BITS Pilani
Dubai Campus

I Semester 2012-2013
II YEAR EEE/ECE/EIE
COMPREHENSIVE EXAMINATION

Course No. ECE F214 / EEE F214 /INSTR F214 — **Course Title: Electronic Devices**
Date: 31-12- 2012 — **Max.Marks:** 80
Weightage: 40% — **Duration:** 3 Hours

Important Notes

- *Answer all the questions.*
- *Draw neat sketches wherever necessary.*
- *Make suitable assumptions if required and clearly state them*
- *Write PART A and PART B in separate answer book*

PART A

1 Determine the volume density of germanium atoms in a germanium semiconductor. The lattice constant of germanium is 5.65 Å. Calculate its density, given that the atomic weight is 72.6 g/mol and the Avogadro number is 6.023×10^{23} atoms/mol. 5M

2 The position of an electron is determined to within 1 Å. What is the minimum uncertainty in its momentum? 5M

3 Assume that Si has dopant concentration of $N_D = 1 \times 10^{13}$ cm^{-3} and $N_A = 2.5 \times 10^{13}$ cm^{-3} at T = 300°K. For Si, $n_i = 1.5 \times 10^{10}$ cm^{-3} 15M

a) Is this material n – type or p – type?
b) Calculate n_o and p_o.
c) Where is E_f relative to E_i? Sketch the energy band diagram.

4 In a very long p–type Si bar with cross–sectional area = 0.5 cm^2 and Na= 10^{17} cm^{-3}, we inject holes such that the steady state excess hole concentration is 5×10^{16} cm^{-3} at x = 0. Assume $\mu_p = 500$ cm^2/V-s and $\tau_p = 10^{-10}$ s. 15M

a) What is the steady state separation between F_p and E_c at x = 1000 Å?
b) What is the hole current there?
c) How much is the excess stored hole charge?

PART A

1. Determine the volume density of germanium atoms in a germanium semiconductor. The lattice constant of germanium is 5.65 Å. Calculate its density, given that the atomic weight is 72.6 g/mol and the Avogadro number is 6.023 x 10^{23} atoms/mol.

[5 M]

Solution

$$\frac{8}{a^3} = \frac{8}{(5.66\times10^{-8})^3} = \boldsymbol{4.41\times10^{22} atoms/cm^3}$$

$$density = \frac{4.41\times10^{22}\times72.6}{6.023\times10^{23}} = \mathbf{5.32 g/cm^3}$$

2. The position of an electron is determined to within 1 Å. What is the minimum uncertainty in its momentum?

[5 M]

Solution

$$\Delta p_x \approx \frac{\hbar}{\Delta x} = \frac{6.63\times10^{-34}}{2\times3.14\times10^{-10}} = 1.06\times10^{-34}\ kg.m/s$$

3. Assume that Si has dopant concentration of N_D = 1 x 10^{13} cm^{-3} and N_A = 2.5 x 10^{13} cm^{-3} at T = 300°K. For Si, n_i = 1.5 x 10^{10} cm^{-3}
   a) Is this material n – type or p – type?
   b) Calculate n_o and p_o.
   c) Where is E_f relative to E_i? Sketch the energy band diagram.

[5+5+5 M]

Solution

a) $N_A >> N_D$, therefore, **p – type material**

b) Charge neutrality requires $n_0 + N_A^- = p_0 + N_D^+$ and $n_0 p_0 = n_i^2$

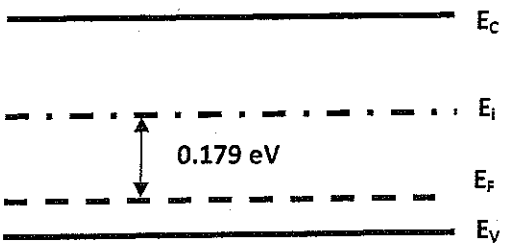
Therefore $p_0 = \frac{-(N_D-N_A)\pm\sqrt{(N_D-N_A)^2+4n_i^2}}{2}$

