# Recitation #7

ENEE 313: Introduction to Device Physics

Fall, 2018

## 1 Week Notes Summary

This week notes include fundamentals of junctions and metal-semiconductor junctions

1. Built-in potential: it occurs at the contact of the two different types of semiconductor.

$$V_0 = \frac{kT}{q} exp(\frac{N_a N_d}{n_i^2}) \tag{1}$$

2. Forward bias: the external potential is applied oppositely to the built-in potential of junction

3. Reverse bias: the external potential is applied to the built-in potential of junction in the same direction

4. Width of depletion region:

$$W(V) = \sqrt{\frac{2\epsilon V_0 - V}{q}(\frac{1}{N_a} + \frac{1}{N_d})} \tag{2}$$

5. Capacitance of diode:

$$C(V) = \frac{\epsilon A}{W(V)} \tag{3}$$

where $A$ is the cross section

6. Schottky barrier: it arises in metal-semiconductor junctions. For n type, $\Phi_m < \Phi_s$; for p type, $\Phi_m > \Phi_s$, where $\Phi_m$ and $\Phi_s$ are the work function of the metal and the semiconductor, respectively.

Summary for the first mid-term exam,

1. Miller indices for crystal structure: how to calculate for a specific plane

2. Understand the logic of unit operations of the fabrication process

3. Understand symmetry, symmetric group, representation of symmetry for crystal
4. Understand the difference of simple cubic, body-centered cubic, face-centered cubic and know how to calculate, e.g., number of atoms per cube, volume density, and packing fraction, etc.
5. Understand the concept of band structure of semiconductors
6. Know what is doping efficiency and how to calculate it
7. Understand two mechanisms of current and how to calculate under certain conditions
8. Study Druid model
9. Study metal-semiconductor junctions:
   (a) Schottky diode: $\phi_m > \phi_s$ for n-type, $\phi_m < \phi_s$ for p-type
   (b) Ohmic diode: $\phi_m < \phi_s$ for n-type, $\phi_m > \phi_s$ for p-type
   (c) built-in potential: $V_0 = |\phi_m - \phi_s|$
   (d) length of the depletion region
   (e) capacitance of the diode.

**Exercise 1.** Built-in potential, prob4.5 from S&B
An intrinsic Si sample is doped with donors from one side such that $N_d = N_0 exp(-ax)$. Find an expression for the built-in electric field at equilibrium over the range for which $N_d >> n_i$ and evaluate the field when $a = 1\mu m^{-1}$

*Solution.* We know

$$J_n = q\mu_n n E(x) + qD_n \frac{dn}{dx} = 0 \tag{4}$$

$$\text{Thus, } E(x) = -\frac{D_n}{\mu_n}\frac{1}{n}\frac{dn}{dx} \tag{5}$$

By the Einstein relationship, $\frac{D_n}{\mu_n} = \frac{kT}{q}$, and $n \approx N_d$ since $N_d >> n_i$, we have

$$\frac{dn}{dx} = -aN_0 exp(-ax) = -an \tag{6}$$

Thus,

$$E(x) = a\frac{kT}{q}\frac{N_0 exp(-ax)}{n} = a\frac{kT}{q} \tag{7}$$

□