3. MOSFET

- A FET is made by growing a very thin layer of SiO_2 ($0.1\mu m$) over a semiconductor material . Metal such as aluminium is deposited over dielectric layer of SiO_2 is known as MOSFET(metal oxide semiconductor field effect transistor).

- There are two types of MOSFET.

  - Enhancement MOSFET
  - Depletion MOSFET

Similar to JFET , It has n-channel as well as p-channel .Construction wise we can categorise the device into four types

i. P-channel Enhancement MOSFET
ii. n-channel Enhancement MOSFET
iii. n-channel Depletion MOSFET
iv. p-channel Depletion MOSFET

3.1 The ideal MOS Structure have the following explicit properties

i. The metallic gate is sufficiently thick so that it can be considered to be an equipotential region under both AC and DC biasing.

ii. The oxide is perfect insulator with zero current flowing through the oxide layer under all static biasing condition.

iii. There are no charge centers located in the oxide or in oxide semiconductor interface .

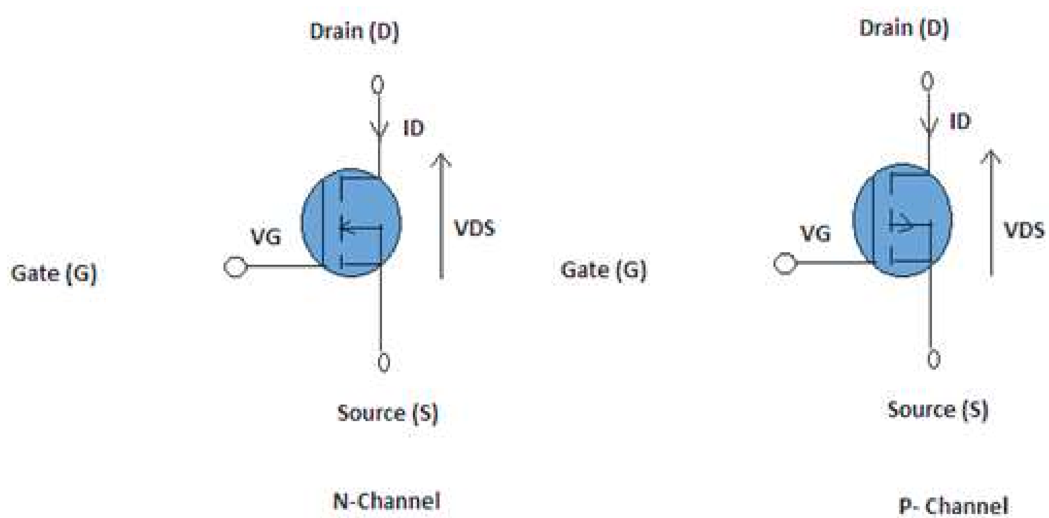
iv. The semiconductor is sufficiently thick to ensure that regardless of the applied gate potential, a field-free region is encountered before reaching the black contact.

v. The semiconductor is uniformly doped.

vi. An ohmic contact has been established between the semiconductor and the metal on the black side of the device.

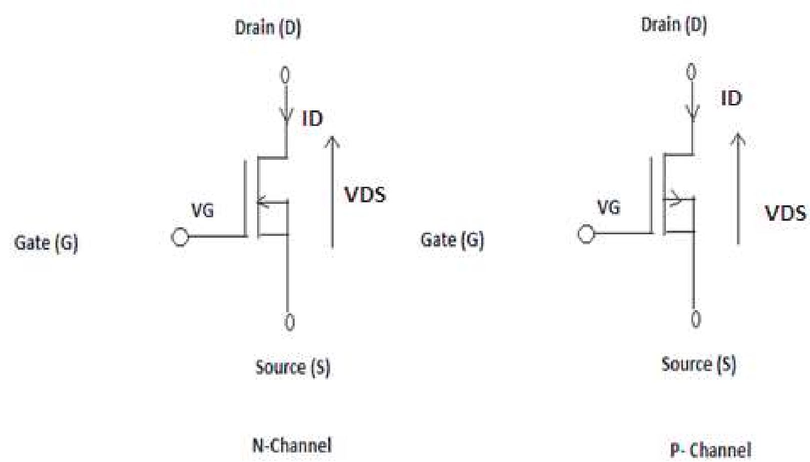
3.2 Enhancement mode

When there is no voltage on the gate, the device doesn't conduct. More voltage on the gate, the better the device can conduct.



