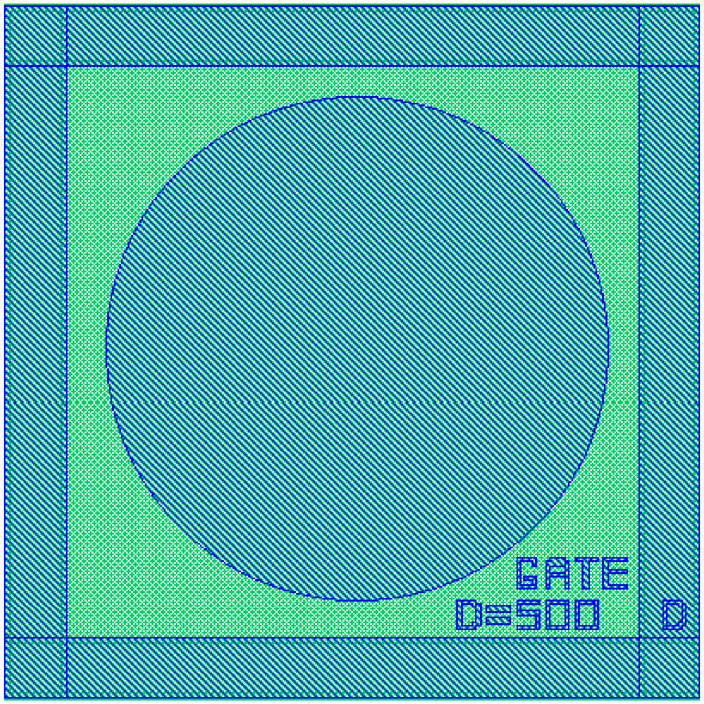
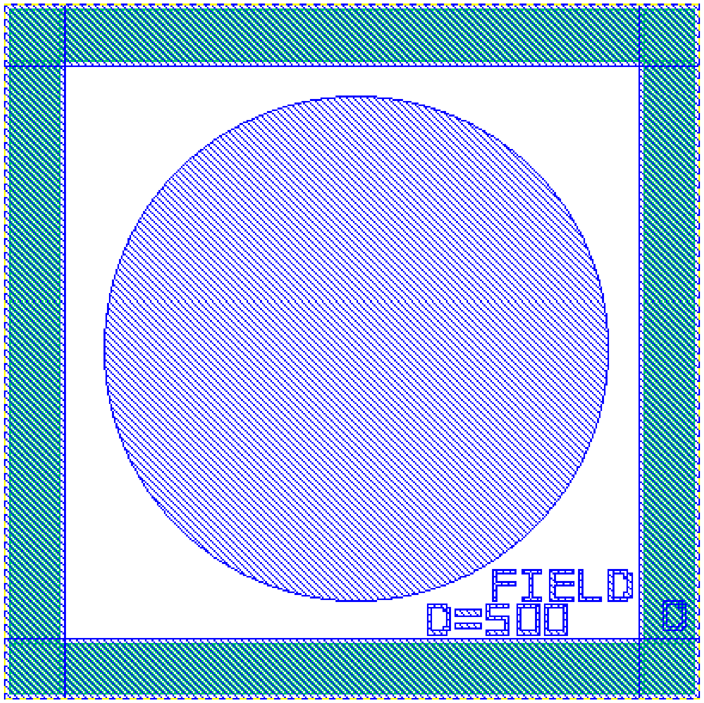
