Reg. No.										

MANIPAL INSTITUTE OF TECHNOLOGY
MANIPAL
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SIXTH SEMESTER B.TECH. (E & C) DEGREE END SEMESTER EXAMINATION
APRIL/MAY 2019
SUBJECT: VLSI/ULSI PROCESS TECHNOLOGY (ECE - 4016)

TIME: 3 HOURS **MAX. MARKS: 50**

Instructions to candidates
- Answer **ALL** questions.
- Missing data may be suitably assumed.

1A. Discuss the film growth rate model applicable to CVD technique. What are the two limiting cases effecting the growth model?

1B. At 300 K, the molecular diameter of oxygen is 0.364 nm, and the number of molecules per unit area Ns is 7.54 $x10^{14}$ cm^{-2}. Find the time required to form a monolayer of oxygen at pressures of 1, 10^{-4} and 10^{-8} Pa.

1C. A DRAM capacitor has the following parameters: C= 40fF, cell size=1.28 μm^2, and k=3.9 for silicon dioxide. If we replace SiO_2 with Ta_2O_5 (k=25) without changing thickness, what is the equivalent cell area of the capacitor?

(4+3+3)

2A. Explain the defects present in Epitaxial layers.

2B. Sketch the following within the unit cell (i) (1 0 -2) (ii) (1 -2 -2) (iii) [3 0 1]

2C. A boule of single crystal silicon is pulled from the melt in a CZ process. The silicon is boron doped. After the boule is pulled, it is sliced into wafers. The wafer taken from the top of the boule has a boron concentration of $4x10^{15}$ cm^{-3}. What would you expect for doping concentration of the wafer taken from the Position corresponding to 80% of the initial charge solidified? Assume for Boron, k=0.8.

(4+3+3)

3A. You have an n-type wafer with 5 x 10^{16} As atoms/cm^3 and you decide to begin to fabricate a MOSFET. After growing your oxide layer, you pattern and etch the wafer to open a window in the oxide to make your MOSFET. You decide to use a boron oxide containing spun-on glass to dope your wafer with boron.

(i). What is the surface concentration of boron in the Si at 1000°C? Describe in one sentence how you determined this number.

(ii). How long should you heat the wafer with boron film on top at 1000°C to diffuse in a total dose of 3 x 10^{14} boron atoms/cm^2? Given, $D=2\times10^{-14}\ cm^2\ s^{-1}$.

(iii). What is the junction depth after heating the wafer at 1000°C for your calculated time?

(iv). What assumption regarding the diffusion coefficient did you make to perform the calculations in (ii)?

3B. Consider the cross-section of **Figure 3B** that is to be doped with As using ion implantation to form the source/drain regions. Assume the Si substrate is initially doped with B with a uniform concentration of 10^{16} cm^{-3}.

(i). Assume that the SiO2 and polysilicon layers have the same ion stopping power as Si, and that SiO2 thickness is 60 nm. What are the ion implantation dose and energy required to achieve a peak concentration of 10^{19} cm^{-3} of As at the SiO2 and Si interface in the source/drain regions (i.e., y = 60 nm)?

(ii). Continuing from (i), calculate the junction depth of the source/drain regions.

(iii). Estimate the required drive-in time of arsenic at 1100 °C. Given, Das=0.32, Ea=3.56ev, $Dt=2.94\times10^{-9}\ cm^2$.

3C. (i). In a four-point probe measurement on a silicon wafer that is uniformly doped n-type, the measured resistance is 30 Ω. If wafer is 300 μm thick and the probe spacing is 1 mm, determine the wafer resistivity and doping concentration.

(ii). TCAD software is used for ………………………

(4+3+3)

4A. Calculate (i) the diffusion profile and plot (ii) junction depth (iii) total amount of dopant introduced after boron pre-deposition performed at 950 ^{0}C for 30 min. Assume the substrate is n-type with a background doping level of 1.5×10^{16} atoms/cm^3 and the boron surface concentration reaches solid solubility ($C_s=1.8\times10^{20}/cm^3$). Given $D_B= 3\times10^{-15}$ cm^2/sec.

4B. According to the Deal Grove model, oxidation kinetics start out linear and become parabolic as the oxidation proceeds. Calculate the oxide thickness at which this transition takes place and plot this versus oxidation temperature (800 ^{0}C to 1200 ^{0}C in step of 50 ^{0}C).

