Semiconductor fundamentals: energy bands and Fermi-level, carrier concentrations

Problem - 1

Sketch the energy band diagram of a moderately and uniformly doped n-type silicon, clearly showing the location of the phosphorus impurity level, Fermi-level and intrinsic level at room temperature. On the diagram, mark the energy differences (E_c - E_v) and (E_f – E_i) for a doping level of 1×10^{15} cm^{-3}, assuming intrinsic concentration of 1×10^{10} cm^{-3} at room temperature.

Problem - 2

Sketch the energy band diagram (E versus x) including quasi-Fermi levels of electrons and holes of a moderately doped p type semiconductor under uniform electric field in x-direction.

Problem - 3

The position of the Fermi level for a silicon sample is at $E_F = E_i - 0.35$ eV at 300 K. The sample is uniformly illuminated, thereby generating an additional 10^{18} electron-hole pairs per cm^3 per second. If the minority carrier lifetime in this sample is 1 μs, what are the positions of the quasi Fermi levels at 300 K for this illuminated sample?

Problem - 4

Answer with reason.

As the temperature is increased from 0 K, the carrier mobility in a moderately doped semiconductor shows

A) a decrease followed by an increase

B) an increase followed by decrease

C) a monotonic increase

D) a monotonic decrease

Problem - 5

Answer with reason.

A silicon sample A is doped with 10^{17} phosphorus atoms/cm^3 and sample B is doped with 10^{17} boron atoms/cm^3. Which of the two samples has a higher resistivity?

Problem - 6

A phosphorus doped (10^{17} atoms/cm^3) Si sample has resistivity of 0.1Ω-cm. Calculate the doping concentration of boron atoms if it is additionally used to reduce the resistivity of this doped sample by 50%. Assume that due to this additional boron doping electron mobility is not reduced further and in the final sample it is three times of the hole mobility.

Problem - 7

A silicon sample is doped with 10^{16} phosphorus atoms/cm^3. Assuming complete ionisation, find out the resistivity of the sample at 300K considering the electron mobility in silicon to be 1350 cm^2/V-sec and the hole mobility 450 cm^2/V-sec.

Problem - 8

A current of 1 mA flows through a bar of uniformly doped n-type silicon with a cross sectional area of 2 mm x 2 mm and a length of 1 cm when it is connected to a 3 V battery at 300K. Calculate the electron and hole concentrations in the bar assuming electron mobility to be 1350 cm^2/V-sec.