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Universiti Tun Hussein Onn Malaysia

UNIVERSITI TUN HUSSEIN ONN MALAYSIA

FINAL EXAMINATION
(ONLINE)
SEMESTER II
SESSION 2019/2020

COURSE NAME : ADVANCED SEMICONDUCTOR DEVICES

COURSE CODE : BED 41003

PROGRAMME CODE : BEJ

EXAMINATION DATE : JULY 2020

DURATION : 3 HOURS

INSTRUCTION : ANSWER **ALL** QUESTIONS
OPEN BOOK EXAMINATION

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THIS QUESTION PAPER CONSISTS OF **ELEVEN (11)** PAGES

For questions **Q1 – Q31**, select only **ONE** correct answer

Q1 Base region in BJT normally has the
- A. biggest area and highest doping concentration
- B. biggest area and lowest doping concentration
- C. smallest area and highest doping concentration
- D. smallest area and lowest doping concentration

(2 marks)

Q2 The following do **NOT** contribute to total minority carriers in BJT
- A. Excess minority carriers
- B. Quasi-Fermi minority carriers
- C. Steady-state minority carriers
- D. Thermal equilibrium minority carriers

(2 marks)

Q3 The value of drain current depends on the current density of
- A. J_{nE}
- B. J_{Pc0}
- C. J_{PE}
- D. J_{RB}

(2 marks)

Q4 Channel area in JFET is controlled through
- A. Drain-to-source current
- B. Drain voltage
- C. Gate voltage
- D. Source voltage

(2 marks)

Q5 Depletion region exist in substrate under gate terminal in MESFET because
- A. Ohmic contact is created at drain terminal
- B. Schottky barrier is created at gate terminal
- C. There is no insulator layer in between gate metal and substrate
- D. Voltage at gate metal is more negative than the substrate

(2 marks)

Q6 Semi-insulating layer in MODFET normally refers to
- A. Electrostatic charge control layer
- B. Excellent heat insulator layer
- C. Good insulation layer
- D. High resistivity layer

(2 marks)

Q7 The following is **NOT** the advantage of double gate transistor

A. Improved circuit noise
B. Improved switching speed
C. Reduced leakage current
D. Reduced circuit delay

(2 marks)

Q8 One of similarity of both FinFET and MOSFET is

A. Definition of its channel width
B. Electrons movement in channel
C. Number of gate terminals
D. Type of gate metal contact

(2 marks)

Q9 Trigate transistor can be formed from FinFET by

A. Extending channel length
B. Extending top metal contact length
C. Patterning additional top metal layer
D. Reducing top dielectric length

(2 marks)

Q10 Varactor is a device that has its

A. Capacitance changes through applied voltage
B. Current changes through applied energy
C. Depletion area change through applied voltage
D. Resistance changes through applied current

(2 marks)

Q11 Intrinsic region of p-i-n diode could **NOT** be realised using

A. High resistivity p-type material
B. High resistivity n-type material
C. Intrinsic material
D. Low-doped n-type material

(2 marks)

Q12 An advantage of IMPATT diode is that it could

A. Function on narrow frequency bands
B. Generate high output power
C. Produce large reactance
D. Respond well to circuit conditions

(2 marks)

Q13 Conditions of **OFF** state of thyristor are

A. High impedance and high current
B. High impedance and low current
C. Low impedance and high current
D. Low impedance and low current

(2 marks)

Q14 State of thyristor junctions during reverse blocking are

A. J_1 forward biased, J_2 forward biased, J_3 reverse biased
B. J_1 reverse biased, J_2 forward biased, J_3 forward biased
C. J_1 reverse biased, J_2 forward biased, J_3 reverse biased
D. J_1 reverse biased, J_2 reverse biased, J_3 reverse biased

(2 marks)

Q15 The following statement do **NOT** related to two-transistor model of thyristor

A. Anode shall have higher potential than cathode in forward conduction mode
B. Avalanche breakdown is necessary in forward blocking mode
C. Gate current is unimportant in forward conduction mode
D. Gate voltage is essential to turn from forward blocking mode

