**ECEN 4303 Digital Integrated Circuit**

**Chapter 1: Semiconductors, Junctions, and MOSFET Overview**

* Intrinsic Semiconductors
  + Energy band,
    - Energy band gap,
      * of silicon at is
  + Intrinsic Carrier Concentration,
    - at
* Extrinsic Semiconductors
  + Free Electron
    - * when
      * when
* Equilibrium in the Absence of Electric Field
  + Neutral Semiconductor
    - Fermi potential,
    - Thermal voltage,
* Equilibrium in the Presence of Electric Field
  + , , and will bend accordingly.

* Nonequilibrium; Quasi-Fermi Levels
  + When a voltage source is present,
    - Fermi energy level change
  + Since it is nonequilibrium,
* Relation Between Charge Density, Electric Field, and Potential; Poisson’s Equation
  + - Concentration can be non-zero
    - Effective concentration, or , which is bigger.
  + Rate of change of electric field,
    - * Permittivity, , where *k* is dielectric constant
* Conduction
  + Transit time,
    - Assume that each electron take the same amount of time to travel the length of a material.
    - Low-field transit time
  + Drift,
    - , where *a* is the length of semiconductor.
    - Electric field, *E* within semiconductor is proportional to velocity drift.
      * Only use when and
  + Total electron charge, *Q*
    - , is the volume of semiconductor.
  + External electric field
    - , where *a* is the length of semiconductor
  + Conductance
  + Conductivity
  + Resistance
  + Sheet resistance
* Diffusion
  + Diffusion constant, *D*
  + Diffusion current
  + Concentration gradient
    - Electron concentration changes at every position within semiconductor.
      * Electron charges per unit area,
        + *x* is the position within length *a*.
    - Diffusion current can be written as
      * Since vs *x* graph is a straight line,
    - Diffusion current can be written as
    - Time transit
      * (when )
* Total Current

Total current due to electrons , caused by both drift and diffusion, can be written as

We know changes when changes,

From , after differentiation we can get

Substitute equations into

In a similar manner, the total hole current can be expressed in terms of drift and diffusion components by

After proceeding similar procedures in electron current, we get

In thermal equilibrium, and is constant. It is clear that thermal equilibrium implies zero total electron current and zero total hole current.

* Contact potential
  + Given two different material and that connected with no external bias.
  + Contact potential,
  + Work function potential,
  + Several materials in series
    - Common voltmeter cannot measure the difference, even the voltmeter is ideal (does not draw any current).
* The *pn* Junction
  + Zero bias
    - No external bias.
    - Depletion region (depletion approximation)
      * Built-in potential,
  + Forward bias
    - Built-in potential,
    - Current,
  + Reverse bias
    - Built-in potential,
    - Depletion region
      * On *n* side,   
        On *p* side,   
        For overall charges neutrality,   
        Therefore,
      * Two sided step junction
        + Electric field in depletion region
        + Potential across depletion region

* + - * + Total width of depletion region
      * One sided step junction
        + For step junction

Because , and

Thus,

* + - * + For step junction

Because , and

Thus,

* + - Small-signal Capacitance (One sided step junction)
      * after differentiation
      * Small-signal capacitance per unit area
        + , where
        + For complex doping transition,
* MOS Transistor
  + **Width** and **Length** are the key in MOS transistor.