EE236: Lab 7
MOS Capacitor C-V Characteristics

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1 Aim of the experiment

1. To plot C_{DUT} vs V_{DC} and obtain the Oxide capacitance, Oxide thickness, Doping density, Flat band voltage, Flat band capacitance, Debye length and the Debye Capacitance for 4 different MOSCAPs.

2 Design & Working

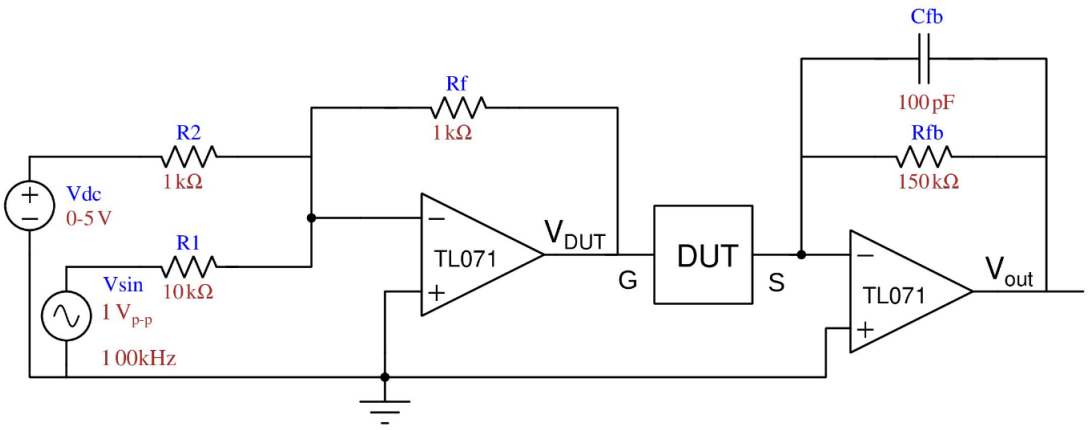

Fig. Circuit for measurements of MOSCAP C-V Characteristics

3 Experimental Results

The AC gain from V_{DUT} to V_{out} is given by:

$$\frac{|V_{out_{p-p}}|}{|V_{DUT_{p-p}}|} = \frac{C_{DUT}}{C_{fb}} \frac{1}{\sqrt{1 + \frac{1}{(\omega R_{fb} C_{fb})^2}}} \tag{1}$$

Thickness of oxide layer is given by,

$$t_{ox} = \frac{A\epsilon_{ox}}{C_{ox}} \tag{2}$$

In order to calculate doping density, we can use the following equations:

$$t_{dep} = 2\sqrt{\frac{\epsilon_{Si}}{qN_A} \frac{kT}{q} ln(\frac{N_A}{n_i})} \tag{3}$$

where the intrinsic carrier concentration of Silicon, $n_i = 1.5 \times 10^{10}\, cm^{-3}$

$$C_s = \frac{A\epsilon_{Si}}{t_{deo}} \tag{4}$$

$$C_{min} = \frac{C_{ox} C_s}{C_{ox} + C_s} \tag{5}$$

Debye capacitance is given by:

$$C_{debye} = \frac{A\epsilon_{Si}}{L_{debye}} \tag{6}$$

Debye length is given by:

$$L_{debye} = \sqrt{\frac{\epsilon_{Si}}{qN_A} \frac{kT}{q}} \tag{7}$$

Flat band capacitance can be calculated using:

$$C_{fb} = \frac{C_{ox} C_{debye}}{C_{ox} + C_{debye}} \tag{8}$$

Flat band voltage corresponds to the flat band capacitance in C-V curve

Given below are my readings for $V_{DUT_{p-p}}$, $V_{out_{p-p}}$, AC gain and the C_{DUT} for varying V_{DC} for the Circular MOSCAP of 1mm diameter:

