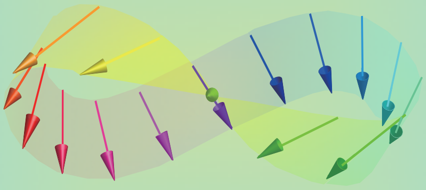
Semiconductor Devices

27



Atsufumi Hirohata

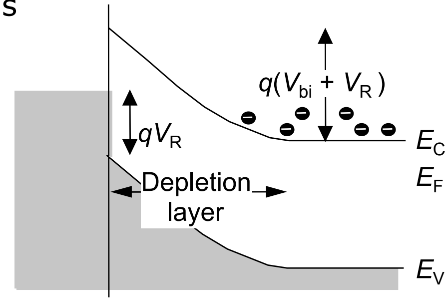
Department of Electronics

THE UNIVERSITY *of York*

11:00 Thursday, 4/December/2014 (P/T 005)

Exercise 6

Calculate the depletion layer capacity at a reverse bias V_R = 0.5 V in a Au/*n*-Si Schottky diode. Assume the following parameters:



Au work function: ϕ_M = 4.80 eV

n-region: doping density of $N_D = 1 \times 10^{21}$ m^{-3}

Si electron affinity: χ = 4.05 eV

Si Fermi level: $E_F = E_C - 0.15$ eV

permittivity: $\varepsilon = \varepsilon \times \varepsilon_0 = 12.0 \times 8.854 \times 10^{-12}$ F/m

and $q = 1.6 \times 10^{-19}$ C.

The built-in potential can be calculated as

$$qV_{bi} = \phi_B - (E_C - E_F)$$

For an *n*-type contact,

$\phi_M < \chi$: (   ) contact

$\phi_M > \chi$: (   ) contact with the barrier height of $\phi_B = \phi_M - \chi$

Hence,

$$qV_{bi} =$$

By substituting the given parameters,

$$qV_{bi} = (4.80 - 4.05) - 0.15 =$$

Depletion layer capacity C is

$$C = \frac{\varepsilon}{w} = \sqrt{\frac{q\varepsilon N_D}{2(V_{bi} + V_R)}}$$

$$= \sqrt{\frac{1.6\times10^{-19}\cdot12.0\times8.854\times10^{-12}\cdot1\times10^{21}}{2(0.60+0.5)}}$$

$$= \sqrt{\frac{1.70\times10^{-8}}{1.3}} = 1.14\cdots\times10^{-4}[\mathrm{C}]$$

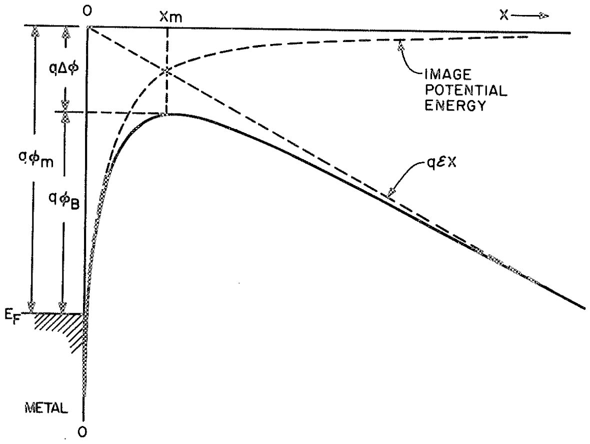
$$\approx$$

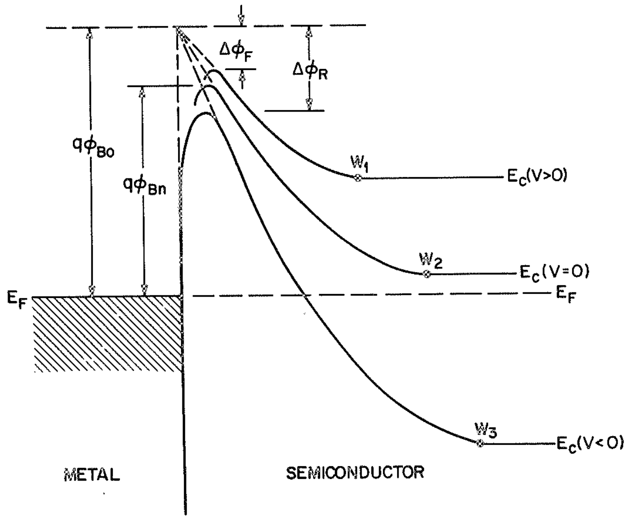
27 Metal Oxide Semiconductor Junction

- Bias application
- Surface space-charge
- MOS FET

Realistic Schottky Barrier

Image force and Shottky barrier :