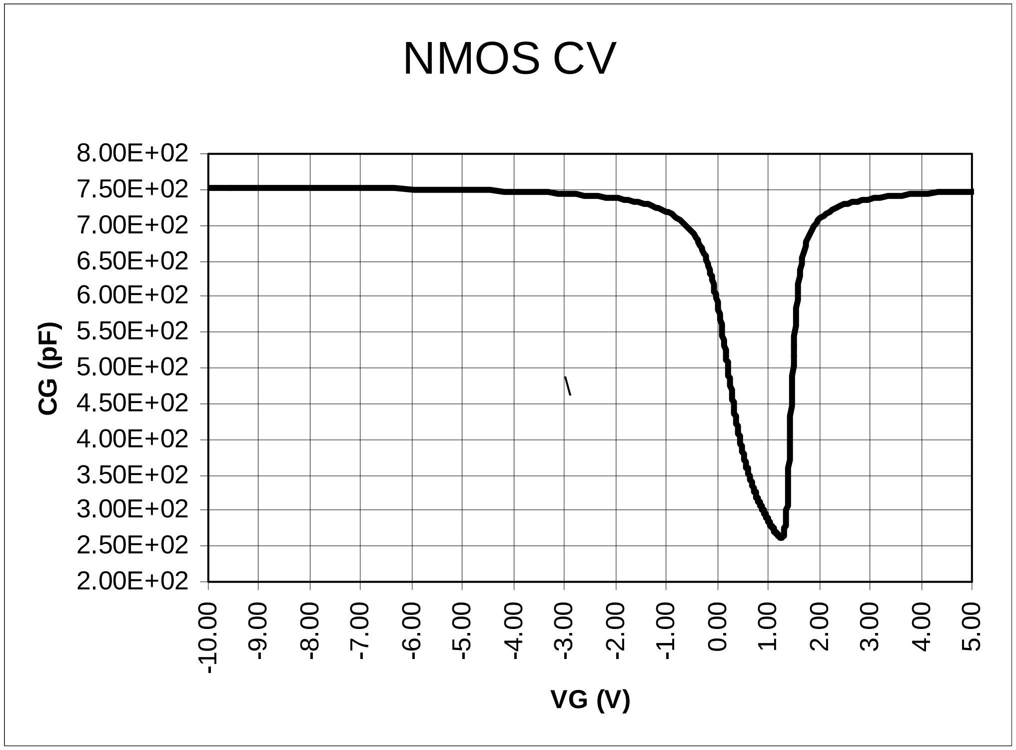
Capacitors

