Schottky Diode IV Characterization and Transient Analysis
EE236: Experiment 6

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1 Aims of the Experiment

- **Part 1:** To plot the forward and reverse bias I/V characteristics of 2 fabricated metal-semiconductor junction diodes (Schottky and Ohmic contact).
- **Part 2a:** To plot the forward and reverse bias I/V characteristics of a packaged Schottky diode.
- **Part 2b:** To compare reverse recovery times of a PN junction diode and a Schottky diode.

2 Schottky Diode

The Schottky Diode is constructed using a metal and an N-type (or P-type) semiconductor. Due to its thin depletion region, it has a lower turn-on voltage than a traditional PN junction diode.

3 Experiment Setup

The following components were used:

- Fabricated Samples
- Probe Station
- 1N5822 Schottky Diode
- 1N4007 PN Junction Diode
- Resistors - 100Ω (×2)
- Potentiometer - 1kΩ
- Breadboard and connecting wires

4 Procedure

4.1 Part 1: I-V Characterization of Fabricated Diodes

Precautions:

- Handle the samples and probe setup with care.
- Do not touch the wafer with bare hands. Use the brass plate to maneuver the sample.

The forward and reverse I-V characteristics of diodes with doping concentrations of $10^{15}\,\mathrm{cm}^{-3}$ and $10^{19}\,\mathrm{cm}^{-3}$ were recorded. Below is the table showing the values obtained during measurements:

Table 1: S24 Forward Characteristics

V_d	V_r	I_d (in mA)	$In(I_d)$ in mA
0.13	0	0	0
0.3	0.001	0.01	-2
0.46	0.005	0.05	-1.301029996
0.59	0.01	0.1	-1
0.75	0.017	0.17	-0.769551079
0.94	0.029	0.29	-0.537602002
1.08	0.038	0.38	-0.420216403
1.21	0.049	0.49	-0.30980392
1.32	0.059	0.59	-0.229147988
1.48	0.074	0.74	-0.13076828
1.65	0.091	0.91	-0.040958608
1.9	0.118	1.18	0.071882007
2.09	0.14	1.4	0.146128036
2.24	0.158	1.58	0.198657087
2.36	0.173	1.73	0.238046103
2.61	0.204	2.04	0.309630167
2.8	0.226	2.26	0.354108439
2.94	0.245	2.45	0.389166084
3.32	0.298	2.98	0.474216264
3.72	0.359	3.59	0.555094449
3.83	0.371	3.71	0.56937391

Table 2: S24 Reverse Characteristics

V_d	V_r (in mV)	V_r (in V)	I_d (in mA)	$In(I_d)$ in mA
-0.15	0.1	0.0001	0.001	-3
-0.26	0.4	0.0004	0.004	-2.397940009
0.48	0.8	0.0008	0.008	-2.096910013
0.76	1.5	0.0015	0.015	-1.823908741
1.01	1.9	0.0019	0.019	-1.721246399
1.27	2.4	0.0024	0.024	-1.619788758
1.6	3	0.003	0.03	-1.522878745
2.13	4.1	0.0041	0.041	-1.387216143
2.4	4.6	0.0046	0.046	-1.337242168
2.87	5.5	0.0055	0.055	-1.259637311
3.1	6	0.006	0.06	-1.22184875
3.55	7.2	0.0072	0.072	-1.142667504
3.92	8	0.008	0.08	-1.096910013
4.28	9	0.009	0.09	-1.045757491
4.53	9.7	0.0097	0.097	-1.013228266