$(N_D - N_A)$ = (1x10^{13}) – (2.5x10^{13}) = 1.5x10^{13}

$\mathbf{p_0 = 1.5x10^{13}\ cm^{-3}}$

$\mathbf{n_o = 1.5x10^{7}\ cm^{-3}}$

c) $E_i - E_F = kTln\frac{p_0}{n_i} = 0.0259ln\frac{1.5\times10^{13}}{1.5\times10^{10}}$ = **0.179eV**



4. In a very long p–type Si bar with cross–sectional area = 0.5 cm^2 and Na= 10^{17} cm^{-3}, we inject holes such that the steady state excess hole concentration is 5 x 10^{16} cm^{-3} at x = 0. Assume μ_p = 500 cm^2/V-s and τ_p = 10^{-10} s.
a) What is the steady state separation between F_p and E_c at x = 1000 Å?
b) What is the hole current there?
c) How much is the excess stored hole charge? [5+5+5 M]

Solution

$$D_p = \frac{kT}{q}\mu_p = 0.0259\times500 = 12.95\,\text{cm}^2/\text{s}$$

$$L_p = \sqrt{D_p\tau_p} = \sqrt{12.95\times10^{-10}} = 3.6\times10^{-5}\,\text{cm}$$

$$p = p_0 + \Delta p e^{-\frac{x}{L_p}} = 10^{17} + 5\times10^{16} e^{-\frac{10^{-5}}{3.6\times10^{-5}}}$$

$$= 1.379\times10^{17} = n_i e^{(E_i-F_p)/kT} = (1.5\times10^{10}\,\text{cm}^{-3}) e^{(E_i-F_p)/kT}$$

$$E_i - F_p = \left(\ln\frac{1.379\times10^{17}}{1.5\times10^{10}}\right)\cdot 0.0259 = 0.415\text{eV}$$

$$E_c - F_p = 1.1/2\text{eV} + 0.415\text{eV} = \mathbf{0.965eV}$$

Hole current :

$$I_p = -qAD_p\frac{dp}{dx} = qA\frac{D_p}{L_p}(\Delta p)e^{-\frac{x}{L_p}}$$

$$= 1.6\times10^{-19}\times0.5\times\frac{12.95}{3.6\times10^{-5}}\times5\times10^{16} e^{-\frac{10^{-5}}{3.6\times10^{-5}}}$$

$$= \mathbf{1.09\times10^{3}\,A}$$

$$Q_p = qA(\Delta p)L_p$$

$$= 1.6\times10^{-19}(0.5)(5\times10^{16})(3.6\times10^{-5})$$

$$= \mathbf{1.44\times10^{-7}\,C}$$

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I Semester 2012-2013
II YEAR EEE/ECE/EIE
Test 2 (OPEN BOOK)

Course No. ECE F214 / EEE F214 /INSTR F214
Course Title: Electronic Devices
Date: 18-11-2012
Max.Marks: 40
Weightage: 20%
Duration: 50 min

Important Notes

- *Answer all the questions.*
- *Draw neat sketches wherever necessary.*
- *Make suitable assumptions if required and clearly state them*

Q.1 In the Haynes – Shockley experiment calculate the hole lifetime τ_p in an n-type sample. Assume the peak voltage of the pulse displayed on the oscilloscope screen is proportional to the hole concentration under the collector terminal at time t_d, and that displayed pulse can be approximated as a Gaussian, as in 10M

$$\delta p(x,t) = \frac{\Delta p e^{-t/\tau_p}}{\sqrt{4\pi D_p t}} \exp\left(-\frac{x^2}{4D_p t}\right)$$

which decays due to recombination by $\exp(-t/\tau_p)$. The electric field is varied and the following data taken: For $t_d = 200$ s, the peak is 20 mV; for $t_d = 50$ s, the peak is 80 mV. What is τ_p?