4C. (i) Consider the **Figure 4C(i)** of triangular shape and Si<110> as reference orientation. INTEL want to grow silicon dioxide (1 μm) using thermal oxidation technique on silicon crystal (triangular shape) with varied orientation. Draw the final shape of silicon crystal after oxidation with relative thickness (w.r.t Si<110> as reference orientation) in all 3 sides.

(ii) Based on the optics of your mask aligner you know the light intensity profile on the photoresist layer is given by the Gaussian function in **Figure 4C(ii)**. Calculate the ideal exposure time. D_{100}=150 mJ/cm^2.

(4+3+3)

5A. Explain the set-up of Electrochemical etch stop with neat diagram.

5B. You have a mask with a square aperture of area 4 μm^2 that you would like to pattern onto an *i-line* resist of thickness 1 μm that has been spin-coated onto a Si wafer.

(i) Use a projection printer which positions the mask some distance x from a lens of diameter 10 cm and focal length f=5 cm. Sketch the setup showing the mask, lens, wafer, the light emanated from the aperture, and the focused light rays; make sure to include relevant lengths in your sketch.

(ii) What value of x should you use to achieve the best resolution, and what is this resolution?

5C. Calculate and plot versus exposure wavelength the theoretical resolution and depth of focus for a projection exposure system with a NA of 0.6 (about the best that can be done today). Assume k1 = 0.6 and k2 = 0.5 (both typical values).

Consider wavelengths between 100 nm and 1000 nm (DUV and visible light). Indicate the common exposure wavelengths being used or considered today on your plot (g-line, i-line, KrF and ArF). Will an ArF source be adequate for the 0.13 μm and 0.1 μm technology generations according to these simple calculations? Given, i-line λ=365 nm, g-line λ=436 nm, KrF λ= 248 nm , ArF λ= 193 nm.

(4+3+3)

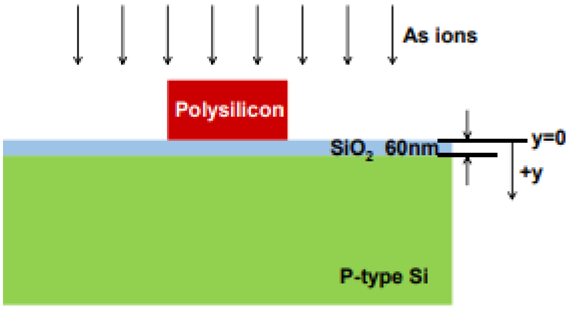

Figure 3B

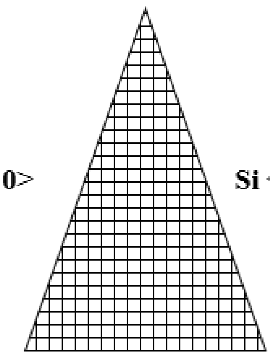

Figure 4C(i)

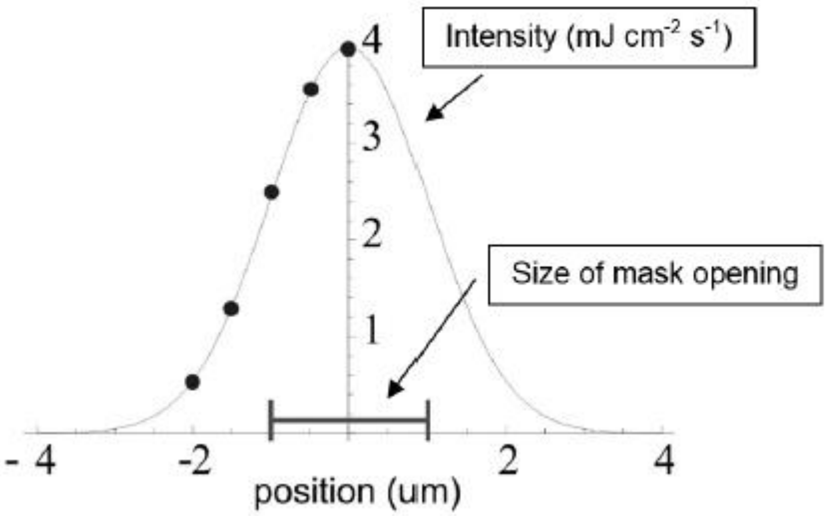

Figure 4C(ii)