- We can extract for the capacitors:
  - Long Channel VT of the transistors
  - VT of the parasitic transistors on the field oxide
  - Substrate doping
  - Fixed oxide charge
  - The capacitance of the oxide
  - In some cases you can extract the thickness of the oxide.

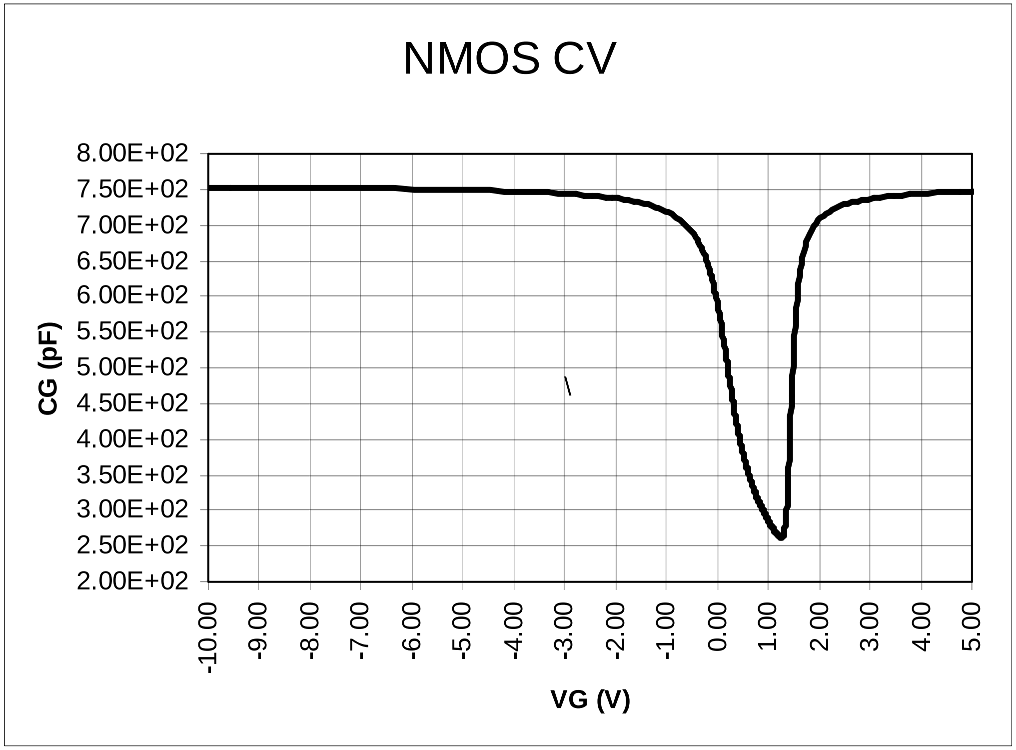

GATE
D=500
D


FIELD
D=500
D

Capacitors


NMOS CV
8.00E+02
7.50E+02
7.00E+02
6.50E+02
6.00E+02
5.50E+02
5.00E+02
4.50E+02
4.00E+02
3.50E+02
3.00E+02
2.50E+02
2.00E+02
CG (pF)
-10.00
-9.00
-8.00
-7.00
-6.00
-5.00
-4.00
-3.00
-2.00
-1.00
0.00
1.00
2.00
3.00
4.00
5.00
VG (V)

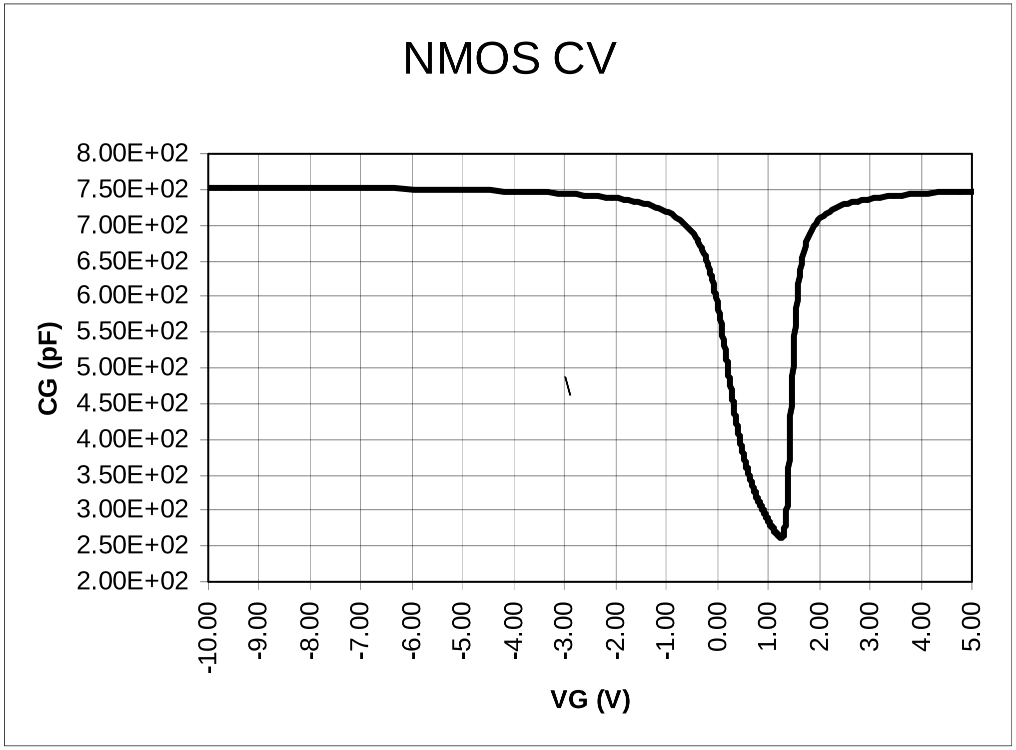
A CV Curve can be used to extract important device data before a transistor is fabricated!