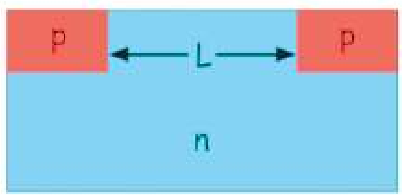
3.3 Depletion mode

When No Voltage On The Gate, The Channel Shows Its Maximum Conductance. As The Voltage On The Gate Is Either Positive Or Negative, The Channel Conductivity Decreases.

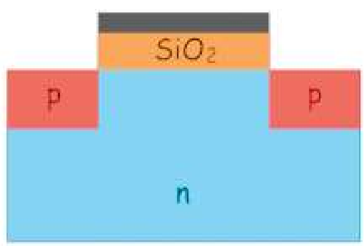


i) P – Channel Enhancement MOSFET

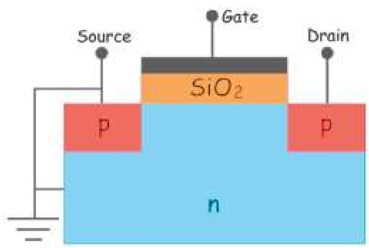
- We also call the **p channel MOSFET** as **PMOS**. Here, a substrate of lightly doped n-type semiconductor forms the main body of the device. We usually use silicon or gallium arsenide semiconductor material for this purpose. Two heavily doped p-type regions are there in the body separated by a certain distance L. We refer this distance L as **channel length** and it is in order of 1 µm.



- Now there is a thin layer of silicon dioxide (SiO_2) on the top of the substrate. We may also use Al_2O_3 for the purpose but SiO_2 is most common. This layer on the substrate behaves as a dielectric. There is an aluminum plate fitted on the top of this SiO_2 dielectric layer. Now the aluminum plate, dielectric and semiconductor substrate form a capacitor on the device.



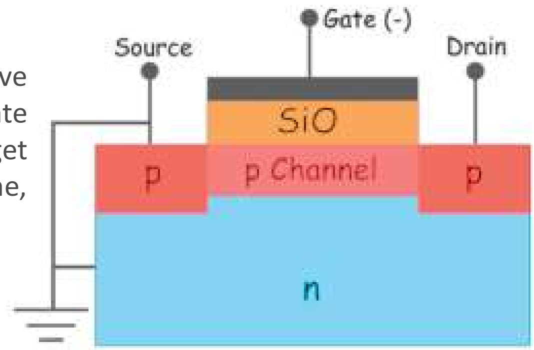
- The terminals connected to two p-type regions are the source (S) and drain (D) of the device respectively. The terminal projected from the aluminum plate of the capacitor is gate (G) of the device. We also connect the source and body of the MOSFET to earth to facilitate the supply and withdrawal of free electrons as per requirement during operation of the MOSFET



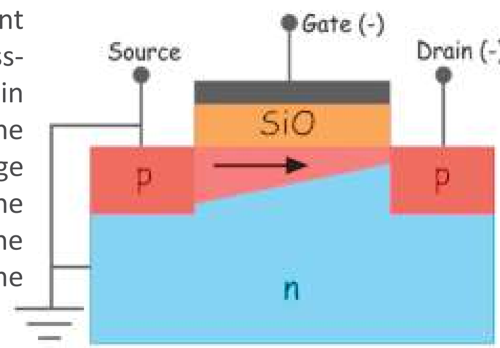
- Now let us apply a negative voltage at gate (G). This will create negative static potential at the aluminum plate of the capacitor. Due to capacitive action, positive charge gets accumulated just below the dielectric layer.

Basically, the free electrons of that portion of the n-type substrate get shifted away due to the repulsion of negative gate plate and consequently layers of uncovered positive ions appear here. Now if we further increase the negative voltage at the gate terminal, after a certain voltage called threshold voltage, due to the electrostatic force, covalent bonds of the crystal just below the SiO_2 layer start breaking. Consequently, electron-hole pairs get generated there. The holes get attracted and free electrons get repealed due to the negativity of the gate. In this way, the concentration of holes increases there and create a channel of holes from source to drain region. Holes also come from both heavily doped p-type source and drain region. Due to the concentration of holes in that channel the channel becomes conductive in nature through which electric current can pass

- Now, let us apply a negative voltage at drain terminal. The negative voltage in the drain region reduces the voltage difference between gate and drain reduces, as a result, the width of the conductive channel get reduced toward the drain region as shown below. At the same time, current flows from source to drain shown by arrowhead.



