EEE506 Assignment 2025.02.23

Please do NOT discuss with other students when working out this assignment.

Question 1. (25 marks)

(a) Fig. Q1a shows schematic cross sectional structures of two types of power MOSFETs. Describe their differences and advantages in terms of device performance and fabrication. (10 marks)

(b) The on-state resistance of the D-MOSFET in Fig. Q1a can be determined by the sum of various components as given in the following equation,

$$Rds(on) = Rsource + Rch + R_A + R_J + R_D + Rsub + Rwcml$$

where Rsource = Source diffusion resistance; Rch = Channel resistance ; R_A = Accumulation resistance ; R_J = "JFET" component-resistance of the region between the two body regions ; R_D = Drift region resistance ; Rsub = Substrate resistance ; Rwcml = sum of bond wire resistance, the contact resistance between the source and drain metallization and the silicon, metallization and leadframe contributions. Fig. Q1b shows the trend of the on state resistance as the blocking voltage increases.

Which resistance component becomes dominant when the blocking voltages reaches 500 V ? How does this knowledge affect our design considerations for the devices ? (8 marks)

(c) The surface roughness scattering is predominant under strong inversion conditions for the MOSFET in Fig.Q1a. Explain the main reason. (7 marks)

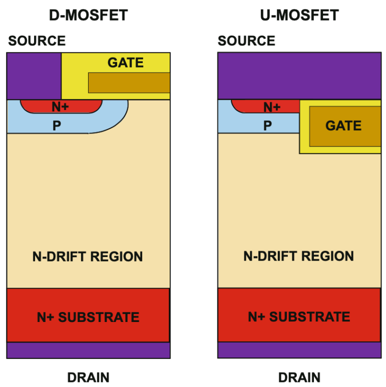

Fig. Q1a

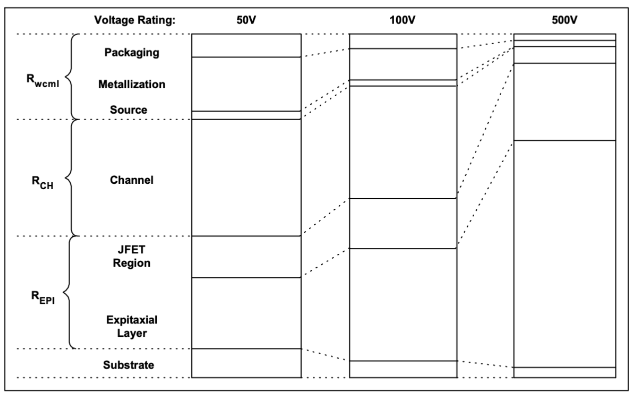

Fig. Q1b

Question 2 (25 marks)

Fig. Q2 shows a planar junction obtained by diffusion through a window in a silicon dioxide mask.

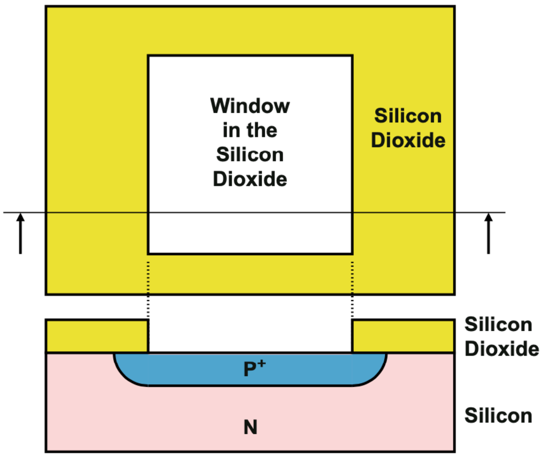

Fig. Q2

(a) Explain why edge termination schemes are used for power devices that have such structures, and describe three popular edge termination methods with schematics.

(15 marks)

(b) Three models are used to determine the maximum electric fields of the p n junction at different locations, that are: plane plates junction model, cylindrical junction model, and spherical junction model, the results are

$$E_{m,PP} = -\frac{qN_D W_D}{\varepsilon_S}$$

for the plane p-n junction;

$$E_{m,CYL}(r_J) = -\frac{qN_D r_D^2}{2\varepsilon_S r_J}$$

for the cylindrical junction ,

and

$$E_{m,SP}(r_J) = -\frac{qN_D r_D^3}{3\varepsilon_S r_J^2}$$

for the spherical junction, respectively, where r_J and r_D are defined in the lecture notes. The P+ body has a depth of 500 nm, and doping of 3 x 10^{18} / cm^3. Then doping is 1x10^{15}/cm^3; Find the maximum electric fields at the bottom of the p n junction, along the edge of the window, and at the corners of the window.

(10 marks)

Question 3 (25 marks)

(a) Fig. Q3a shows empirical observations of relative stability (or occurrence) of individual polytypes in SiC bulk growth; Fig.Q3b shows (a) Low-field electron mobility versus donor density and (b) hole mobility versus acceptor density for 4H-SiC and 6H-SiC at room temperature. Which SiC polytype should be chosen for power SiC MOSFETs ? What growth conditions shall be used for its growth ?