You need to know the oxide thickness from an other measurement tool (Nanospec)

Nb, N, VT, Qi, VFB

Find the Area and convert Cg max and Cg minimum to 1 dimension.



From CV Curve

$$C_{g\_max} := 750 \cdot 10^{-12} F$$

$$T_{ox} := 3.577 \cdot 10^{-4} cm$$

$$\varepsilon_{SiO2} := 3.9 \cdot 8.85 \cdot 10^{-14} \frac{F}{cm}$$

$$\frac{\varepsilon_{SiO2}}{T_{ox}} = \frac{Cg\_max}{Area}$$

$$Area := \frac{C_{g\_max} \cdot T_{ox}}{\varepsilon_{SiO2}}$$

$$Area = 7.773 \times 10^{-3}\ cm^2$$

$$C_{g\_max} := \frac{C_{g\_max}}{Area} \qquad C_{g\_max} = 9.649 \times 10^{-8} \frac{F}{cm^2}$$

$$C_{g\_min} := 270 \cdot 10^{-12} F$$

From CV curve

$$C_{g\_min} := \frac{C_{g\_min}}{Area} \qquad C_{g\_min} = 3.474 \times 10^{-8} \frac{F}{cm^2}$$

Find the doping concentration by finding the minimum depletion capacitance.

$$C_{g\_max} := \frac{C_{g\_max}}{Area} \qquad C_{g\_max} = 9.649 \times 10^{-8} \frac{F}{cm^2}$$

$$C_{g\_min} := 270 \cdot 10^{-12} F$$

$$C_{g\_min} := \frac{C_{g\_min}}{Area} \qquad C_{g\_min} = 3.474 \times 10^{-8} \frac{F}{cm^2}$$

Find the doping concentration by finding the minimum depletion capacitance.

$$C_{g\_min} = \frac{C_{si\_min} \cdot C_{g\_max}}{C_{si\_min} + C_{g\_max}}$$

$$C_{si\_min} := \frac{C_{g\_max} \cdot C_{g\_min}}{C_{g\_max} - C_{g\_min}}$$

$$C_{si\_min} = 5.428 \times 10^{-8} \frac{F}{cm^{2}}$$

Find the doping concentration by finding the minimum depletion capacitance.

$$C_{si\_min} = \frac{\varepsilon_{si}}{\left(2\cdot\left(\frac{\varepsilon_{si}\cdot U_T\cdot \ln\left(\frac{Nb}{ni}\right)}{q\cdot N_b}\right)\right)^{\frac{1}{2}}}$$

$$N_b := 10^{30.388+1.683\cdot\log\left(C_{si\_min}\right)-0.03177\cdot\left(\log\left(C_{si\_min}\right)\right)^2}$$

$$N_b = 3.043\times 10^{16}$$

To Find VT we need the flat band voltage. To find VFB we need CFB.

$$L_D := \sqrt{\frac{\varepsilon_{si} \cdot U_T}{q \cdot N_b}} \qquad L_D = 2.357 \times 10^{-6}$$

$$C_{Debye} := \frac{\varepsilon_{si} \cdot \sqrt{2}}{L_D} \qquad C_{Debye} = 6.266 \times 10^{-7}$$

