SPICE Problem Set#3
Application of p-n Junction Diode

At 300 K assume

E_g=1.12 eV, N_C= 2.8x10^{19}/cm^3, N_V=10^{19}/cm^3, μ_n=1500 cm^2/V-s, μ_p= 500 cm^2/V-s, $\varepsilon_{r,Si}$=11.9, τ_n=τ_p=1 μs for Si,

E_g=0.66 eV, N_C= 1x10^{19}/cm^3, N_V=6x10^{18}/cm^3, μ_n=3900 cm^2/V-s, μ_p= 1900 cm^2/V-s, $\varepsilon_{r,Ge}$=16, τ_n=τ_p=1 μs for Ge,

E_g=1.42 eV, N_C= 4.7x10^{17}/cm^3, N_V=7x10^{18}/cm^3, μ_n=8500 cm^2/V-s, μ_p= 400 cm^2/V-s, $\varepsilon_{r,GaAs}$=13.1, τ_n=τ_p=0.1 μs for GaAs,

and kT=0.0259 eV, ε_0=8.85x10^{-14} F/cm.

Q1. Implement a Si n^+-p junction diode (*p-sided acceptor doping as N_A=10^{16} /cm^3 and n-sided donor doping as N_D=10^{18} /cm^3*) with cross-sectional area A=10 cm^2 being used for a solar cell where a photo-generated current source is connected in parallel with the ideal diode current in reverse direction. The diode has a very thin n+ region whereas the p-region is 10 μm thick. Assume that there is a resistance R in series with the cell and plot the I-V characteristics when R is varying from 1 mΩ to 1 Ω. Assume photo-generation rate as g_{op}= 10^{18}/cm^3-s and depletion width is negligible compared to the diffusion lengths of carriers.

Q2. Implement a p^+-i-n^+ detector (*p-sided acceptor doping as N_A=10^{19} /cm^3 and n-sided donor doping as N_D=10^{19} /cm^3*) with cross-sectional area A=10 μm^2 that is used to detect incoming light intensity with different i-layer width. Plot its I-V characteristics for a given g_{op} = 10^{18}/cm^3-s with i-layer thicknesses varying from 1 μm to 10 μm to see the influence of the i-layer thickness on the detected current. For a given i-layer thickness of 2 μm, plot I-V characteristics for different g_{op} varying from 10^{16}/cm^3-s to 10^{19}/cm^3-s.

Q3. A p^+n diode is connected in series with an external resistor R=1 kΩ and the whole circuit is put across a time dependent voltage source that is switched from +5 V to -5 V at t=0 sec. One wishes to see the time dependent current through the diode. Implement the diode and resistor network and plot the time-dependent current. Find out the storage delay times if the diode is made of (a) Si and (b) GaAs. Check if the storage delay time is matching with the calculated ones.

Q4. A Si p^+n diode is connected in series with an external resistor R=1 kΩ and the whole circuit is put across a time dependent voltage source that is switched from +5 V to 0 V at t=0 sec. One wishes to see the time dependent current through the diode. Implement the diode and resistor network and plot the time-dependent current.

Q5. A Si p^+n diode is forward biased yielding a current of 5 mA. At t=0 sec the diode is open-circuited. One wishes to see the time dependent voltage across the diode. Implement the diode under such excitation and plot the time-dependent voltage across it. Check if the time-dependent voltage is matching with the calculated ones.

Q6. Design an envelope detector circuit using a diode in series with a parallel R-C network (across which one has to take the output) for amplitude modulated signal detection. Use suitable values of R and C to detect the signal m(t) which is modulated as (A+m(t))cos(ω_ct). The modulated signal is fed as input to the detector and the output of the detector is expected to be m(t) which may be assumed as a low frequency sine wave. Note that the frequency of the signal m(t) is significantly lower than the carrier frequency f_c=ω_c/2π.