(8 marks)

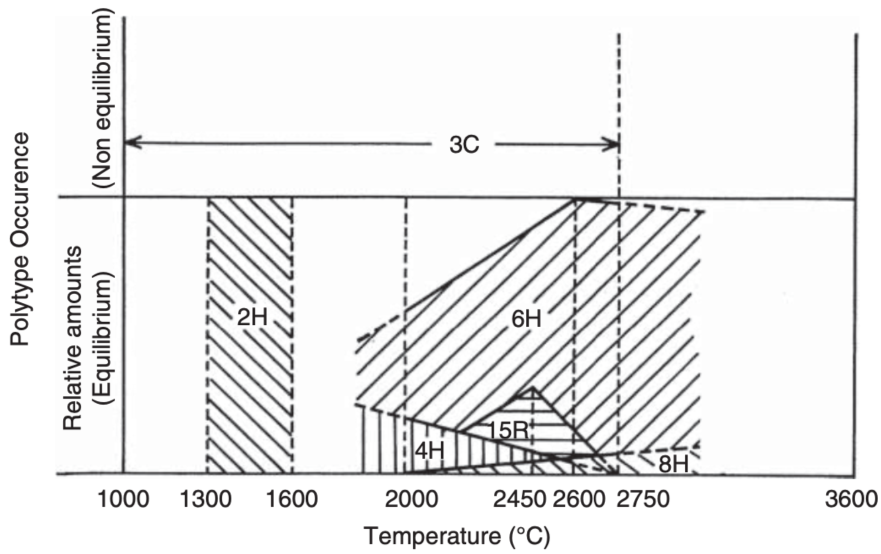

Fig. Q3a

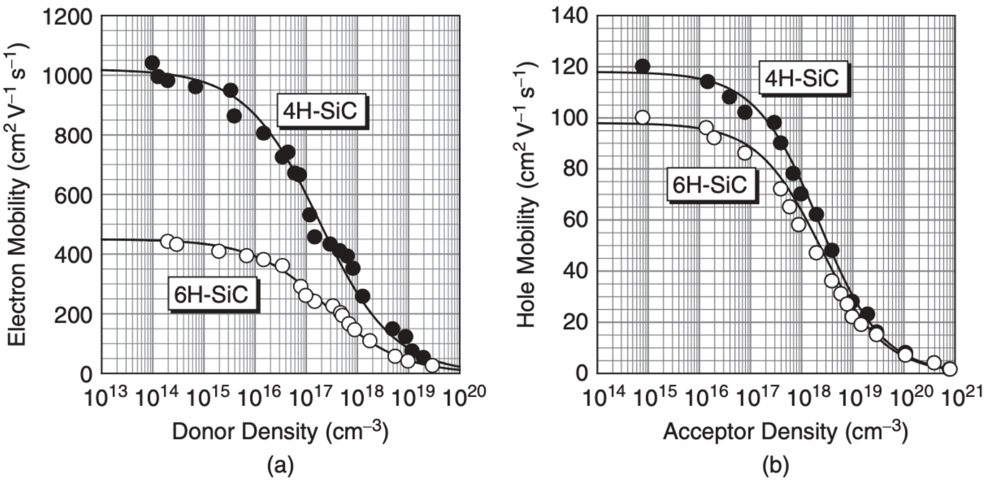

Fig. Q3b

(b) After the bulk growth, what processes are used to obtain a high quality n-type SiC substrate ?

(7 marks)

(c) Fig. Q3c is a generic growth schematic profile, describe the steps involved in making a n-type SiC epitaxial layer on top of the above substrate ? What common measurements are taken to check its quality after the growth?

(5 marks)