V_{DC}	$V_{DUT_{p-p}}$	$V_{out_{p-p}}$	AC gain	C_{DUT}
-5	5.84E-01	0.1	5.84	701.8804
-2	5.84E-01	0.1	5.84	701.8804
-1	5.84E-01	0.1	5.84	701.8804
-0.5	5.84E-01	0.1	5.84	701.8804
-0.4	5.88E-01	0.1	5.88	706.6878
-0.3	5.92E-01	0.1	5.92	711.4952
-0.2	5.92E-01	0.1	5.92	711.4952
-0.1	6.04E-01	0.1	6.04	725.9174
0	6.60E-02	0.1	0.66	79.3221
0.5	5.80E-02	0.1	0.58	69.7073
0.7	1.48E-01	0.1	1.48	177.8738
0.8	1.88E-01	0.1	1.88	225.9478
1	2.20E-01	0.1	2.2	264.407
1.5	2.36E-01	0.1	2.36	283.6366
2	3.40E-01	0.1	3.4	408.629
2.5	3.80E-01	0.1	3.8	456.703
3	2.64E-01	0.1	2.64	317.2884
3.5	2.80E-01	0.1	2.8	336.518
4	3.20E-01	0.1	3.2	384.592

We obtain $C_{ox} = 701.88pF$, $C_{min} = 384.59pF$, $C_s = 579.05133pF$, $A = 0.786mm^2$, $t_{dep} = 0.14\mu m$, $t_{ox} = 0.039\mu m$, $N_A = 5.15 \times 10^{16}$, $L_{debye} = 18.06\mu m$, $C_{debye} = 4.495pF$, $C_{fb} = 4.47pF$ and $V_{fb} = 4V$

Given below is the plot for C_{DUT} vs V_{DC} for Circular MOSCAP of 1mm diameter:

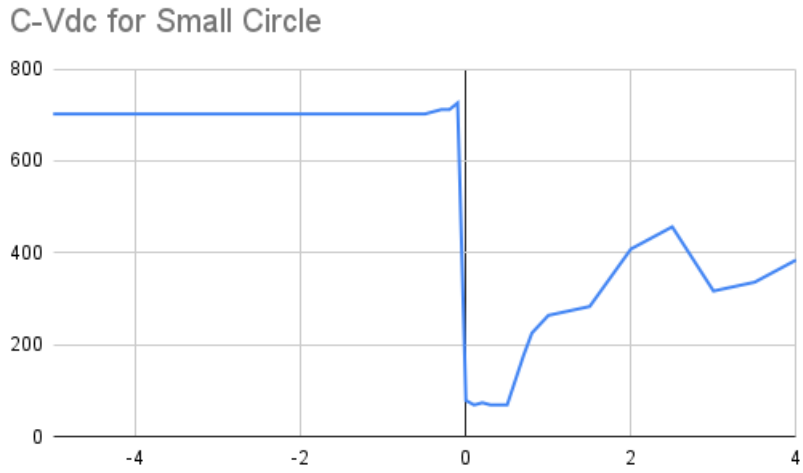

Fig. C-V Characteristics for the Circular MOSCAP of 1mm diameter

Given below are my readings for $V_{DUT_{p-p}}$, $V_{out_{p-p}}$, AC gain and the C_{DUT} for varying V_{DC} for the Circular MOSCAP of 2mm diameter:

V_{DC}	$V_{DUT_{p-p}}$	$V_{out_{p-p}}$	AC gain	C_{DUT}
-5	5.64E-01	0.1	5.64	677.8434
-2	5.72E-01	0.1	5.72	687.4582
-1	5.68E-01	0.1	5.68	682.6508
-0.5	5.68E-01	0.1	5.68	682.6508
-0.4	5.72E-01	0.1	5.72	687.4582
-0.3	5.76E-01	0.1	5.76	692.2656
-0.2	5.80E-01	0.1	5.8	697.073
-0.1	5.84E-01	0.1	5.84	701.8804
0	5.80E-02	0.1	0.58	69.7073
0.5	5.40E-02	0.1	0.54	64.8999
0.7	7.80E-02	0.1	0.78	93.7443
0.8	1.88E-01	0.1	1.88	225.9478
0.9	2.56E-01	0.1	2.56	307.6736
1	2.40E-01	0.1	2.4	288.444
1.5	2.64E-01	0.1	2.64	317.2884
2	2.80E-01	0.1	2.8	336.518

We obtain $C_{ox} = 687.4582pF$, $C_{min} = 307.6736pF$, $C_s = 556.928pF$, $A = 3.1416mm^2$, $t_{dep} = 0.5831\mu m$, $t_{ox} = 0.1577\mu m$, $N_A = 3.35 \times 10^{17}$, $L_{debye} = 7.081\mu m$, $C_{debye} = 45.86pF$, $C_{fb} = 42.99pF$ and $V_{fb} = 1.5V$