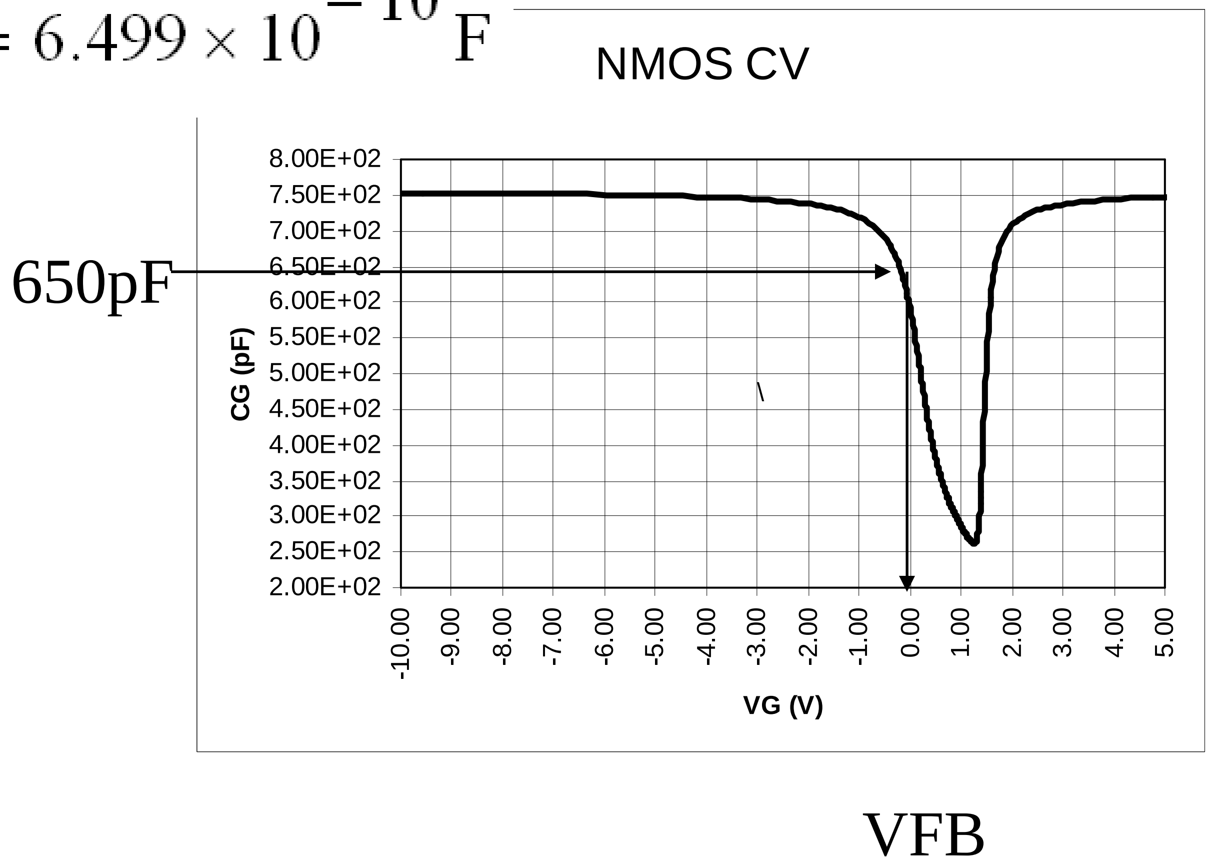
$$C_{FB} := \frac{C_{g\_max} \cdot C_{Debye}}{C_{g\_max} + C_{Debye}} \qquad C_{FB} = 8.362 \times 10^{-8}$$

To find VFB we need CFB in F so we can look up the CFB, VFB pair from the original CV data.

$C_{FB} := C_{FB} \cdot Area$

VFB is very close to Zero!

$C_{FB} = 6.499 \times 10^{-10}\ F$



It would have been exactly zero but reading the chart introduces errors.