- The channel created in the MOSFET offers a resistance to the current from source to drain. The resistance of the channel depends on the cross-section of the channel and the cross section of the channel again depends on the applied negative gate voltage. So we can control the current from the source to drain with the help of an applied gate voltage hence MOSFET is a voltage controlled electronic device. As the concentration of holes forms the channel, and the current through the channel gets enhanced due to increase in negative gate voltage, we name the MOSFET as P – Channel Enhancement MOSFET.



3.4 I-V Characteristics

- The transfer characteristics of **p-type enhancement MOSFETs** from which it is evident that I_{DS} remains zero (cutoff state) until V_{GS} becomes equal to $-V_T$. This is because, only then the channel will be formed to connect the drain terminal of the device with its source terminal.

- After this, the I_{DS} is seen to increase in reverse direction (meaning an increase in I_{SD}, signifying an increase in the device current which will flow from source to drain) with the decrease in the value of V_{DS}.

- This means that the device is functioning in its ohmic region wherein the current through the device increases with an increase in the applied voltage (which will be V_{SD}).

- However as V_{DS} becomes equal to $-V_P$, the device enters into saturation during which a saturated amount of current (I_{DSS}) flows through the device, as decided by the value of V_{GS} .

- Further it is to be noted that the value of saturation current flowing through the device is seen to increase as the V_{GS} becomes more and more negative i.e. saturation current for V_{GS3} is greater than that for V_{GS2} and that in the case of V_{GS4} is much greater than both of them as V_{GS3} is more negative than V_{GS2} while V_{GS4} is much more negative when compared to either of them (Figure 2b)

- **In addition, from the locus of the pinch-off voltage it is also clear that as V_{GS} becomes more and more negative, even the negativity of V_P also increases.**

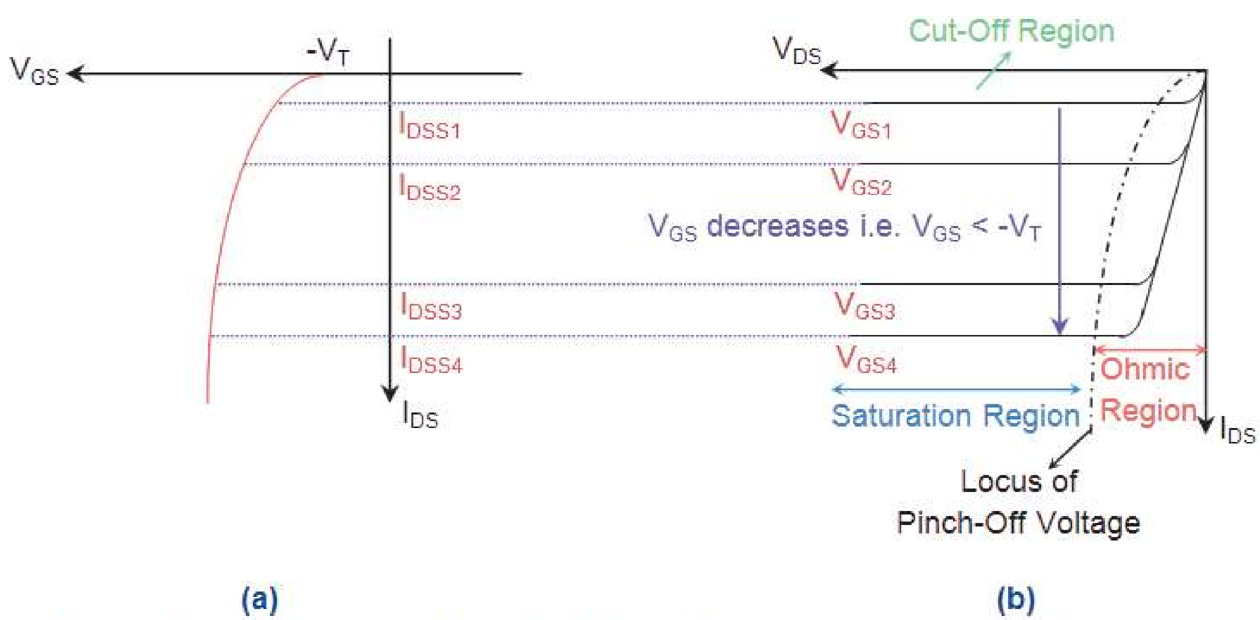
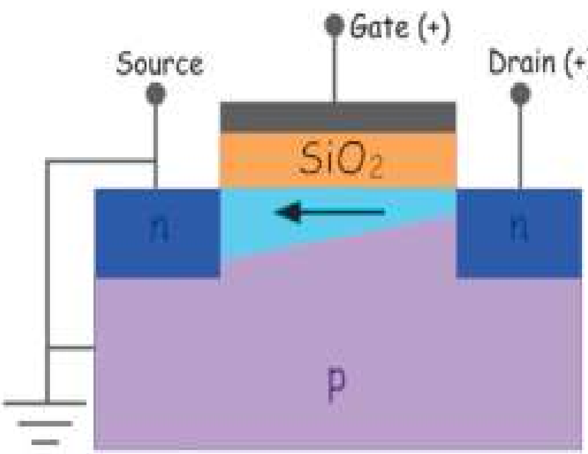


