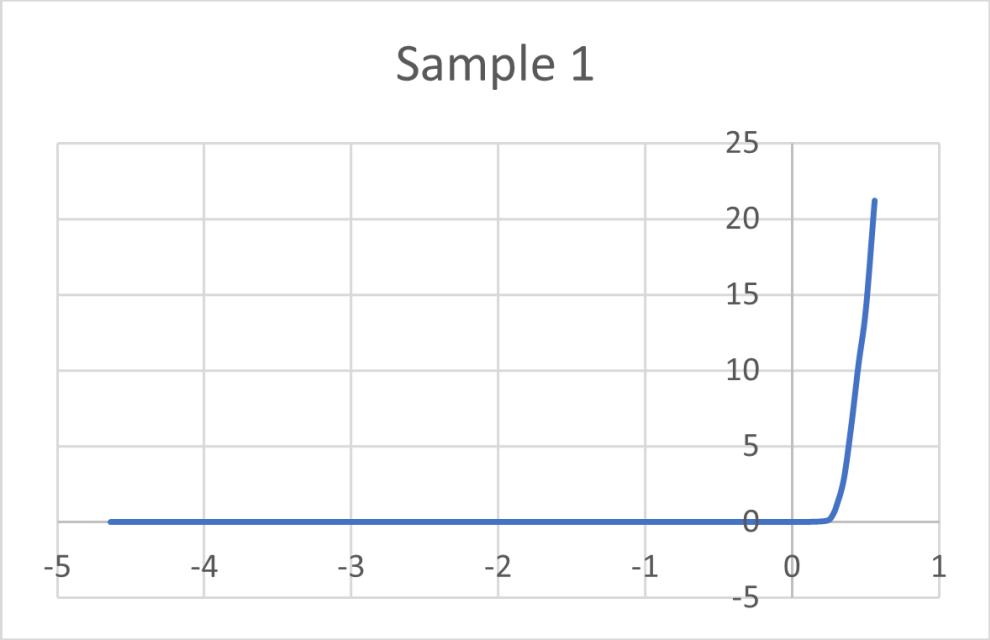

Figure 1: I-V Characteristics of Sample 1 (10^{15} cm^{-3})

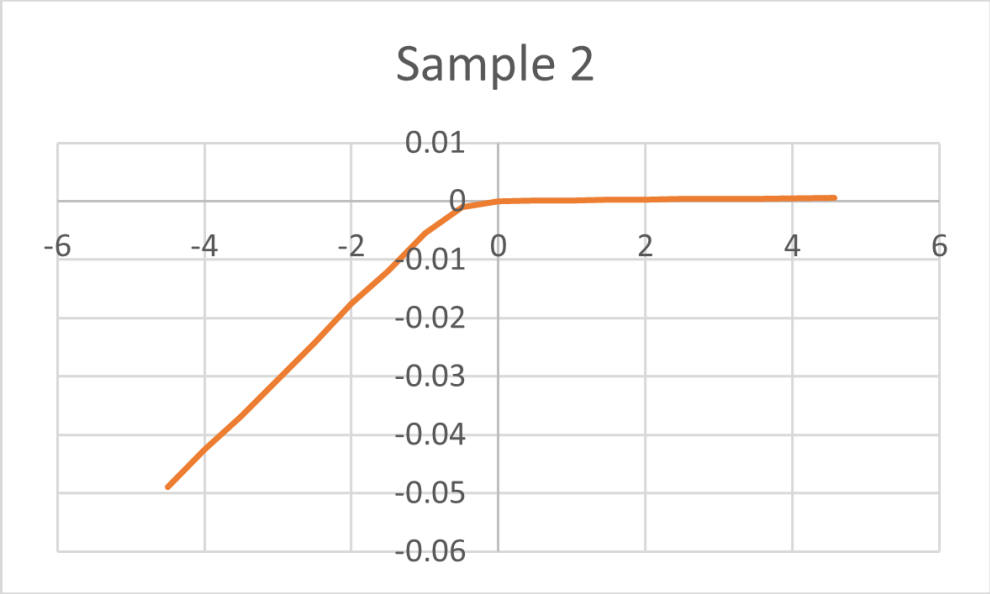

Figure 2: I-V Characteristics of Sample 2 (10^{19} cm^{-3})

Analysis:

- Sample 1 (10^{15} cm^{-3}) exhibits characteristics of a Schottky contact, with a lower turn-on voltage and higher forward current.
- Sample 2 (10^{19} cm^{-3}) shows behavior more consistent with an Ohmic contact, with a nearly linear I-V relationship and much lower current levels.