VT for VFB=0

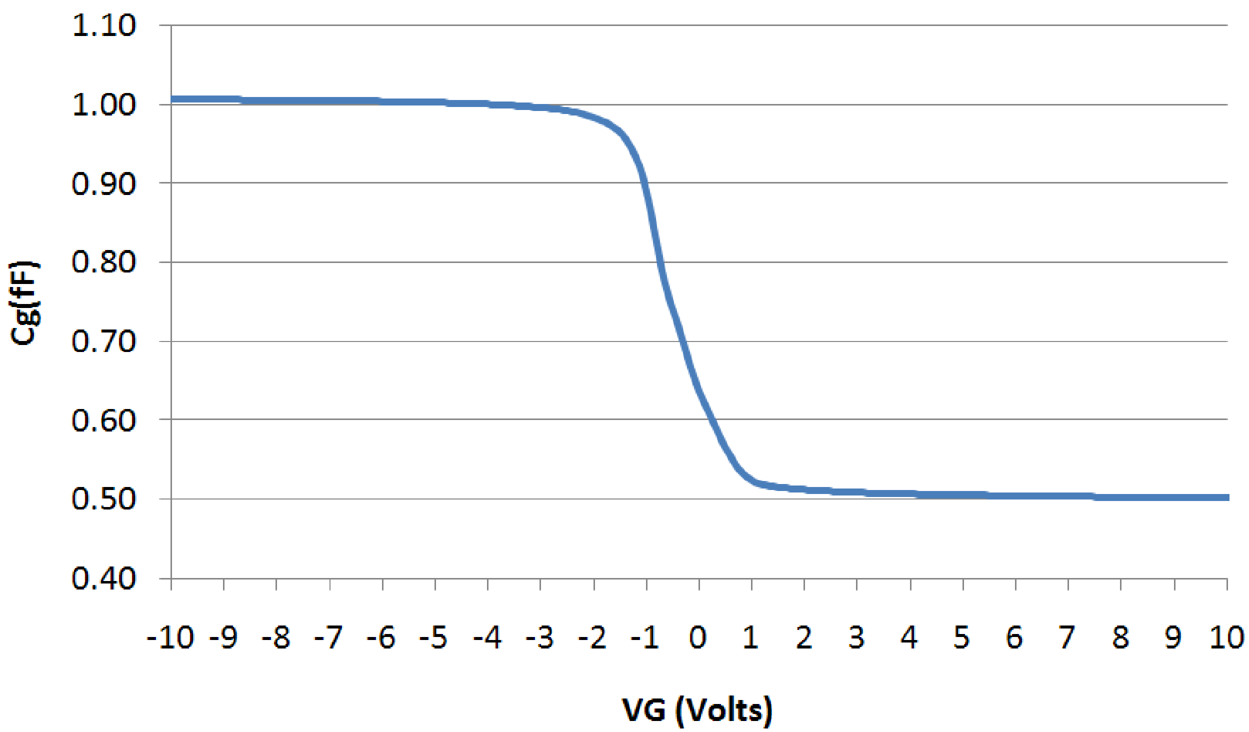
$$C_{ox} := C_{g\_max}$$

$$V_{FB} := 0 \quad ni := 1.5 \cdot 10^{10}$$

$$Q_D := -2 \cdot \left(\varepsilon_{si} \cdot q \cdot N_b \cdot U_T \cdot \ln\left(\frac{N_b}{ni}\right)\right)^{\frac{1}{2}} \quad Q_D = -8.675 \times 10^{-8}$$

$$V_T := V_{FB} - \frac{Q_D}{C_{ox}} + 2 \cdot 0.0259 \cdot \ln\left(\frac{N_b}{ni}\right) \quad V_T = 1.65$$

Another Example



Another Example

ITEM	Units	VALUE
T	K	300
k	J/K	1.38E-23
Eps Si	F/cm	1.05315E-12
q	C	1.60E-19
Ni	cm^-3	1.50E+10
AREA	cm^2	0.00000003
CMAX From Wafer	F	1.01E-15
CMIN From Wafer	F	4.98E-16
CMAX	F/cm^2	3.36E-08
CMIN	F/cm^2	1.66E-08
CDMIN	F/cm^2	3.28E-08
NA	cm^-3	1.03E+16
LD	cm	4.0684E-06
CDEBYE	F/cm^2	3.66085E-07
CFB	F/cm^2	3.08E-08
CFB to READ From Wafer	F	9.23E-16
VFB from CVFB	V	-1.1
WM	cm	2.98E-05
VT	V	1.06E+00
QI	q/cm^2	3.20E+10