Given below is the plot for C_{DUT} vs V_{DC} for Circular MOSCAP of 2mm diameter:

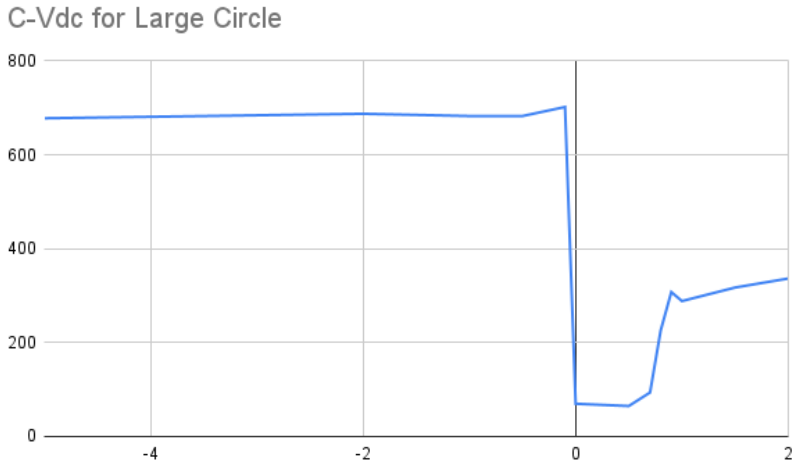

Fig. C-V Characteristics for the Circular MOSCAP of 2mm diameter

Given below are my readings for $V_{DUT_{p-p}}$, $V_{out_{p-p}}$, AC gain and the C_{DUT} for varying V_{DC} for the Square MOSCAP of 1mm side length:

V_{DC}	$V_{DUT_{p-p}}$	$V_{out_{p-p}}$	AC gain	C_{DUT}
-5	5.88E-01	0.1	5.88	706.6878
-2	5.84E-01	0.1	5.84	701.8804
-1	5.80E-01	0.1	5.8	697.073
-0.5	5.84E-01	0.1	5.84	701.8804
-0.4	5.88E-01	0.1	5.88	706.6878
-0.3	5.88E-01	0.1	5.88	706.6878
-0.2	5.96E-01	0.1	5.96	716.3026
-0.1	6.00E-01	0.1	6	721.11
0	5.80E-02	0.1	0.58	69.7073
0.1	6.40E-02	0.1	0.64	76.9184
0.5	5.80E-02	0.1	0.58	69.7073
0.7	9.00E-02	0.1	0.9	108.1665
0.8	1.56E-01	0.1	1.56	187.4886
0.9	2.78E-01	0.1	2.78	334.1143
1	2.30E-01	0.1	2.3	276.4255
1.5	2.16E-01	0.1	2.16	259.5996
2	2.74E-01	0.1	2.74	329.3069
2.5	2.56E-01	0.1	2.56	307.6736
3	2.60E-01	0.1	2.6	312.481
3.5	2.64E-01	0.1	2.64	317.2884

We obtain $C_{ox} = 706.6878pF$, $C_{min} = 307.6736pF$, $C_s = 544.9159pF$, $A = 1mm^2$, $t_{dep} = 0.1897\mu m$, $t_{ox} = 0.0489\mu m$, $N_A = 2.70 \times 10^{16}$, $L_{debye} = 24.94\mu m$, $C_{debye} = 4.144pF$, $C_{fb} = 4.12pF$ and $V_{fb} = 2.5V$

Given below is the plot for C_{DUT} vs V_{DC} for Square MOSCAP of 1mm side length:

