Experiment 1: C-V Measurements

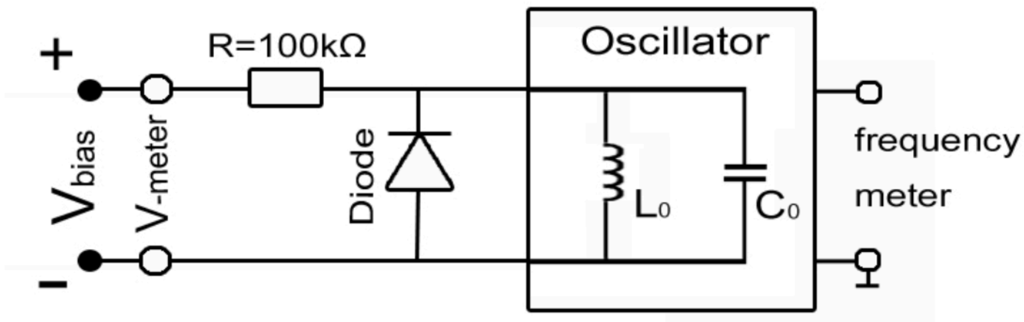

Figure 1: Circuit Diagram for CV Measurements

The circuits shown in Figure 1 is used to conduct the CV Measurements.
The open-loop frequency of the oscillator $f_0 = 1629.9 \pm 0.05$kHz.
The "10 pF" capacitor $C_{10} = 10.48 \pm 0.005pF$.
With C_{10} connected, the frequency $f_{10} = 1467.4 \pm 0.05$kHz.
From theories of oscillators, the circuit capacitance $C_0 = \frac{C_{10}}{(\frac{f_0^2}{f_{10}^2})-1} = 44.84 \pm 0.054$pF. The error ΔC_0 is found by: $\Delta C_0 \approx |\frac{\partial C_0}{\partial C_{10}}|\Delta C_{10} + |\frac{\partial C_0}{\partial C_0}|\Delta f_0 + |\frac{\partial C_0}{\partial f_{10}}|\Delta f_{10}$.
In this experiment, the total capacitance C_r is consisted of the stray capacitance C_s, and capacitance of the depletion region C_{diode}: $C_r = C_s + C_{diode}$.
Where C_s is constant and $C_{diode} = A_c(\frac{\epsilon_s e N_d}{2(V_o - V_{rev})})^{1/2}$, $V_o = 0.5V$ is the built-in voltage.
The bias voltage V_{rev} is varied in a range and corresponding C_r is found from $C_r = C_0[(\frac{f_0}{f_r})^2 - 1]$, where f_r is the frequency measured on the frequency meter.
The data table is shown in Figure 9 in appendix.
To extrapolate C_s and N_D from the data, a scatter plot and a linear fit are applied, where C_r is plotted against $(V_0 - V_{ref})^{-1/2}$.
Rearrangements gives: $C_r = C_s + [A_d(\frac{\epsilon_s e N_D}{2})^{1/2}] \cdot (V_0 - V_{ref})^{-1/2}$.
For the linear fit $y = kx + b$, $C_s = b$ and $N_D = \frac{2}{\epsilon_s e}(\frac{k}{A_c})^2$.

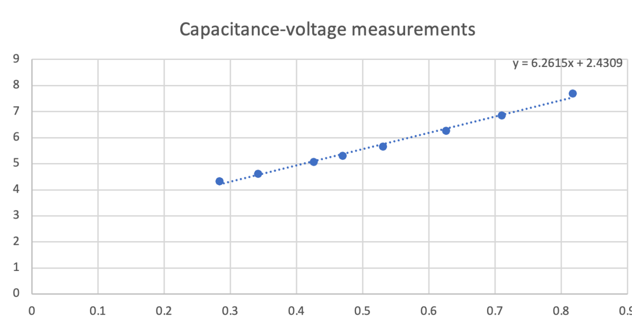

Figure 2: Linear Fit of the CV Measurements

With k = 6.2615, b = 2.4309, $C_s = 2.4309pF$, $N_D = 8.2 \times 10^{26} m^{-3}$.