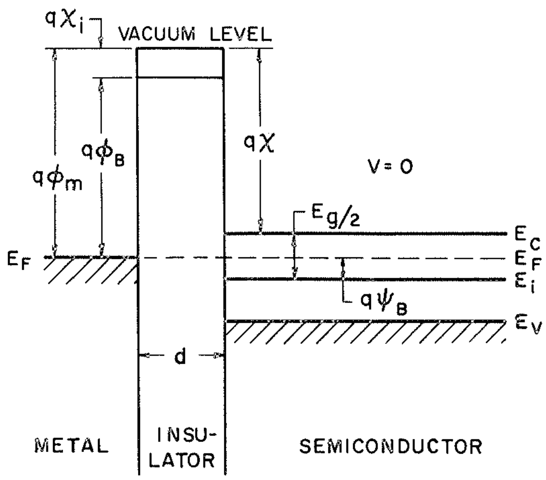




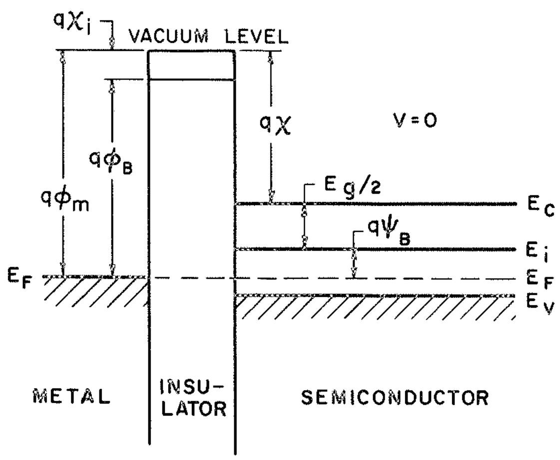
* S. M. Sze, *Physics of Semiconductor Devices* (Wiley, New York, 2006).

Metal Oxide Semiconductor Junction

n-type semiconductor at V = 0 :



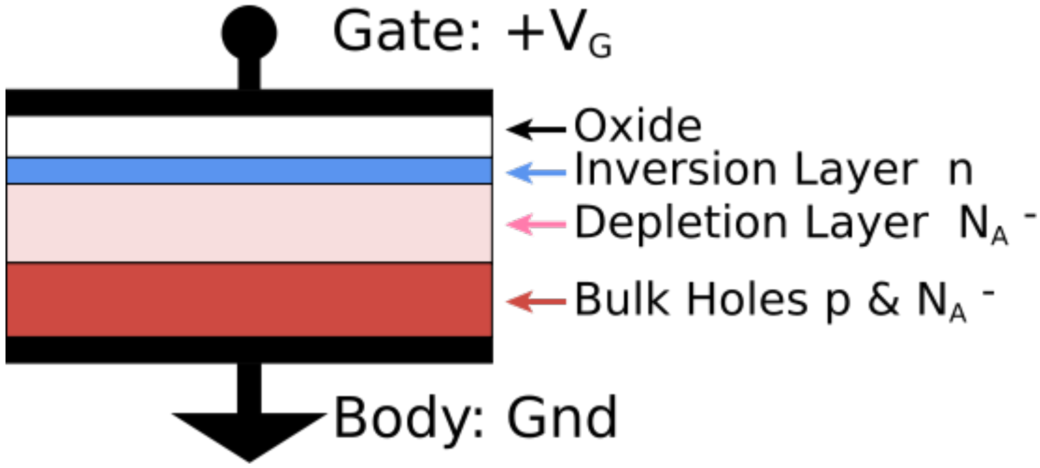
p-type semiconductor at V = 0 :



* S. M. Sze, *Physics of Semiconductor Devices* (Wiley, New York, 2006).

