BIRLA INSTITUTE OF TECHNOLOGY AND SCIENCE, PILANI

MID-SEMESTER EXAMINATION

Semester I: 2022-2023

Open Book

MEL G631: Physics and Modelling of Microelectronic Devices

Date: **04/11/2022** Maximum Marks: **60** Maximum Time: **90 minutes**

Given (Use, if not specified in the questions):
$q=1.6\times10^{-19}$ C, $k=1.38\times10^{-23}$ $m^2kgs^{-2}k^{-1}$, T=300 K, kT/q=0.026 V, $\varepsilon_0=8.85\times10^{-14}$ F/cm
Si: $\varepsilon_r=11.8$, $n_i=1.45\times10^{10}$ cm^{-3}, $E_g=1.12$ eV, $\mu_n=1200$ cm^2/V-s, μ_p(Si)=480 cm^2/V-s, $q\chi=4.05$ eV, $N_C=2.8\times10^{19}$ cm^{-3}, $N_V=1.04\times10^{19}$ cm^{-3}.
Ge: $\varepsilon_r=16.2$, $n_i=2.4\times10^{13}$ cm^{-3}, $E_g=0.66$ eV, $q\chi=4.13$ eV
GaAs: $\varepsilon_r=12.88$, $n_i=1.8\times10^6$ cm^{-3}, $E_g=1.42$ eV, $q\chi=4.07$ eV
Au: φ_M = 4.75 eV

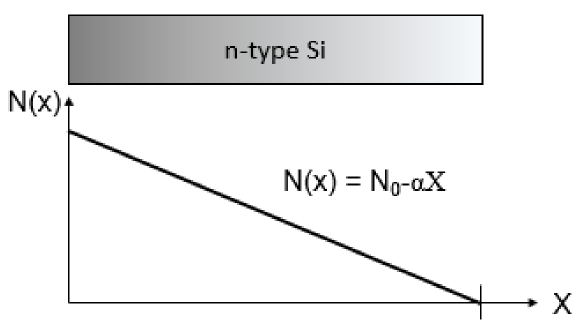
Q1.

(a) Consider an Au/*n*-Si Schottky Junction under thermal equilibrium. Find the electron and hole concentrations in *n*-Si exactly at the interface. Also, find the potential at the interface. [5]

(b) An Au/*n*-Si ($N_d=10^{16}$ cm^{-3}) Schottky junction is operated under 5 V reverse bias. How many fold the reverse current will increase due to the Schottky barrier lowering? [5]

(c) A *n*-channel JFET having t = 1.5 μm, $N_a = 5\times10^{17}$ cm^{-3}, $N_d = 5\times10^{15}$ cm^{-3}, operating at 3 V gate voltage. Find the particular V_{DS} voltage beyond that the current become saturate. [5]

Q2. The following *n*-type semiconductor is showing non-uniform doping profile as $N(X)= N_0-\alpha X$. 'α' is a constant.



Under equilibrium,

(a) Derive the expression of electric field E(X), $J_{n(diff)}$ and $J_{n(drift)}$. [6]
(b) Draw the qualitative profile of E(X), $J_{n(diff)}$, $J_{n(drift)}$, and $J_{n(total)}$ as a function of X. [4]
(c) Show the direction of e- flow, E(X), $J_{n(diff)}$, $J_{n(drift)}$, and $J_{n(total)}$ on the given figure. [2]

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Q3. Draw an energy band diagram of a MS junction under thermal equilibrium where metal have the work function of 4.15 eV and the semiconductor (Si) have the donor doping of 2×10^{15} cm^{-3}.

(a) What potential will build up at the junction. [2]

(b) What is the electron concentration in Si exactly at the MS interface? [3]

(c) Sketch and label energy band diagram of the MS junction. [3]

(d) Sketch and label the electric filed distribution for the MS junction. [3]

(e) Sketch and label the potential distribution for the MS junction. [2]

Q4. Sketch and label energy band diagram across a junction of A and B material at room temperature. Material A is Ge doped with 2.4×10^{17} cm^{-3} donor and material B is GaAs is doped with 1.8×10^{10} cm^{-3} acceptor impurity. [7]

(a) Find built in potential (φ_i) across the junction. Also find individual built in potential of A (φ_{iA}) and B (φ_{iB}) side. [3]

(b) Find depletion depth (X_d) across the junction. Also find individual depletion depth of A (X_{dA}) and B (X_{dB}) side. [2]

(c) Find the capacitance across the junction. [2]

Q5. The general expression of maximum electric field of a *pn* junction has been given below.

$$|E_{max}| = \frac{q}{\epsilon_s}\left[\frac{2\epsilon_s(\varphi_i - V)}{q}\left(\frac{N_a N_d}{N_a + N_d}\right)\right]^{1/2}$$

(a) Derive an expression of break down voltage (V_{BR}) for a p^+n junction as a function of 'break down critical electric field ($E_{Critical}$)'. Use the above electric field expression to derive V_{BR}. [3]

(b) Calculate the break down voltage (V_{BR}) if $N_a=5\times10^{17}$ cm^{-3} and $N_d=10^{15}$ cm^{-3}. Consider $E_{Critical}$ = 80 kV/cm. [3]