Experiment 2: I-V Measurements

Reverse Bias

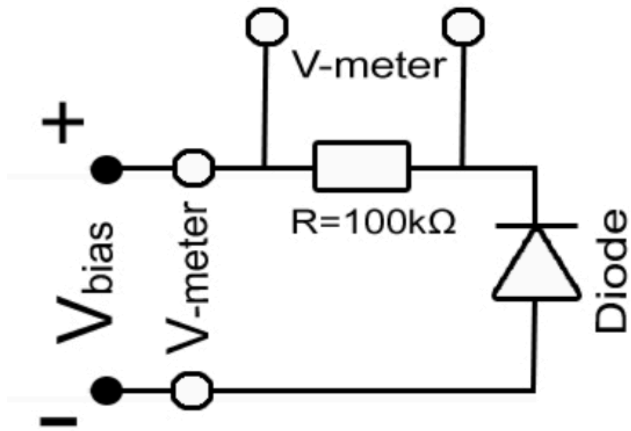

Figure 3: Circuit Diagram of Measuring Reverse Saturation Current

Figure 3 shows the circuits diagram for measuring reverse saturation current under reverse bias. The reverse current I_{rev} is related to reverse saturation current I_s and leak resistance R_{leak} by: $I_{rev} = I_s[\exp \frac{eV_{rev}}{\eta kT} - 1] + \frac{V_{rev}}{R_{leak}}$

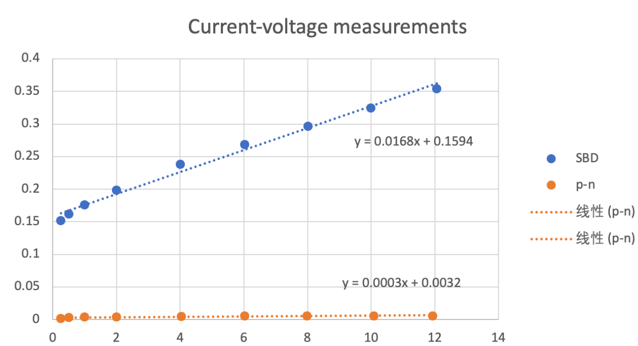

Figure 4: Linear Fit for Current - Voltage Measurements

Figure 4 shows a linear fit of measured values of $I_{rev} - V_{rev}$.
The reverse saturation current can be estimated by the intercept as $I_{rev} \approx -I_s$ when $V_{rev} = 0$. $I_s \approx 0.1594\mu A$.
The leak resistance can be estimated by the gradient. $R_{leak} \approx 59.2k\Omega$.

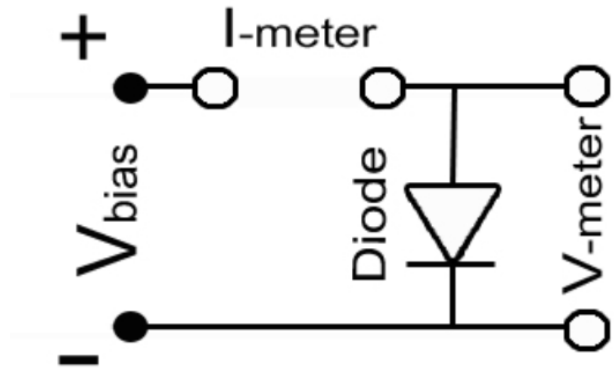

Figure 5: Circuit Diagram of Measuring Forward Current

Weak Forward Bias

Figure 5 shows the circuits diagram for measuring current under both weak forward bias and strong forward bias.
For a Schotkky barrier diode under forward bias, $I_F = I_s[\exp\frac{eV}{\eta kT} - 1]$. Rearrangement gives $V_F = \eta\frac{kT}{e}[\ln(\frac{I_F}{I_s}) + 1]$.
V_F is plotted against $(\ln(\frac{I_F}{I_s}) + 1)$, shown in Figure 6. The gradient equals to $\eta\frac{kT}{e}$. Under the lab circumstance, $\frac{kT}{e} = 25.68mV$. $\eta = 1.47$.