Metal Oxide Semiconductor (MOS)

p-type Si / SiO_2 / poly-Si :

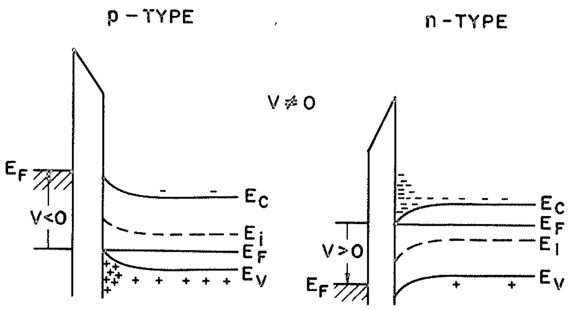


In 2007, Intel introduced p-type Si / high-k oxides (HfO_2 etc.) / metal.

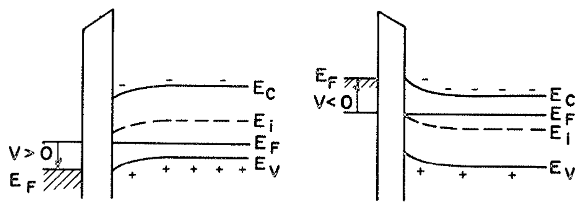
* http://www.wikipedia.org/

Bias Applications

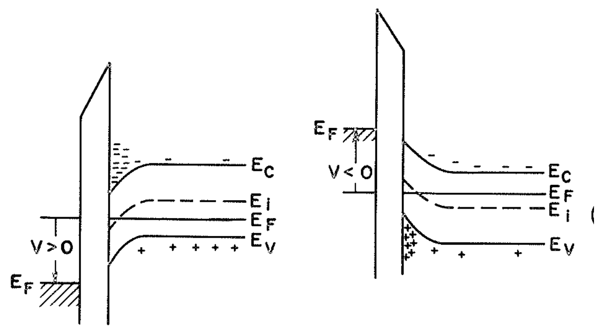
Reverse bias ( ) :



Forward bias ( ) :



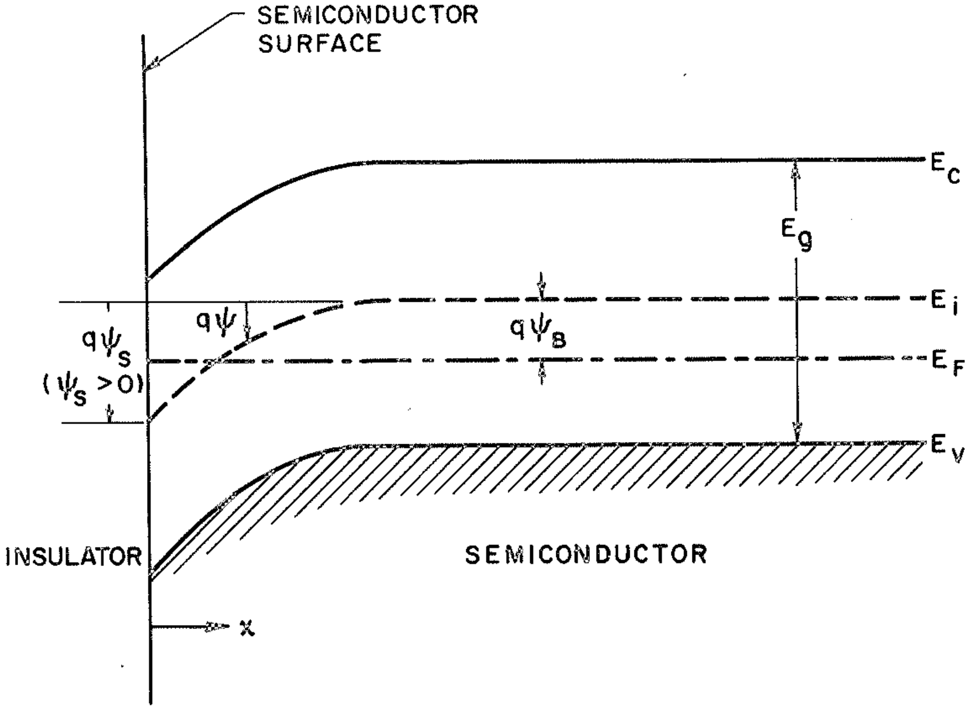
Forward bias ( ) :



* S. M. Sze, *Physics of Semiconductor Devices* (Wiley, New York, 2006).