- The difference in characteristics can be attributed to the higher doping concentration in Sample 2, which reduces the barrier height and depletion region width, leading to more Ohmic-like behavior.

5.2 Part 2a: Packaged Schottky Diode Characterization

Table 2: I-V Characteristics of 1N5822 Schottky Diode

V (V)	I (mA)
-4.63	-0.007
-3.61	-0.006
-2.78	-0.005
-2.16	-0.004
-1.4	-0.003
-0.66	-0.002
-0.11	-0.001
0	0
0.1	0.15
0.13	0.34
0.148	0.65
0.16	1.05
0.175	1.8
0.18	2.22
0.2	4.51
0.21	6.63
0.22	9.33
0.23	14.1
0.245	22.1

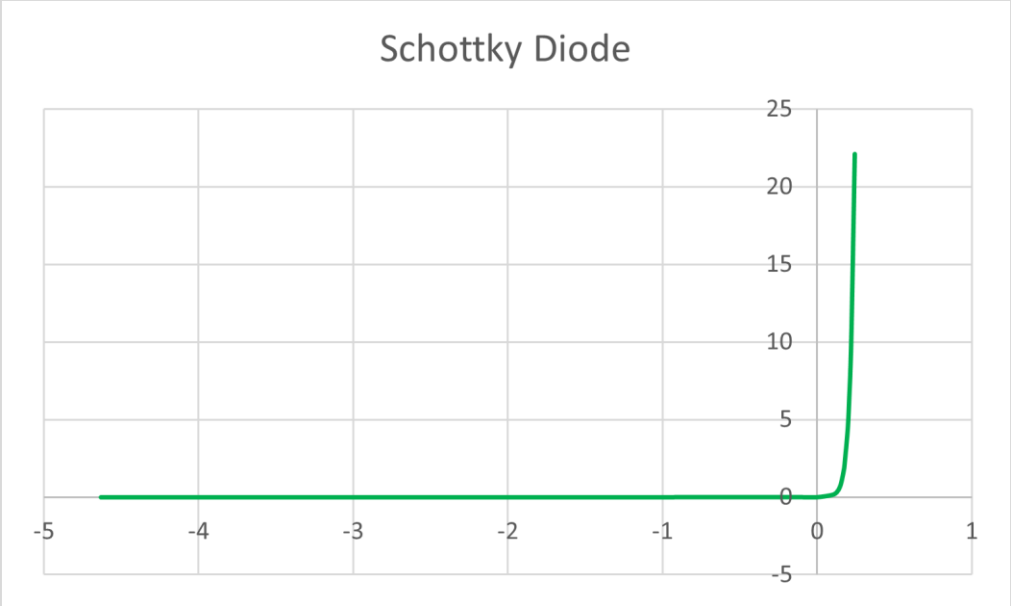

Figure 3: I-V Characteristics of 1N5822 Schottky Diode

Analysis:

- The 1N5822 Schottky diode shows a low turn-on voltage of approximately 0.2V, which is characteristic of Schottky diodes.
- The forward current increases rapidly after the turn-on voltage, demonstrating the high efficiency of the Schottky diode in forward conduction.
- The reverse leakage current is very low, indicating good rectification properties.

5.3 Part 2b: Reverse Recovery Time Measurement

Table 3: Reverse Recovery Time Comparison

Diode Type	Reverse Recovery Time
Schottky Diode (1N5822)	998 ns
PN Junction Diode (1N4007)	1.34 μs

Analysis:

- The Schottky diode exhibits a shorter reverse recovery time (998 ns) compared to the PN junction diode (1.34 μs).
- This faster switching behavior of the Schottky diode can be attributed to its metal-semiconductor junction, which doesn't involve minority carrier injection and storage.

- The PN junction diode's longer recovery time is due to the time required for minority carriers to recombine or be swept out of the depletion region.
- The faster reverse recovery of Schottky diodes makes them suitable for high-frequency applications and more efficient in switching circuits.

6 Conclusion

This experiment successfully characterized the behavior of Schottky diodes and compared them with regular PN junction diodes:

- The fabricated samples demonstrated the effect of doping concentration on the metal-semiconductor junction characteristics, with higher doping leading to more Ohmic-like behavior.
- The packaged Schottky diode (1N5822) showed typical Schottky diode characteristics, including a low turn-on voltage and rapid current increase in forward bias.
- The reverse recovery time measurement clearly demonstrated the superior switching speed of Schottky diodes compared to PN junction diodes, highlighting their advantage in high-frequency applications.

These results underscore the unique properties of Schottky diodes and their advantages in certain applications, particularly where fast switching and low forward voltage drop are crucial.

7 Experiment completion status

All parts of the experiment were completed in the lab itself and also checked by my TA