Module 2 : MOSFET
Lecture 5 : MOS Capacitor (Contd...)

Objectives

In this course you will learn the following
- Threshold Voltage Calculation
- C-V characteristics
- Oxide Charge Correction

5.1 Threshold Voltage Calculation

Threshold voltage is that gate voltage at which the surface band bending is twice φ_F,

Where $\varphi_F = \frac{kT}{q} ln(\frac{N_A}{n_i})$

We know that the depth of depletion region for φ_S is between **0** and $2\varphi_F$ and is given by,

$$x_d = \sqrt{\frac{2 \in_s \varphi_s}{qN_a}}$$

Charge in depletion region at $\varphi_S = 2\varphi_F$ is given by $Q_D = -qN_a x_{dmax}$ where

$$x_{dmax} = \sqrt{\frac{2 \in_s (2\varphi_F)}{qN_a}}$$

Beyond threshold, the total charge $\mathbf{Q}_D$ in the seminconductor has to balance the charge on gate electrode, $\mathbf{Q_s}$ i.e. $Q_S = -(Q_i + Q_D)$ where we define the charge in the inversion layer as a quantity which needs to be determined.

This leads to following expression for gate voltage-

$$V_{GS} = V_{FB} + \varphi_s + \frac{Q_S}{C_{ox}} = V_{FB} + \varphi_s - \frac{(Q_i + Q_D)}{C_{ox}}$$

In case of depletion, there in no inversion layer charge, so $\mathbf{Q_i} = \mathbf{0}$, i.e. gate voltage becomes

$$V_{GS} = V_{FB} + \varphi_s - \frac{Q_D}{C_{ox}} = V_{FB} + \varphi_s + \frac{2\sqrt{qN_a \in_s \varphi_F}}{C_{ox}} \text{ for } 0 \le \varphi_S \le 2\varphi_F$$

but in case of inversion, the gate voltage will be given by :

The second term in second equality of last expression states our basic assumption, namely that any change in gate voltage beyond the threshold requires a change in inversion layer charge. Also from the same expression, we obtain threshold voltage as :

$$V_T = V_{FB} + 2\varphi_F + \frac{2\sqrt{qN_a \in_s \varphi_F}}{C_{ox}}$$

5.2 C-V Characteristics

The low frequency and high frequency C-V characteristics curves of a MOS capacitor are shown in fig 5.2.

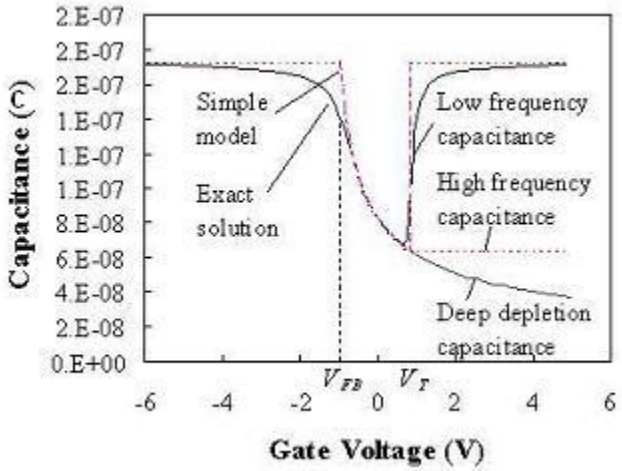

Fig 5.2 : Low & High Frequency C-V curves

The **low frequency** or quasi-static measurement maintains thermal equilibrium at all times. This capacitance is the ratio of the change in charge to the change in gate voltage, measured while the capacitor is in equilibrium. A typical measurement is performed with an electrometer, which measures the charge added per unit time as one slowly varies the applied gate voltage.

The **high frequency** capacitance is obtained from a small-signal capacitance measurement at high frequency. The bias voltage on the gate is varied slowly to obtain the capacitance versus voltage. Under such conditions, one finds that the charge in the inversion layer does not change from the equilibrium value corresponding to the applied DC voltage. The high frequency capacitance therefore reflects only the charge variation in the depletion layer and the (rather small) movement of the inversion layer charge.

5.3 Oxide Charge Correction

To keep the value of within -1 Volt and +1 Volt, an n-channel device has high doping (similarly, pchannel device has high doping).

Recap

In this lecture you have learnt the following

- Threshold Voltage Calculation
- C-V characteristics
- Oxide Charge Correction

Congratulations, you have finished Lecture 5.