Surface Space-Charge

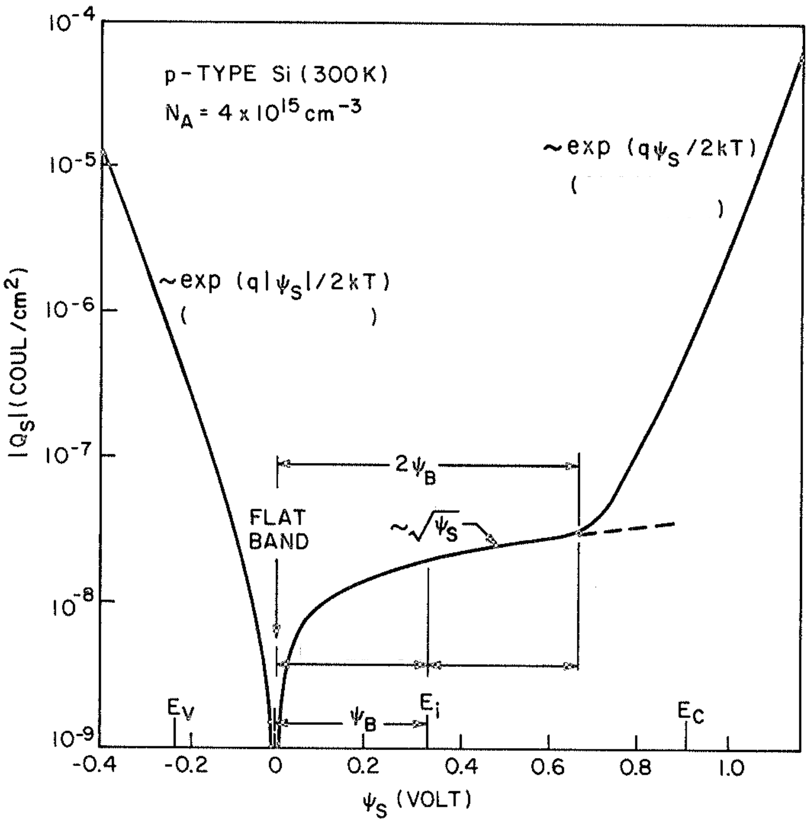
p-type semiconductor :



* S. M. Sze, *Physics of Semiconductor Devices* (Wiley, New York, 2006).

Space-Charge Variation

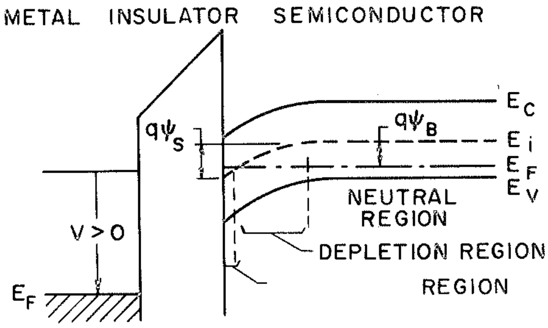
With different surface potentials Ψ_S :



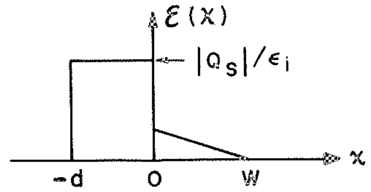
* S. M. Sze, *Physics of Semiconductor Devices* (Wiley, New York, 2006).

Charge Distributions

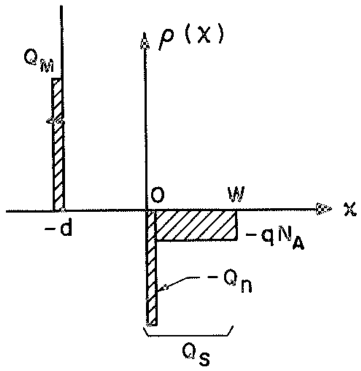
Band diagram of a metal oxide semiconductor junction under an inversion condition :



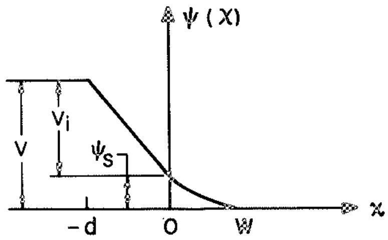
Electric field distributions :



Charge distributions :