Figure 2 *p*-Channel Enhancement type MOSFET (a) Transfer Characteristics (b) Output Characteristics

ii) n – Channel Enhancement MOSFET

- Its working is similar to that of p-channel enhancement MOSFET but only operationally and constructionally there are different from each other.

- The Characteristics is shown in figure



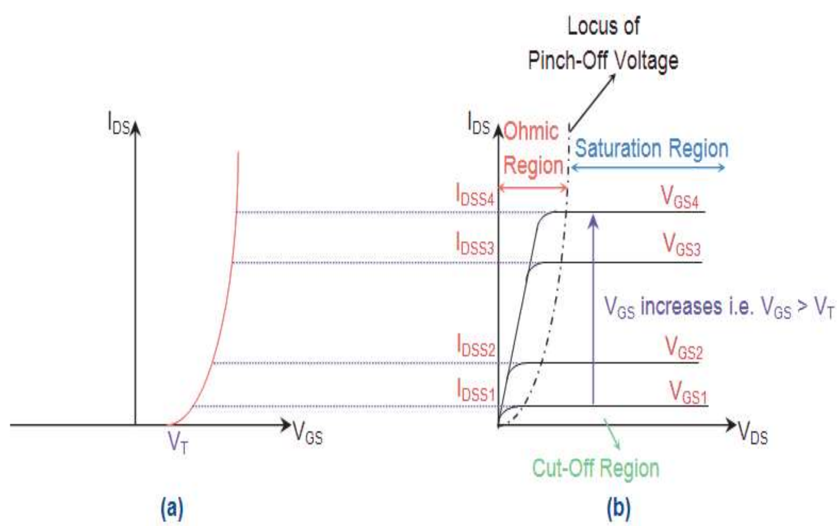
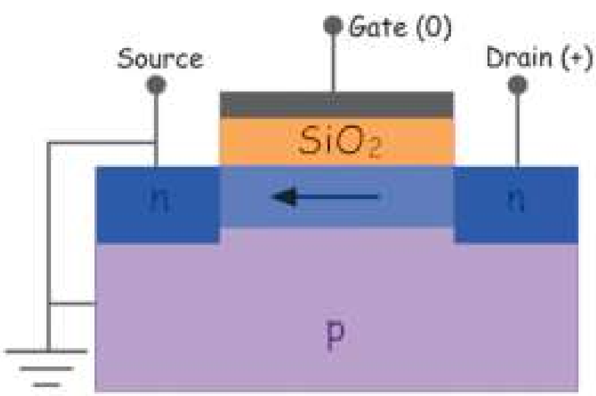