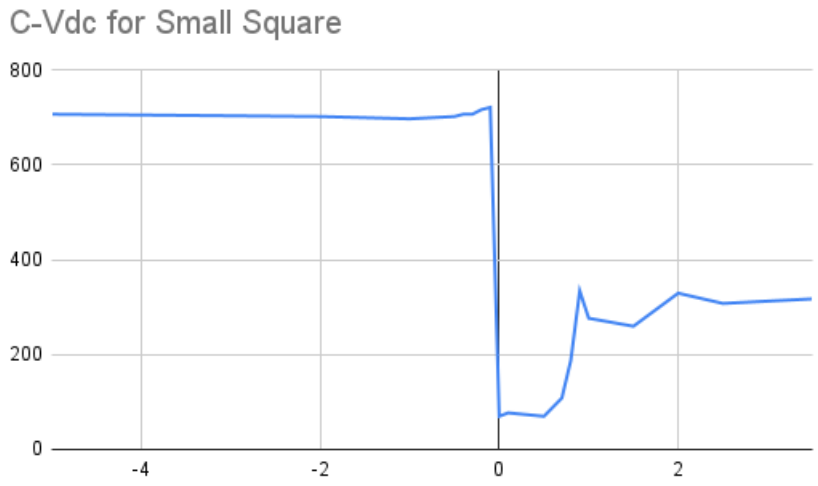

Fig. C-V Characteristics for the Square MOSCAP of 1mm side length

Given below are my readings for $V_{DUT_{p-p}}$, $V_{out_{p-p}}$, AC gain and the C_{DUT} for varying V_{DC} for the Square MOSCAP of 2mm side length:

V_{DC}	$V_{DUT_{p-p}}$	$V_{out_{p-p}}$	AC gain	C_{DUT}
-5	5.64E-01	0.1	5.64	677.8434
-2	5.56E-01	0.1	5.56	668.2286
-1	5.60E-01	0.1	5.6	673.036
-0.5	5.60E-01	0.1	5.6	673.036
-0.4	5.64E-01	0.1	5.64	677.8434
-0.3	5.64E-01	0.1	5.64	677.8434
-0.2	5.72E-01	0.1	5.72	687.4582
-0.1	5.84E-01	0.1	5.84	701.8804
0	6.20E-02	0.1	0.62	74.5147
0.5	5.90E-02	0.1	0.59	70.90915
0.7	8.40E-02	0.1	0.84	100.9554
0.8	1.44E-01	0.1	1.44	173.0664
0.9	2.48E-01	0.1	2.48	298.0588
1	2.32E-01	0.1	2.32	278.8292
1.5	2.40E-01	0.1	2.4	288.444
2	2.88E-01	0.1	2.88	346.1328
2.5	2.80E-01	0.1	2.8	336.518
3	2.80E-01	0.1	2.8	336.518

We obtain $C_{ox} = 677.8434pF$, $C_{min} = 336.518pF$, $C_s = 668.296pF$, $A = 4mm^2$, $t_{dep} = 0.6187\mu m$, $t_{ox} = 0.2037\mu m$, $N_A = 2.95 \times 10^{17}$, $L_{debye} = 7.546\mu m$, $C_{debye} = 54.795pF$, $C_{fb} = 50.696pF$ and $V_{fb} = 2.5V$

Given below is the plot for C_{DUT} vs V_{DC} for Square MOSCAP of 2mm side length:

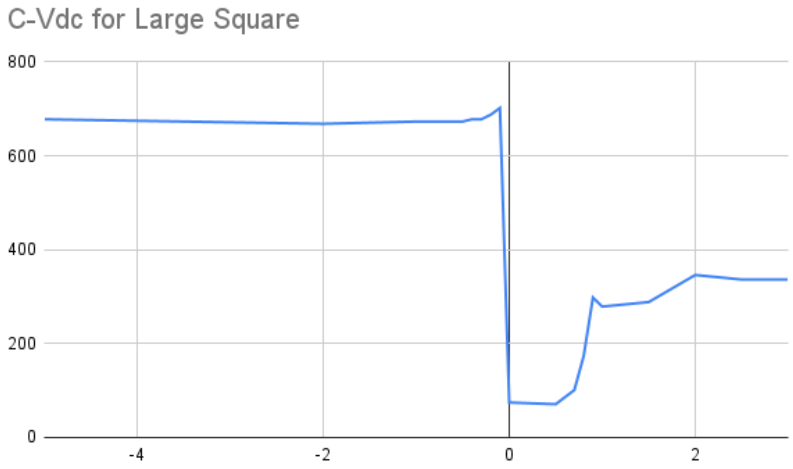

Fig. C-V Characteristics for the Square MOSCAP of 2mm side length