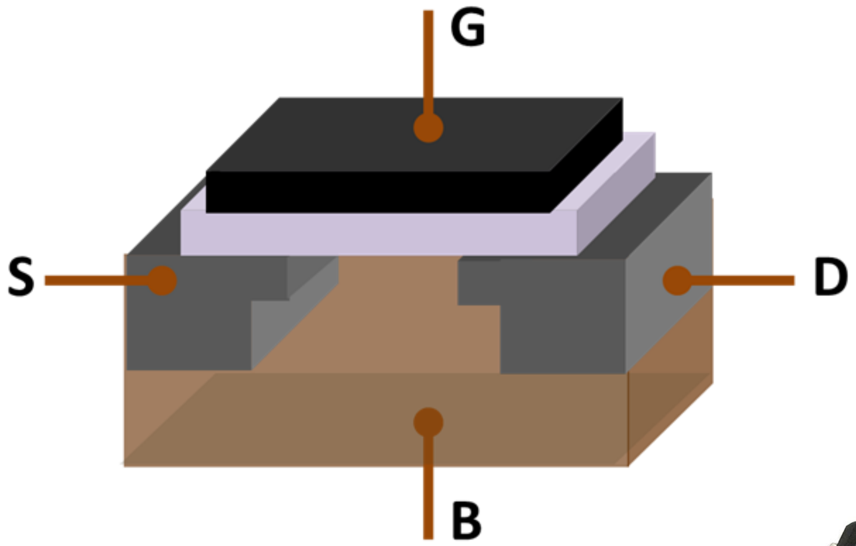
Potential distributions :

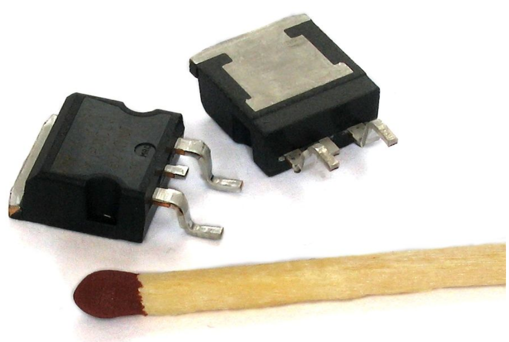


* S. M. Sze, *Physics of Semiconductor Devices* (Wiley, New York, 2006).

MOS Field Effect Transistor (FET)

One of the most popular transistors for amplification and switching :

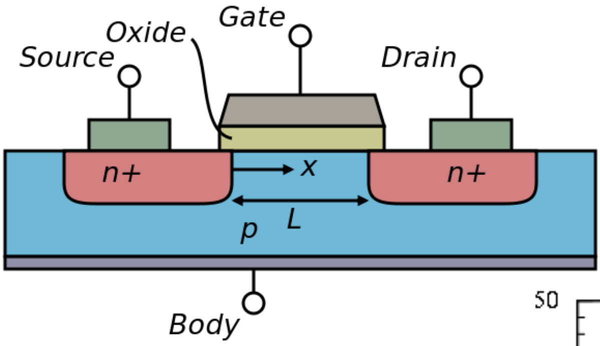


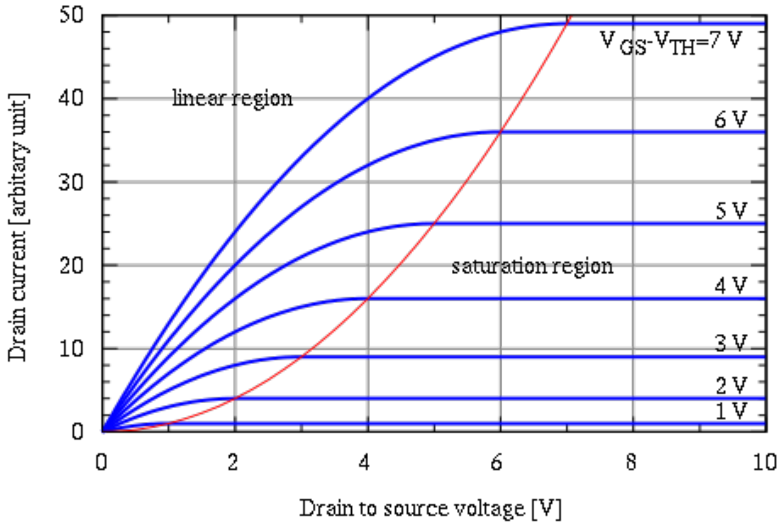


* http://www.wikipedia.org/

MOS FET Operation

Current-Voltage characteristics :





* http://www.wikipedia.org/

MOS FET Operation

Gate functionality :

* https://www.youtube.com/watch?v=DquJSQasWG0