Q.2 Calculate the electron and hole densities in an n-type silicon wafer ($N_d = 10^{17}$ cm^{-3}) illuminated uniformly with 10 mW/cm^2 of red light ($E_{ph} = 1.8$ eV). The absorption coefficient of red light in silicon is 10^{-3} cm^{-1}. The minority carrier lifetime is 10 ms. 10M

Q.3 A silicon pn junction at T=300K with zero applied bias has doping concentrations $N_d=5\times10^{16}$ cm^{-3} and $N_a=5\times10^{15}$ cm^{-3}. Determine the penetration of the transition region into n and p type materials, space charge width and maximum value of the electric field. (*Intrinsic concentration* $n_i=1.5\times10^{10}$ *cm*$^{-3}$) 10M

Q.4 An abrupt Si p-n junction has $N_a=10^{17}$ cm^{-3}, on the p side and $N_d=10^{16}$ cm^{-3} on the n side. At 300K, 10M

a) Calculate the Fermi levels, and draw an equilibrium band diagram and find V_0.

b) Compute the V_0 from the equation which relates doping concentrations.
(*Intrinsic concentration* $n_i=1.5\times10^{10}$ *cm*$^{-3}$)

1. In the Haynes – Shockley experiment calculate the hole lifetime τ_p in an n-type sample. Assume the peak voltage of the pulse displayed on the oscilloscope screen is proportional to the hole concentration under the collector terminal at time t_d, and that displayed pulse can be approximated as a gaussian, as in

$$\delta p(x,t) = \frac{\Delta p e^{-t/\tau_p}}{\sqrt{4\pi D_p t}} \exp(-\frac{x^2}{4D_p t})$$

which decays due to recombination by $\exp(-t/\tau_p)$. The electric field is varied and the following data taken: For t_d = 200 s, the peak is 20 mV; for t_d = 50 s, the peak is 80 mV. What is τ_p? **[10M]**

Solution

To include recombination, let the peak value vary as $\exp(-t/\tau_p)$

$$\delta p(x,t) = \frac{\Delta p e^{-t/\tau_p}}{\sqrt{4\pi D_p t}} \exp(-\frac{x^2}{4D_p t})$$

At the peak (x=0), V_p = peak $= B\frac{\Delta p e^{-t/\tau_p}}{\sqrt{4\pi D_p t}}$, where B =constant

$$\frac{V_{p1}}{V_{p2}} = \sqrt{\frac{t_2}{t_1}}\frac{e^{-t_1/\tau_p}}{e^{-t_2/\tau_p}} = \sqrt{\frac{t_2}{t_1}}e^{t_2-t_1/\tau_p} \Rightarrow \frac{80}{20} = \sqrt{\frac{200}{50}}\ e^{150/\tau_p}$$

$\therefore\ \tau_p$ = 216.4 µs

2. Calculate the electron and hole densities in an n-type silicon wafer ($N_d = 10^{17}$ cm^{-3}) illuminated uniformly with 10 mW/cm^2 of red light (E_{ph} = 1.8 eV). The absorption coefficient of red light in silicon is 10^{-3} cm^{-1}. The minority carrier lifetime is 10 ms. **[10M]**

Solution

The generation rate of electrons and holes equals:

~~$G_n = G_p = \alpha\frac{P_{opt}}{E_{ph}A} = 10^{-3}\frac{10^{-2}}{1.8\times1.6\times10^{-19}} = 3.5\times10^{13}\ \mathrm{cm}^{-3}\mathrm{s}^{-1}$~~

~~where the photon energy was converted into Joules. The excess carrier densities are then obtained from:~~

~~$\delta n = \delta p = \tau_p G_p = 10\times10^{-6}\times3.5\times10^{13} = 3.5\times10^{8}\ \mathrm{cm}^{-3}\mathrm{s}^{-1}$~~