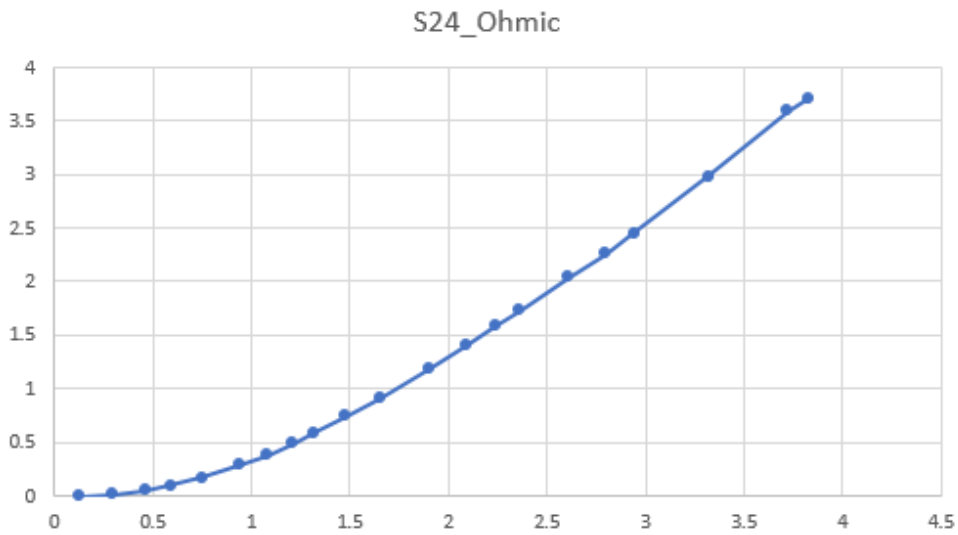

Figure 1: S24 I-V Characteristics Plot

Table 3: N15 Forward Characteristics

V_d	V_r (mV)	I_d (in mA)
0	0	0
1.13	0	0
1.56	0.5	0.005
1.69	0.8	0.008
1.78	1.2	0.012
2.05	1.7	0.017
2.46	2.3	0.023
2.64	2.7	0.027
2.79	2.9	0.029
3.02	3.3	0.033
3.25	3.7	0.037
3.43	4	0.04
3.52	4.4	0.044
3.66	4.4	0.044
3.79	4.5	0.045
3.83	4.9	0.049
3.93	4.9	0.049
4.05	5	0.05
4.1	5.3	0.053
4.13	5.2	0.052
4.53	5.9	0.059

Table 4: N15 Reverse Characteristics

V_d	V_r (in mV)	V_r (in V)	I_d (in mA)	$In(I_d)$ in mA
-2.45	0	0	-	-
3.77	0.1	0.0001	0.001	-3
3.94	0.2	0.0002	0.002	-2.698970004
4.22	0.2	0.0002	0.002	-2.698970004
4.54	0.2	0.0002	0.002	-2.698970004

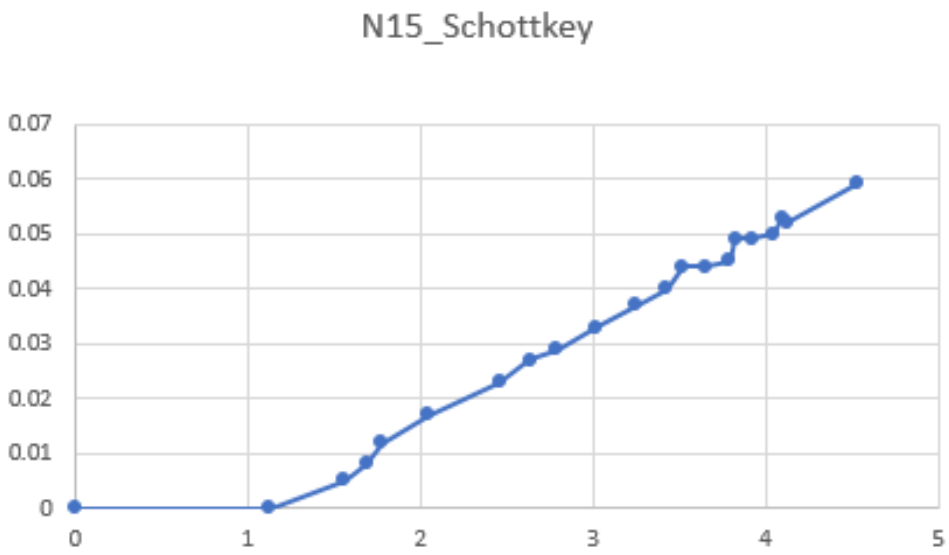

Figure 2: N15 I-V Characteristics Plot

Observation: The Schottky contact exhibited a lower turn-on voltage than the Ohmic contact. The I-V curve showed a typical exponential increase in forward bias, with a significant reverse leakage current at higher doping levels.

