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NATIONAL UNIVERSITY OF IRELAND
GALWAY

SEMESTER I EXAMINATIONS 2002/2003

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

Paper II: Microelectronics (EP411)

4EL3-EP441-2, 4EL4-AX402-2
4BS2-EP443-1, 4BS2-AX405-1
1EM1-EP411-1

Prof. S.G. Jennings
Prof. E. Kennedy
Dr. J. P. Larkin

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^{3}s, and (c) 10^{4}s. Use values for temperature, T = 1000 °C; solid solubility, $N_0 = 2 \times 10^{26}$ m^{-3}; diffusion coefficient $D_1 = 2.7 \times 10^{-18}$ m^2 s^{-1} and

$$Q = N_0(4D_1t)^{1/2} / \sqrt{\pi} \text{ atoms m}^{-2}$$

[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} and time $t = 3.6 \times 10^{3}$ s, 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 $\exp[-x^2/(4Dt)]$

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_0 = minimum oxide thickness = $R_P + m\,\Delta R_P$. Explain the significance of the value of m. [8 marks]

Note: $N(x) = N_P \exp[-(x - R_P)^2 / 2\Delta R_P^2]$

(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 $1 \times 10^{13} cm^{-2}$, the peak concentration $N_P = 3.5 \times 10^{18}\ cm^{-3}$, the straggle $\Delta R_P = 0.023\ \mu m$, and the range $R_P = 0.05\ \mu m$. How thick should the SiO_2 layer be in areas which are not to be implanted, if the background concentration is $1 \times 10^{16} cm^{-3}$? [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 Answer (a) and (b)

(a) The growth of SiO_2 on Si, during the oxidation process is given by the equation

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

from which the growth time can be determined.

A 50 nm thick SiO_2 layer is first grown on top of the Si. Calculate the time t taken to grow an additional 0.2μm thick SiO_2 film on top of the 50nm SiO_2, in wet oxygen at 1000°C.

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. [16 marks]

(b) Using n-MOS gate circuits with a depletion load transistor, draw sketches of a two input NAND gate and a two input NOR gate. Briefly explain their operation.

Determine the channel lengths for the transistors in an n-MOS inverter made using a 3μm process if the channel widths are to be equal. The voltage values for the fabrication process are $V_{DD} = 5V$, $V_{Tn} = 1.0V$, $V_{TD} = -4.0V$, $V_{LO} = 0.5V$.
Assume $\mu_n / \mu_D = 1.2$ (9, 8 marks)

Note: $\beta_n V_{LO} (V_{DD} - V_{Tn} - V_{LO}/2) = \beta_D |V_{TD}|^2 / 2$

Q.5 (i) Draw a vertical cross-section of the fabrication layout for a u.v. erasable MOST EPROM transistor and explain its WRITE and ERASE operation. [11 marks]

(ii) Explain the design and use of programmable logic devices (PLDs) or user-configurable ICs (USICs). [10 marks]

(iii) Draw the functional circuit for a PLD to implement the logic function

$$(\overline{A}.\overline{B}.C) + (\overline{A}.B.\overline{C})$$

using the MOST EPROMs as in (i) above.

Explain the circuit operation. [6, 6 marks]