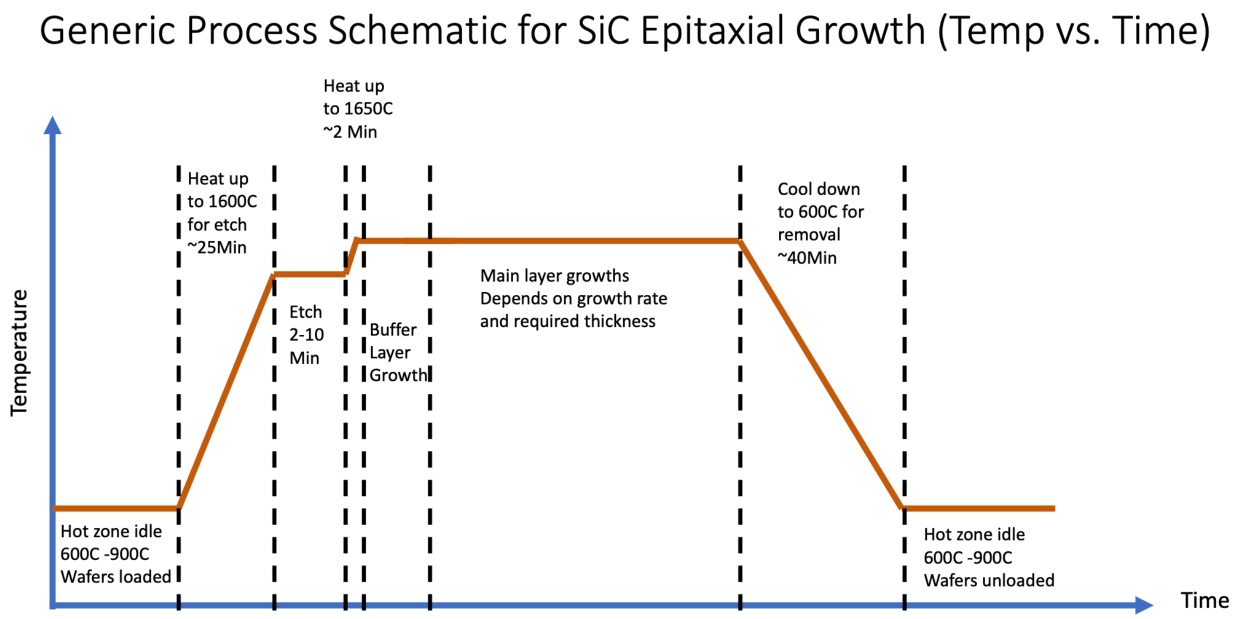

Fig.Q3c

(d) Describe how reflectance measurement can be used to measure the epitaxial thin film thickness ?

(5 marks)

Question 4 (25 marks)

(1) Fig.Q4a is an SEM picture of a cross sectional SiC MOSFET. Identify various parts of the transistor in the image by drawing a schematic of the transistor and indicate their length if possible.

(8 marks)

(2) Fig.Q4b is a top view optical image of part of a SiC MOSFET, what are the structures marked by red letters A and B. (7 marks)

(3) Fig. Q4c is a mask designed for SiC MOSFET cells. The shape of the transistor cell is square. Straight stripe cells can be used also, compare the current Ids these two patterns for the same active area in the figure.

(10 marks)

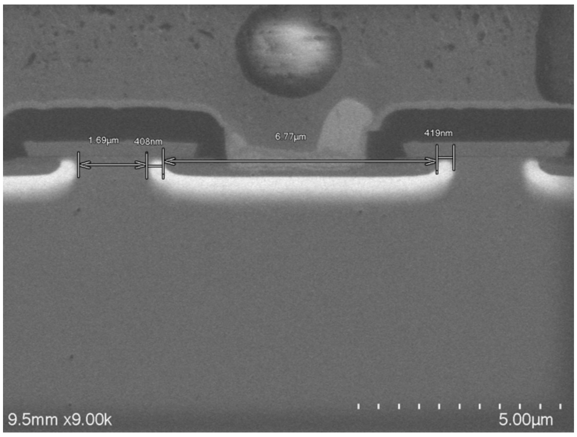

Fig. Q4a

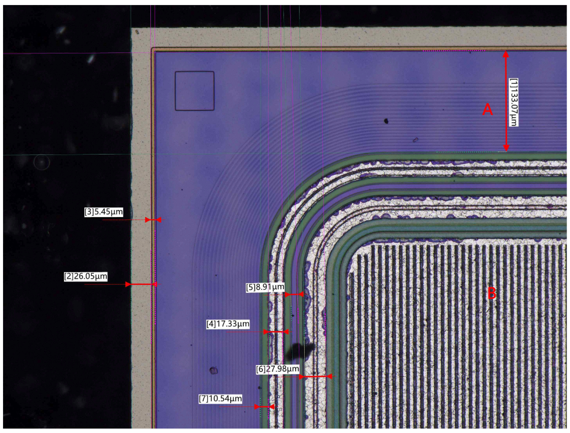

Fig. Q4b

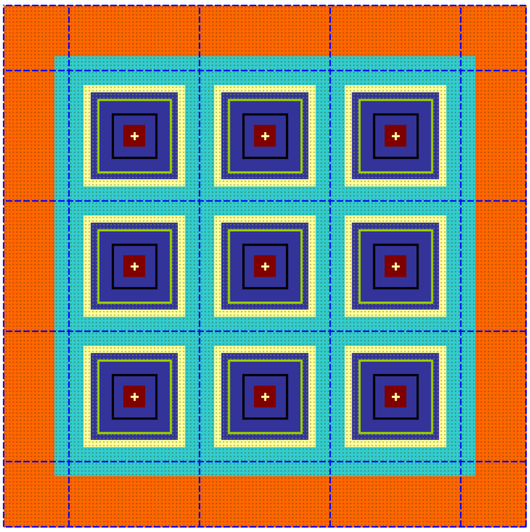
Fig. Q4c