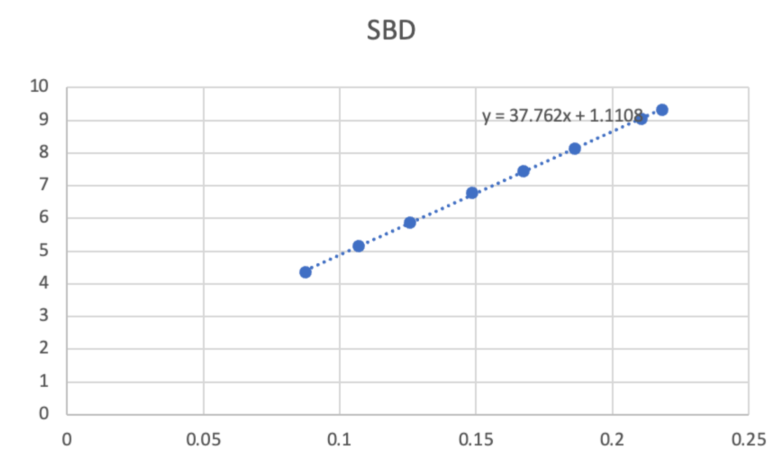

Figure 6: Linear Fit of Forward Voltage and $\ln(\frac{I_F}{I_s}) + 1$

Strong Forward Bias

In this section, a same circuit is used as the test in weak forward bias.
From the lab sheet, $I_F = \frac{1}{r_c}(V_F - \frac{\eta kT}{e}\ln(\frac{I_F}{I_s}))$.
$r_{cSBD} = 2.5\Omega$, $r_{cpn} = 0.9\Omega$.