For the Schottky diode, the built-in potential (V_{bi}) was extracted from the I-V data. The formula for depletion width is:

$$W = \left(\frac{2\varepsilon_{Si}}{qN_D} (V_{bi} - V_A) \right)^{1/2}$$

Built-in Potential (V_{bi}) and Depletion Width Calculation

S24 Diode

For the S24 diode with the following parameters:

- Dielectric constant of Silicon, $\epsilon_{Si} = 1.033 \times 10^{-10}\,\mathrm{F/m}$
- Elementary charge, $q = 1.602 \times 10^{-19}\,\mathrm{C}$
- Doping concentration, $N_D = 10^{22}\,\mathrm{m}^{-3}$
- Built-in potential, $V_{bi} = 0.22$ V

1. Depletion Width for No Bias ($V_A = 0$ V)

The formula for the depletion width W is:

$$W = \sqrt{\frac{2\epsilon_{Si}}{qN_D}(V_{bi} - V_A)}$$

Substituting $V_A = 0$ V:

$$W_{0V} = \sqrt{\frac{2 \times 1.033 \times 10^{-10}}{1.602 \times 10^{-19} \times 10^{22}} \times 0.22}$$

Calculate:

$$\text{Numerator} = 2 \times 1.033 \times 10^{-10} = 2.066 \times 10^{-10}$$

$$\text{Denominator} = 1.602 \times 10^{-19} \times 10^{22} = 1.602 \times 10^{11}$$

$$\frac{2.066 \times 10^{-10}}{1.602 \times 10^{11}} = 1.287 \times 10^{-21}$$

$$W_{0V} = \sqrt{1.287 \times 10^{-21}} \approx 1.135 \times 10^{-11}\ \mathrm{m} = 113.5\ \mathrm{nm}$$

2. Depletion Width for 0.5V Forward Bias ($V_A = 0.5$ V)

Substitute $V_A = 0.5$ V:

$$W_{0.5V} = \sqrt{\frac{2 \times 1.033 \times 10^{-10}}{1.602 \times 10^{-19} \times 10^{22}} \times (0.22 - 0.5)}$$

Calculate: Not Valid

N15 Diode

For the N15 diode with the following parameters:

- Dielectric constant of Silicon, $\epsilon_{Si} = 1.033 \times 10^{-10}\,\mathrm{F/m}$
- Elementary charge, $q = 1.602 \times 10^{-19}\,\mathrm{C}$
- Doping concentration, $N_D = 10^{17}\,\mathrm{m}^{-3}$
- Built-in potential, $V_{bi} = 0.7$ V

1. Depletion Width for No Bias ($V_A = 0$ V)

Substitute $V_A = 0$ V:

$$W_{0V} = \sqrt{\frac{2 \times 1.033 \times 10^{-10}}{1.602 \times 10^{-19} \times 10^{17}} \times 0.7}$$

Calculate:

$$\text{Denominator} = 1.602 \times 10^{-19} \times 10^{17} = 1.602 \times 10^{-10}$$

$$\frac{2.066 \times 10^{-10}}{1.602 \times 10^{-10}} = 1.287 \times 10^{-20}$$

$$1.287 \times 10^{-20} \times 0.7 = 2.574 \times 10^{-20}$$

$$W_{0V} = \sqrt{2.574 \times 10^{-20}} \approx 5.074 \times 10^{-10}\ \text{m} = 51\ \text{nm}$$

2. Depletion Width for 0.5V Forward Bias ($V_A = 0.5$ V)

Substitute $V_A = 0.5$ V:

$$W_{0.5V} = \sqrt{\frac{2 \times 1.033 \times 10^{-10}}{1.602 \times 10^{-19} \times 10^{17}} \times (0.7 - 0.5)}$$

Calculate:

$$\frac{2.066 \times 10^{-10}}{1.602 \times 10^{-10}} = 1.287 \times 10^{-20}$$

$$1.287 \times 10^{-20} \times 1.5 = 1.931 \times 10^{-20}$$

$$W_{0.5V} = \sqrt{1.931 \times 10^{-20}} \approx 4.39 \times 10^{-10}\ \text{m} = 44\ \text{nm}$$

4.2 Part 2a: I-V Characterization of 1N5822 Schottky Diode

The forward and reverse I-V characteristics of the 1N5822 Schottky diode were recorded using the circuit shown below:

The table below summarizes the data obtained for the 1N5822 diode:

Observation: The Schottky diode exhibited a much lower forward voltage drop (around 0.2V) compared to a standard PN junction diode.