Figure 1 *n*-Channel Enhancement type MOSFET (a) Transfer Characteristics (b) Output Characteristics

iii) n-channel Depletion-type MOSFET

- **The construction and the characteristics regions are shown below**



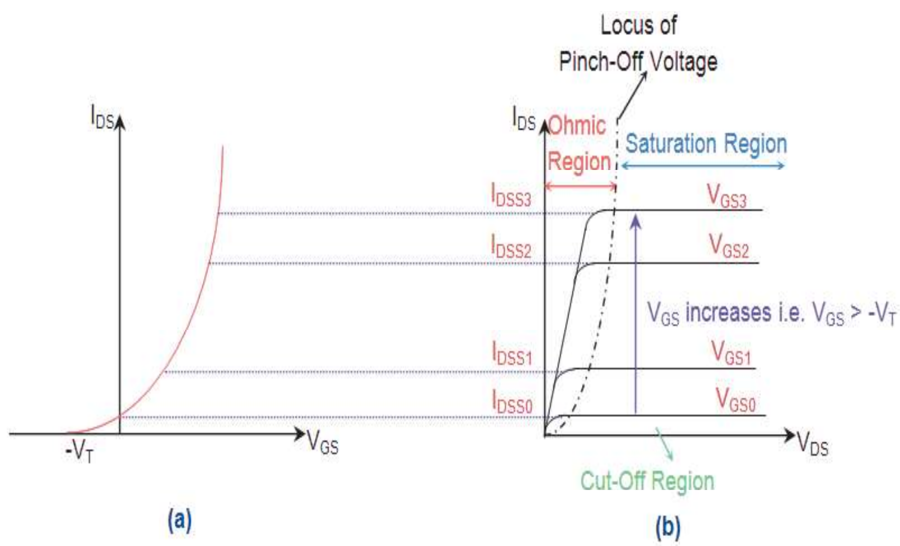
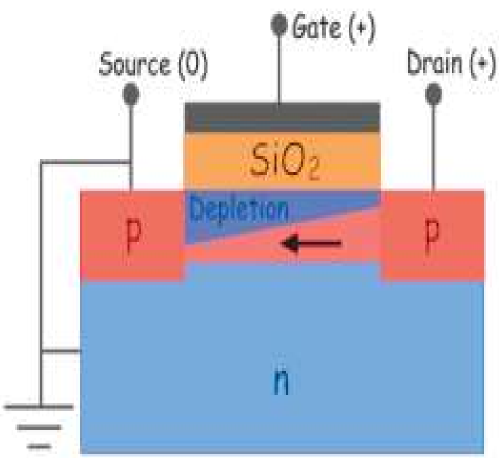


Figure 3 *n*-Channel Depletion type MOSFET (a) Transfer Characteristics (b) Output Characteristics

iv) p-channel Depletion-type MOSFET

- **Construction wise p-channel DE-MOSFET is just reverse of the n channel depletion MOSFET**



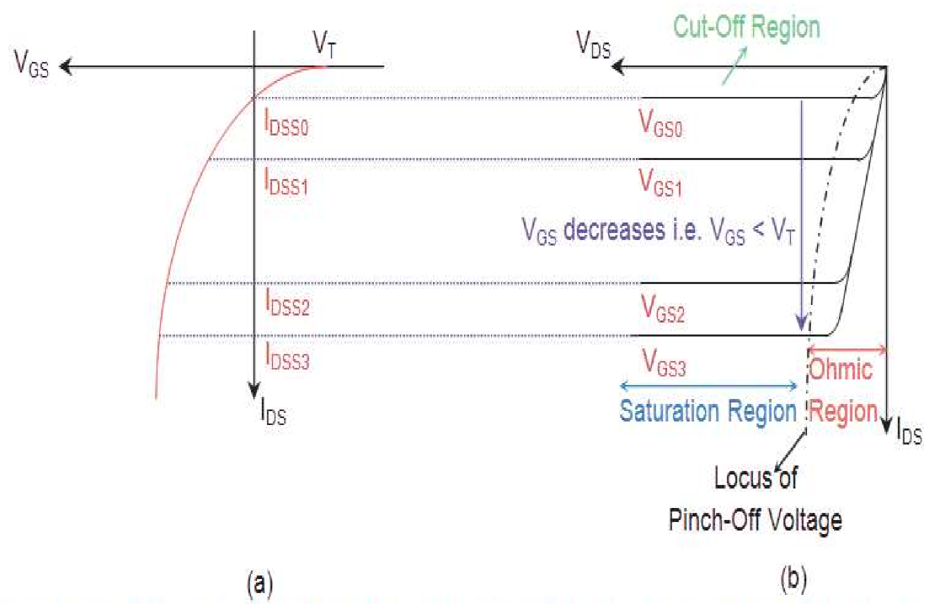


Figure 4 *p*-Channel Depletion type MOSFET (a) Transfer Characteristics (b) Output Characteristics