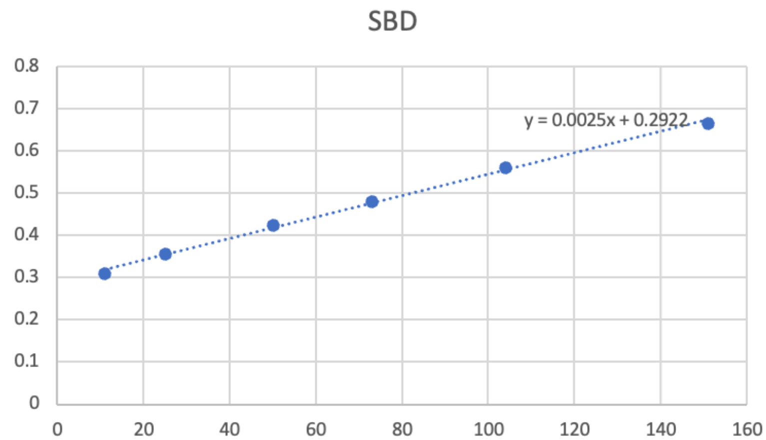

Figure 7: Linear Fit of Forward Voltage and Forward Current

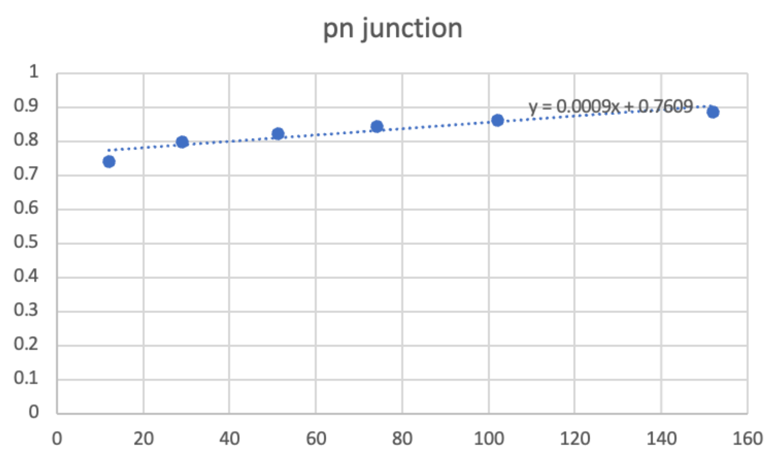

Figure 8: Linear Fit of Forward Voltage and Forward Current

Data Tables

	10 pf as measured on bridge ↓	Take V_o= 0.5 V	Measured Frequency [kHz]	C_r is C_{SBD} corresponding to f_r
(+ 10pf) V_{rev} none	C_{10} = 10.48 [pF]		f_{10}= 1467.4	$C_{10}/[(f_0^2/f_{10}^2)-1]$ = ↓
(+ 0 pf) V_{rev} none			f_0= 1629.9	C_o = 44.83546
Suggested V_{rev} [V]	**Measured V_{rev} [V] ↓**	$(V_o - V_{rev})^{-½}$ $[V^{-½}]$ ↓	f_r = ↓	$C_o [(f_0^2/f_r^2)-1]$ = C_r ↓
–12.0	11.95	0.283410101	1556.63	4.320112786
–8.0	8.05	0.341992784	1551.9	4.620209707
–5.0	5.01	0.426014323	1544.992	5.063452871
–4.0	4.035	0.469581906	1541.339	5.300255742
–3.0	3.048	0.530894461	1535.823	5.661033323
–2.0	2.053	0.625856249	1526.768	6.261781717
–1.5	1.484	0.709952293	1517.936	6.858122776
–1.0	0.998	0.817041457	1505.866	7.690125286

Figure 9: Data Table for CV Measurements

Suggested $V_{Reverse}$ [V]	Measured $V_{Reverse}$ [V]	Measured SBD (voltage drop at the resistor when SBD connected) $V_{Reverse}$ [mV]	Measured *SBD* I_{Rev} [µA]	Measured $V_{Reverse}$ [V]	Measured p-n ((voltage drop at the resistor when p-n diode connected) $V_{Reverse}$ [mV]	Measured *p-n diode* I_{Rev} [µA]
–0.25	0.2504	15.2	0.152	0.2497	0.2	0.002
–0.50	0.5009	16.2	0.162	0.4962	0.3	0.003
–1.0	1.002	17.6	0.176	0.994	0.4	0.004
–2.0	2.004	19.9	0.199	1.999	0.4	0.004
–4.0	4.004	23.8	0.238	4.042	0.5	0.005
–6.0	6.032	26.9	0.269	6.021	0.6	0.006
–8.0	8.01	29.7	0.297	7.99	0.6	0.006
–10.0	9.99	32.5	0.325	10.09	0.6	0.006
–12.0	12.06	35.4	0.354	11.93	0.6	0.006

Figure 10: Data Table for Reverse Saturation Current

Suggested $V_{Reverse}$ [V]	Measured $V_{Reverse}$ [V]	Measured SBD (voltage drop at the resistor when SBD connected) $V_{Reverse}$ [mV]	Measured *SBD* I_{Rev} [μA]	Measured $V_{Reverse}$ [V]	Measured p-n ((voltage drop at the resistor when p-n diode connected) $V_{Reverse}$ [mV]	Measured *p-n diode* I_{Rev} [μA]
–0.25	0.2504	15.2	0.152	0.2497	0.2	0.002
–0.50	0.5009	16.2	0.162	0.4962	0.3	0.003
–1.0	1.002	17.6	0.176	0.994	0.4	0.004
–2.0	2.004	19.9	0.199	1.999	0.4	0.004
–4.0	4.004	23.8	0.238	4.042	0.5	0.005
–6.0	6.032	26.9	0.269	6.021	0.6	0.006
–8.0	8.01	29.7	0.297	7.99	0.6	0.006
–10.0	9.99	32.5	0.325	10.09	0.6	0.006
–12.0	12.06	35.4	0.354	11.93	0.6	0.006

Figure 11: Data Table for Weak Forward Bias

	SBD current	SBD forward voltage	p-n current	p-n forward voltage
Suggested $I_{forward}$ [mA]	Measured $I_{forward}$ [mA]	Measured $V_{forward}$ [V]	Measured $I_{forward}$ [mA]	Measured $V_{forward}$ [V]
10	11	0.31	12	0.742
25	25	0.3572	29	0.798
50	50	0.424	51	0.823
75	73	0.4822	74	0.844
100	104	0.5616	102	0.863
150	151	0.667	152	0.886

Figure 12: Data Table for Strong Forward Bias