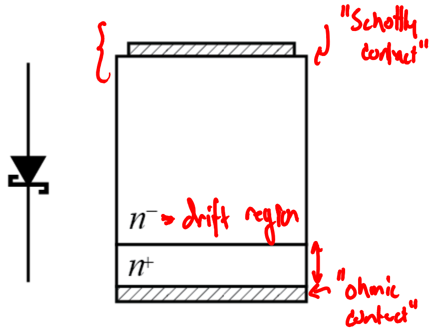
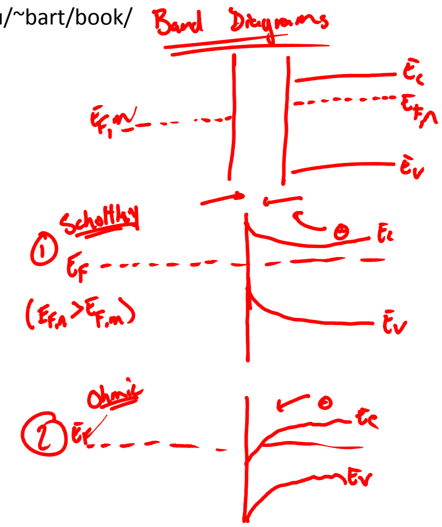
Semiconductor Electrostatics

Chapter 3.3

→ http://ecee.colorado.edu/~bart/book/





- **The parameter ϕm is the metal work function (measured in volts),**
- **ϕs is the semiconductor work function,**
- **X is known as the electron affinity.**

Table 9.1 | Work functions of some elements

Element	Work function, ϕ_m
Ag, silver	4.26
Al, aluminum	4.28
Au, gold	5.1
Cr, chromium	4.5
Mo, molybdenum	4.6
Ni, nickel	5.15
Pd, palladium	5.12
Pt, platinum	5.65
Ti, titanium	4.33
W, tungsten	4.55

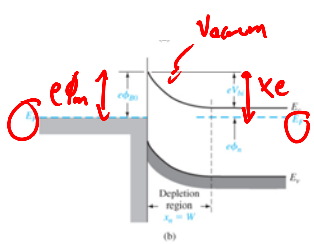


Figure 9.1 | (a) Energy-band diagram of a metal and semiconductor before contact; (b) ideal energy-band diagram of a metal–n-semiconductor junction for $\phi_m > \phi_s$.

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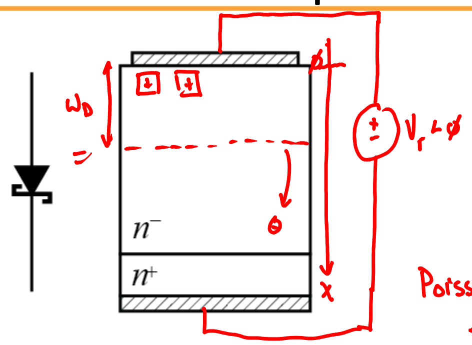
Table 9.2 | Electron affinity of some semiconductors

Element	Electron affinity, χ
Ge, germanium	4.13
Si, silicon	4.01
GaAs, gallium arsenide	4.07
AlAs, aluminum arsenide	3.5

Depletion Region



Goal: Determine how
- V_{BV}
- r_{on}
- C_d

depend on structure & their interdependence

Poisson's Equation:

$$\nabla^2 \psi = \frac{-\rho_f}{\varepsilon}$$

ρ_f = charge density

$\varepsilon = \varepsilon_0 \varepsilon_r$ permittivity of material

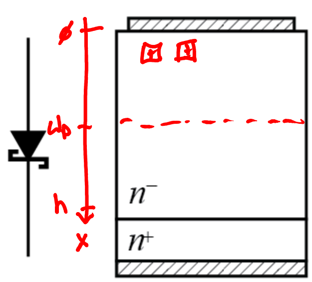
Laplace operator

electric potential

Assumptions:
(1) Uniform in y & z
(2) Uniform doping throughout drift region
n_D $\left(\frac{\#}{\text{length}}\right)$

$$Q_{tot} = q n_D W_D$$

Electric Field



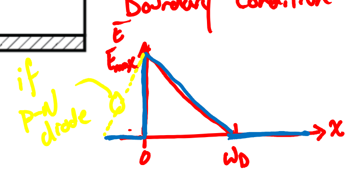
Poisson's Equation in 1-D

$$\frac{\partial^2 V}{\partial x^2} = \frac{-q n_D}{\varepsilon}$$

$$E = \frac{\partial V}{\partial x} = \int_0^x \frac{-q n_D}{\varepsilon} dx = \frac{-q n_D}{\varepsilon} x + E_0$$

Boundary condition $E(x \geq W_D) = 0$

$$E = \frac{-q n_D}{\varepsilon}(x - W_D)$$

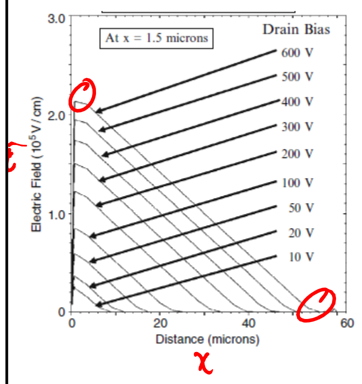


for valid operation
(1) $E_{max} < E_{crit}$
(2) $W_D < h$

$$E_{max} = E(0) = \frac{q n_D W_D}{\varepsilon}$$

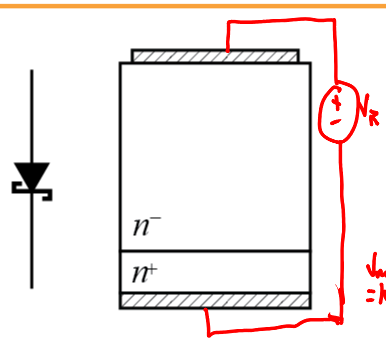
$$W_D = \frac{\varepsilon E_{max}}{q n_D}$$

Electric Field Measurement



Baliga, B J, "Advanced Power MOSFET Concepts"

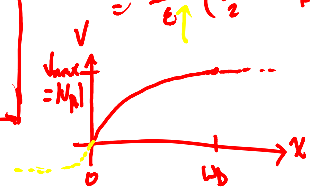
Electric Potential



$$E = \frac{dV}{dx} = -\frac{-qn_D}{\varepsilon}(x - W_D)$$

$$V = \int_0^x \frac{-qn_D}{\varepsilon}(x - W_D)\,dx$$

$$= \frac{-qn_D}{\varepsilon}\left(\frac{x^2}{2} - W_D x\right) + \cancel{V_0} \to \emptyset$$



$$|V_R| = \frac{qn_D}{\varepsilon}\frac{W_D^2}{2}$$

$$W_D = \sqrt{\frac{2\varepsilon|V_R|}{qn_D}}$$

to block $V_{BV} = |V_R|$

$$\boxed{h > \sqrt{\frac{2\varepsilon V_{BV}}{qn_D}}}$$

$$E_{max} = \frac{qn_D}{\varepsilon}\sqrt{\frac{2\varepsilon V_{BV}}{qn_D}} = \boxed{\sqrt{\frac{2qn_D V_{BV}}{\varepsilon}} \leq E_{crit}}$$