~~The excess carrier densities are then obtained from: So that the electron and hole densities equal:~~

~~$n = n_o + \delta n = 10^{17} + 3.5\times10^{13} \cong 10^{17}\ \mathrm{cm}^{-3}\mathrm{s}^{-1}$~~

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I Semester 2012-2013
II YEAR EEE/ECE/EIE
Test 1 (Closed Book)

Course No. ECE F214 / EEE F214 /INSTR F214
Course Title: Electronic Devices
Date: 30-09-2012
Max.Marks: 50
Weightage: 25%
Duration: 50 min

Important Notes

- *Answer all the questions.*
- *Draw neat sketches wherever necessary.*
- *Make suitable assumptions if required and clearly state them*
- *Weightage is given for formula and steps written*

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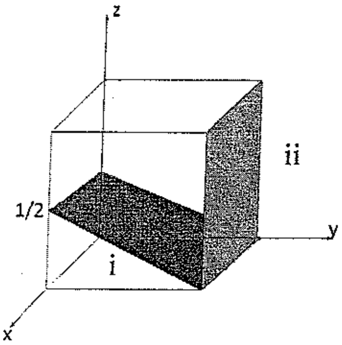
1. Compute the interplanar spacings for the **(110)** and **(221)** sets of planes for aluminum which has an FCC crystal structure and an atomic radius of 0.1431 nm. **[8MARKS]**

2. a) Sketch the $(2\ 4\ \bar{3})$ plane in a cube of lattice constant 0.6 nm.
   b) Find the Miller indices of the planes shown below **[5X2=10MARKS]**



3. a) The lattice constant of GaAs is 5.65 Å, Determine the number of Ga atoms and As atoms per cm^3.
   b) Determine the volume density of germanium atoms in a germanium semiconductor. The lattice constant of germanium is 5.65 Å. **[8 MARKS]**

4. Find the solution of Schrödinger equation for a particle in a 1-D square well of length L, Calculate the expectation value of p for a particle in the state n=1. **[10MARKS]**

5. A Si crystal is to be grown by the Czochralski method, and it is desired that the ingot contain 10^{20} phosphorous atoms/cm^3. **[8MARKS]**

   a) What concentration of P atoms should the melt contain to give this impurity concentration in the crystal during the initial growth? For P in Si, kd=0.4.

   b) If the initial load of Si in the crucible is 5kg, how many grams of P should be added? The automatic weight of P is 31.

   (Given density of silicon atom is 2.33 gm/cm^3)

6. Starting from the raw silicon dioxide, explain the chemical process involved in the generating EGS

   [6MARKS]

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A

I Semester 2012-2013
II YEAR EEE/ECE/EIE
QUIZ 2 (Closed Book)

Course No. ECE F214 / EEE F214 /INSTR F214
Course Title: Electronic Devices
Date: 12-12-2012
Max.Marks: 14
Weightage: 7%
Duration: 20 min

Important Notes: Answer all the questions

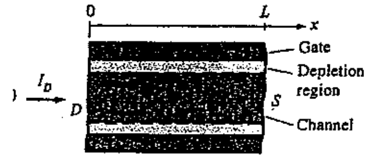
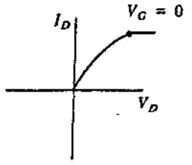
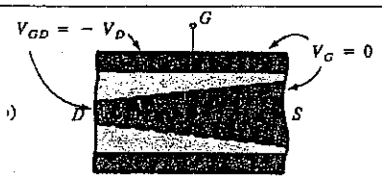
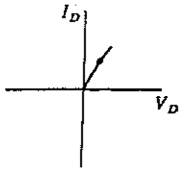
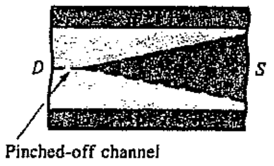
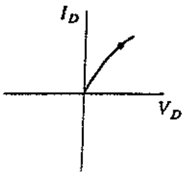
ID. No:

Sec No. :

Name:

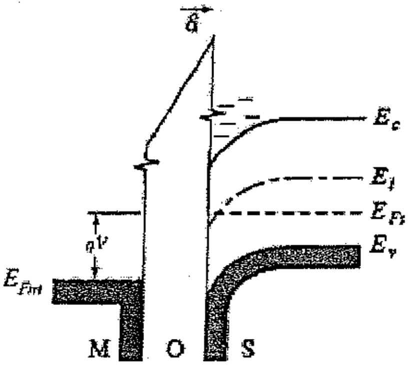
Q.1	If a p-n junction is heavily doped, breakdown voltage will _______________	1M
Q.2	When a Zener diode is used in a circuit, it is always ____________ biased.	1M
Q.3	**Say True or False** In a p-n junction Avalanche breakdown occurs at low voltage	1M
Q.4	**Say True or False** A reverse biased p-n junction has a wide depletion layer	1M
Q.5	Avalanche breakdown results basically due to A. impact ionisation, B. strong electric field across the junction, C. emission of electrons D. rise in temperature	1M
Q.6	A general purpose diode is more likely to suffer an avalanche breakdown rather than a zener breakdown because A. It is heavily doped, B. it is lightly doped, C. it has weak covalent bond, D. none of the above	1M
Q.7	What are the capacitance of the p-n junction?	1M

Q.8	Some n channel MOS devices have a channel already with zero gate voltage and __________ voltage is required to turn the device off, such a device is called as ____________ transistor.	2M
Q.9	Match the following	3M

A		A	
B		B	
C		C	

Ans:

Q.10	Following figure is an energy band diagram for the ideal MOS structure; we get this effect for ______________ voltage, causes ______________formed on the surface of the semiconductor.	2M



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A

I Semester 2012-2013
II YEAR EEE/ECE/EIE
QUIZ 1 (Closed Book)

Course No. ECE F214 / EEE F214 /INSTR F214
Course Title: Electronic Devices
Date: 24-10-2012
Max.Marks: 16
Weightage: 8%
Duration: 20 min

Important Notes: Answer all the questions

ID. No:
Sec No. :
Name:

Q.1 An electron can be ______________________excited out of a bond and there by become _______ to participate in conduction. 2M

Q.2 In an intrinsic semiconductor rate of recombination of electrons and holes is proportional to __________________________________ 2M

Q.3 Draw the energy band diagram for n type semiconductors showing all the energy levels 2M

Q.4 The expression for the effective mass of an electron in a band with given E-k diagram is given by 2M

Q.5 The current is a function of electron velocity. Name the parameter which describes how fast an electron moves in a semiconductor when an electric field is applied. 1M

____

Q.6 6 Volts is applied across a 2 cm long semiconductor bar. The average drift velocity is 10^4 cm/ s. The electron mobility is 2M

a) 4396 $cm^2/V - s$

b) 3×10^4 $cm^2/V - s$

c) 6×10^4 $cm^2/V - s$

d) 3333 $cm^2/V - s$

Q.7 The Fermi level is defined as 1M

a) The level at which the probability of electron occupancy is ½

b) The level at which the probability of electron occupancy is 1

c) The level at which the probability of electron occupancy is ¼

d) None of the above

Q.8 A GaAs semiconductor is at T = 300K is doped with impurity concentration $N_d = 10^{16}$ cm^{-3}. The mobility μ_n is 7500 $cm^2/V - s$. For an applied field of 10 V/cm the drift current density is 2M

____

Q.9 Find the resistance R of a Silicon bar which is doped with $10^{17}/cm^3$ of phosphorus, with width w=0.1mm, thickness t=10μm and length L=5mm. The mobility of electron in the silicon is given by 1350 cm^2/V-s. 2M

Ans R=