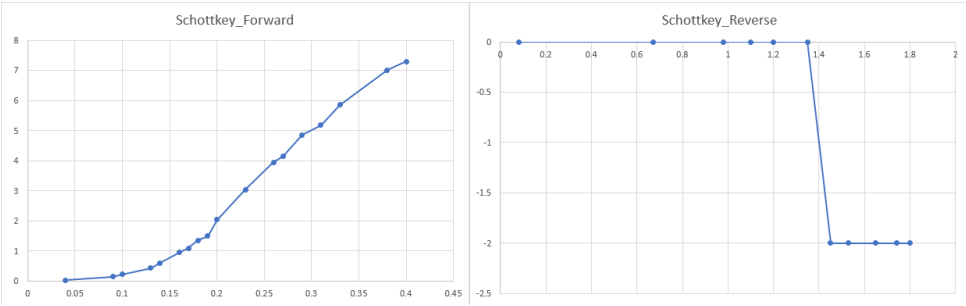

Figure 3: I-V characteristics of 1N5822 Schottky Diode

Table 5: Schottky Diode Forward Characteristics

V_d	V_r	I_d	I_d (in mA)	$In(I_d)$ (in mA)
0	0	0	0	
0.04	0.003	0.00003	0.03	-1.522878745
0.09	0.015	0.00015	0.15	-0.823908741
0.1	0.023	0.00023	0.23	-0.638272164
0.13	0.043	0.00043	0.43	-0.366531544
0.14	0.06	0.0006	0.6	-0.22184875
0.16	0.096	0.00096	0.96	-0.017728767
0.17	0.11	0.0011	1.1	0.041392685
0.18	0.135	0.00135	1.35	0.130333768
0.19	0.15	0.0015	1.5	0.176091259
0.2	0.204	0.00204	2.04	0.309630167
0.23	0.304	0.00304	3.04	0.482873584
0.26	0.395	0.00395	3.95	0.596597096
0.27	0.415	0.00415	4.15	0.618048097
0.29	0.486	0.00486	4.86	0.686636269
0.31	0.518	0.00518	5.18	0.71432976
0.33	0.586	0.00586	5.86	0.767897616
0.38	0.702	0.00702	7.02	0.846337112
0.4	0.73	0.0073	7.3	0.86332286

4.3 Part 2b: Reverse Recovery Time

A square wave of 2V peak-to-peak at 100kHz was applied. Below are the observed values:

Observation: The reverse recovery time of the Schottky diode was significantly shorter (around 1.3 us) compared to the PN junction diode (3.06 ns), indicating faster switching due to lower stored charge.

Table 6: Schottky Diode Reverse Characteristics

V_d	V_r	I_d	I_d (in mA)	$In(I_d)$ (in mA)
0	0	0	0	
0.08	0	0	0	-
0.67	0	0	0	-
0.98	0	0	0	-
1.1	0	0	0	-
1.2	0	0	0	-
1.35	0	0	0	-
1.45	0.001	0.00001	0.01	-2
1.53	0.001	0.00001	0.01	-2
1.65	0.001	0.00001	0.01	-2
1.74	0.001	0.00001	0.01	-2
1.8	0.001	0.00001	0.01	-2

Table 7: RRT Values for Different Diodes

Diode Type	RRT (μs)
Normal Diode	3.06
Schottky Diode	1.3

5 Conclusion

The experiment successfully demonstrated the I-V characteristics of both Schottky and Ohmic contact diodes. The reverse recovery time was measured for both the PN junction and Schottky diodes, with the Schottky diode exhibiting a faster switching time due to its lower stored charge.