CHE323/CHE384
Chemical Processes for Micro- and Nanofabrication

Lecture 6
P-N Junctions

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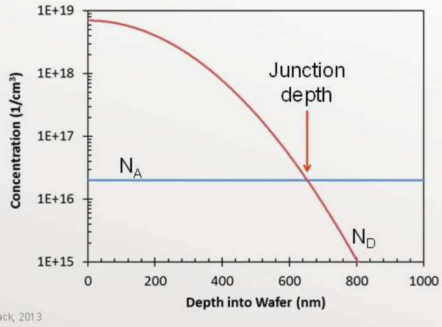
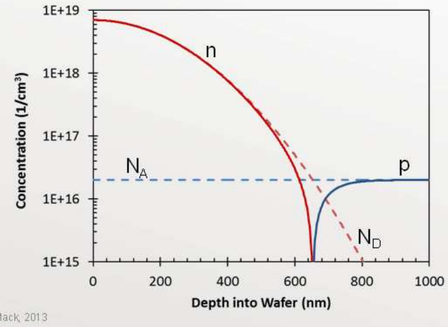
Forming a p-n Junction

- Consider a wafer doped uniformly p-type (or with a p-type well)
- N-type dopant is introduced at the top and diffuses in, forming a Gaussian dopant profile with depth into the wafer (peak concentration at the top)

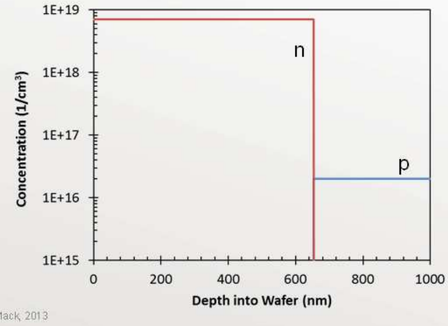
Forming a p-n Junction



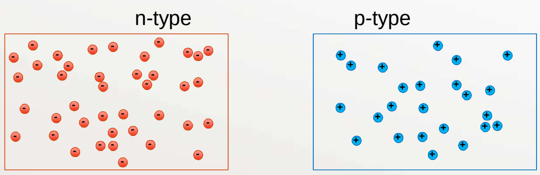
Forming a p-n Junction



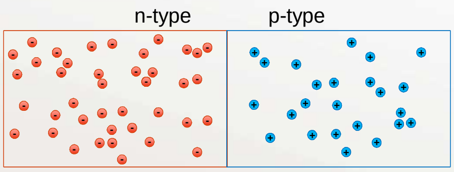
Idealized p-n Junction



P-N Junction Behavior

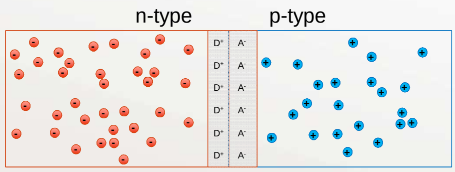


P-N Junction Behavior



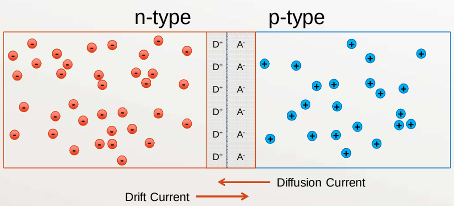
1. Diffusion of holes from p-type material into n-type material, followed by recombination
2. Diffusion of electrons from n-type material into p-type material, followed by recombination
3. Formation of a “depletion region” at the junction

Depletion Region



1. Depletion region has virtually no mobile charge carriers
2. Ionized dopants remain and are fixed charged – thus depletion region is also called the space charge region
3. A built-in voltage is created across the p-n junction

Steady State: Diffusion = Drift



1. Built-in voltage creates a drift current: electric field pushes electrons/holes in the opposite direction as diffusion
2. The depletion width and built-in voltage grow until a steady state is reached, where diffusion current equals drift current

P-N Junction Math

- We can write equations for drift current (Ohm’s Law) and diffusion current (Fick’s Law)
- At steady state, we can solve for the built-in voltage (V_0) and the depletion width (W)

$$V_0 = \frac{kT}{q}\ln\left(\frac{N_A N_D}{n_i^2}\right) \qquad \text{At } T = 300\text{ K,} \quad \frac{kT}{q} = 25\, mV$$

$$W = \sqrt{\frac{2\varepsilon_{Si} V_0}{q}\left(\frac{1}{N_A} + \frac{1}{N_D}\right)} \qquad \varepsilon_{Si} = 11.7\varepsilon_0, \quad \varepsilon_0 = 8.8542\times 10^{-12}\ C/V\,m$$

Lecture 6: What have we learned?

- How are p-n junctions typically formed?
- What is drift current? Diffusion current?
- Define “depletion region” (space charge region)
- Why does a p-n junction form a depletion region?
- Why does a p-n junction have a built-in voltage?
- Be able to calculate the p-n junction built-in voltage and depletion width

