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| **AL-Mustaqbal University College**  **Department of Medical Physics**  **The Second Stage**  **Semiconductors**  **Dr. Rusul Abdul Ameer** | **شعار المستقبل جديد فقط.jpg** | **كلية المستقبل الجامعة**  **قسم الفيزياء الطبية**  **المرحلة الثانية**  **أشباه موصلات** |

**Lecture .3**

# Equilibrium Carrier Concentration

Semiconductors have majority carriers and minority carriers. The charge carriers more abundant are the majority carriers; while the minority carriers are the charge carriers less abundant. Doping can increase the equilibrium carrier concentration. Equilibrium carrier concentration is the total number of carriers in the conduction and valence bands. A constant is the product of the minority and majority charge carriers. Equilibrium carrier concentration is the number of carriers in the conduction and valence band with no externally applied bias. The equilibrium carrier concentration for majority carriers is equal to the intrinsic carrier concentration plus the free carriers number added by doping the semiconductor. In most cases, doping of the semiconductor is several orders of magnitude greater than the intrinsic carrier concentration, so that the majority carriers number is nearly equal to the doping.

**Thermal Equilibrium**

An important equation for determining the carrier concentrations in a material is defined by the Law of Mass Action, we must first understand the description of thermal equilibrium before further discussing. Thermal equilibrium is a relationship between the concentrations of charge carriers at a certain temperature. Described differently, at a given temperature, there is an equilibrium between both generation - formation of pairs of electron-hole as a result of thermal excitation or photon absorption - and recombination which is the natural destruction of pairs that happen when electrons from conduction band fall back again into valence band. In the intrinsic case, the bound electrons number is much higher than the free electrons number, thus the charge carriers generation is independent of the electron-hole pairs number which have been already formed. Though, as soon as generation occurs, recombination happens and it depends on the charge carriers concentration in the material. In fact recombination is directly proportional to the charge carriers number.

**Law of Mass action Equations**

The product of the majority and minority carrier concentration at equilibrium is a constant, which is mathematically expressed by the Law of Mass Action.

**nopo = ni2**

where **ni**: is the intrinsic carrier concentration

**n0**: electron equilibrium carrier concentrations.

**p0**: the hole equilibrium carrier concentrations.

By using the Law of Mass Action above, the majority and minority carrier concentrations can be expressed in the following equations:

**n-type: no = ND, po = ni2 / ND**

**p-type: po = NA, no = ni2 / NA**

where **ND**: donor atoms concentration , **NA** : acceptor atoms concentration.

The equations above show that the minority carriers number decrease with the increase of the doping level. As an example, in the n-type material, some of the extra electrons which are added by doping the material will occupy the empty spots (the holes) which are in the valence band, thus lowering the number of holes.

# Summery

1. Semiconductors contain majority and minority carriers. The more abundant charge carriers are the majority carriers; the less abundant are the minority carriers.
2. The equilibrium carrier concentration can be increased through doping.
3. The total number of carriers in the conduction and valence band is called the equilibrium carrier concentration.
4. The product of minority and majority charge carriers is a constant.

**What is carrier drift?**

When an electric field is applied across the semiconductors, the carriers drift through the semiconductors. The carriers move with a constant [drift velocity](https://byjus.com/physics/drift-velocity/). The drift current in a semiconductor is caused due to the carrier drift.













