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NATIONAL UNIVERSITY OF IRELAND
GALWAY

SEMESTER I (WINTER) EXAMINATIONS 2000/2001

B.Sc. (Honours) in
Applied Physics & Electronics
Experimental Physics
Physics & Computing

Paper II: Microelectronics (EP411)

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Time allowed: TWO hours

Answer THREE questions.

Each question carries 33 marks.

Q.1 A silicon sample has a uniform donor doping of 3×10^{22} m^{-3}.

(i) Calculate the total number of atoms Q deposited during a predeposition of p type doping using boron diffusion for times, t, of (a) 1s, (b) 2×10^3s, and (c) 10^4s. Use values for temperature, T = 1000 °C; solid solubility, $N_o = 2 \times 10^{26}$ m^{-3}; diffusion coefficient $D_1 = 2.7 \times 10^{-18}$ $m^2\,s^{-1}$ and

$$Q = \frac{N_o(4D_1t)^{1/2}}{\sqrt{\pi}} \quad \text{atom m}^{-2}$$

(3,3,3 marks)

From a practical and economic point of view explain the significance of the three times chosen above, and describe the characteristics of the junction formed. (10 marks)

(ii) A limited source drive-in diffusion is now performed for T = 1100 °C, $D_2 = 3 \times 10^{-17}$ $m^2\,s^{-1}$, time t = 3.6×10^3s, and using the appropriate value of Q, from (i). Calculate the junction depth following the drive-in.

(14 marks)

Note: Useful expressions: $Q/\sqrt{\pi DT}$ and $\exp\left[-\frac{x^2}{4Dt}\right]$.

Q.2 (i) In ion implantation explain the design rule that relates to the allowed value of dopant concentration in the tail of the distribution profile. (6 marks)

(ii) From (i) above and using a SiO_2 layer on doped Si, derive the equation x_o = minimum oxide thickness = $R_p + m\Delta R_p$. Explain the significance of the value of m. (8 marks)

Note: $$N(x) = N_p \exp\left[-(x-R_p)^2/2\Delta R_p^2\right]$$

(iii) A boron implantation is to be performed through a 50 nm gate oxide so that the peak of the distribution is at the Si – SiO_2 interface. The dose of the implant in silicon is to be 1×10^{13} cm^{-2}, the peak concentration $N_p = 3.5 \times 10^{18}$ cm^{-3}, the straggle $\Delta R_p = 0.023$ µm, and the range $R_p = 0.05$ µm. How thick should the SiO_2 layer be in areas which are not to be implanted, if the background concentration is 1×10^{16} cm^{-3} ? (11 marks)

(iv) In (iii) above, suppose the oxide is 50 nm thick everywhere. How much photo resist is required on top of the oxide to completely mask the ion implantation ? Use a value of 1.8 as the stopping ratio for photoresist and SiO_2. (8 marks)

Q.3 Explain the use of resists in lithography under the following headings:

(i) Initial criteria. (8 marks)

(ii) Image type. (6 marks)

(iii) Radiation type. (7 marks)

(iv) Process chemistry. (12 marks)

Q.4 Outline the three main requirements for integrated diode components. (6 marks)

Explain the importance of the epitaxial layer in optimum diode design. (8 marks)

A varactor diode has the following design parameters for a $p^+ n n^+$ epitaxial design .

Junction diameter = 500 µm
Junction depth x_j = 2.0 µm
Epitaxial layer thickness = 10 µm
Epitaxial layer doping, $N_{epi} = 1 \times 10^{15}$ cm^{-3} ($\rho_{epi} = 5\ \Omega$ cm)
Substrate resistivity, $\rho_{sub} = 0.005\ \Omega$ cm.
Substrate thickness t_{sub} = 300 µm.
$\varepsilon = 1.044\ 10^{-12}$ F cm^{-1}.

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What is the maximum and minimum value of capacitance for this design? (12 marks)

What is the maximum value for the quality factor if the frequency = 50 MHz. (7 marks)

Useful information:

$$C_J = A\sqrt{\frac{q\varepsilon N}{2V_J}} = 289 \text{ pF mm}^{-2} \quad \text{for } V_J = 1\text{V}$$

$$W = \sqrt{\frac{2\varepsilon V_J}{qN}} = 0.361\ \mu\text{m} \quad \text{for } V_J = 1\text{V}$$

Q.5 The growth of SiO_2 on Si, during the oxidation process is given by the equation

$$\text{Oxide thickness} = x_o = d_{ox} = \frac{A}{2}\left[\left(1+\frac{t+\tau_o}{A^2/4B}\right)^{1/2} - 1\right]$$

(i) Derive an expression for t (the time) from this equation. (5 marks)

(ii) Very briefly explain the significance of the constants A and B. (8 marks)

(iii) How does the magnitude of $A^2/4B$ with respect to $t + \tau_o$ explain the growth process of SiO_2 on Si ? (8 marks)

(iv) Using the equation for t derived above, calculate the total time required for the following oxidation process. A 50 nm thick SiO_2 layer is grown in dry oxygen at 1000 °C. An additional 0.2 µm thick SiO_2 layer is then grown on top of the 50 nm SiO_2 layer, in wet oxygen at 1000 °C. (12 marks)

At 1000 °C for dry oxidation
$B = 0.012\ \mu m^2\ h^{-1}$, $B/A = 0.071\ \mu m\ h^{-1}$ and $\tau_o = 0.37$ h
At 1000 °C for wet oxidation
$B = 0.29\ \mu m^2\ h^{-1}$, $B/A = 1.27\ \mu m\ h^{-1}$ and $\tau_o = 0$ h.