(2 marks)

Q16 The number of excess minority carriers in emitter region of BJT at $x' = 0$ is $2.50 \times 10^{12}\ cm^{-3}$. At $x' = \frac{1}{2}x_E$, the number of excess minority carriers would equal to

A. $1.25 \times 10^{12}\ cm^{-3}$
B. $2.50 \times 10^{12}\ cm^{-3}$
C. $3.75 \times 10^{12}\ cm^{-3}$
D. $5.00 \times 10^{12}\ cm^{-3}$

(2 marks)

Q17 A BJT with base width of $4.20 \times 10^{-4}\ cm$ would produce collector current of $1.62 \times 10^{-3}\ A$. If the base width is changed to $5.04 \times 10^{-4}\ cm$, the new collector current would be

A. $0.90 \times 10^{-3}\ A$
B. $1.35 \times 10^{-3}\ A$
C. $1.94 \times 10^{-3}\ A$
D. $2.92 \times 10^{-3}\ A$

(2 marks)

Q18 Base transport factor of a BJT is 0.99581 when ratio ${}^{x_B}/_{L_B} = 0.265$. If the ratio is increased to ${}^{x_B}/_{L_B} = 0.272$, the new base transport factor would equal to

A. 0.93066
B. 0.94839
C. 0.96680
D. 0.98595

(2 marks)

Q19 A JFET with doping concentration of $N_D = N_A = 10^{15}\ cm^{-3}$ produced a built-in potential of $1.35\ V$. If the doping concentration changed to $N_D = 10^{17}\ cm^{-3}$ and $N_A = 10^{13}\ cm^{-3}$, the resulting built-in potential would be

A. $6.21\ V$
B. $3.11\ V$
C. $1.35\ V$
D. $0.29\ V$

(2 marks)

Q20 A MESFET with germanium substrate has pinch off voltage of $1.60\ V$. Another MESFET with silicon substrate would have pinch off voltage of

A. $1.17\ V$
B. $1.43\ V$
C. $1.79\ V$
D. $2.19\ V$

(2 marks)

Q21 A MODFET that has AlGaAs layer thickness of $3.2 \times 10^{-4}\ cm$ produced pinch off voltage of $1.85\ V$. If the AlGaAs layer thickness is changed to $4.0 \times 10^{-4}\ cm$, the pinch off voltage would be

A. $2.89\ V$
B. $2.31\ V$
C. $1.48\ V$
D. $1.18\ V$

(2 marks)

Q22 A double gate transistor with substrate doping concentration of $10^{14}\ cm^{-3}$ produced semiconductor work function $1.25\ V$. If the doping concentration is changed to $10^{16}\ cm^{-3}$, the semiconductor work function would be

A. $0.27\ V$
B. $0.87\ V$
C. $1.81\ V$
D. $5.76\ V$

(2 marks)

Q23 A double gate transistor with silicon substrate has drain current of $8 \times 10^{-3}\ A$. If the substrate is changed to gallium arsenide, the drain current would be

A. $5.85 \times 10^{-3}\ A$
B. $7.15 \times 10^{-3}\ A$
C. $8.96 \times 10^{-3}\ A$
D. $10.94 \times 10^{-3}\ A$

(2 marks)

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Q24 A varactor with $m = -0.8$ would have device sensitivity of

A. $s = 2.5$
B. $s = 5$
C. $s = 7.5$
D. $s = 10$

(2 marks)

Q25 A p-i-n diode that has $V_F = 2.5 \times 10^{-2}\,V$ produced current density of $3 \times 10^{-4}\,\frac{A}{cm^2}$. If another p-i-n diode has $V_F = 5 \times 10^{-2}\,V$, the current density would be

A. $6 \times 10^{-4}\,\frac{A}{cm^2}$
B. $11 \times 10^{-4}\,\frac{A}{cm^2}$
C. $22 \times 10^{-4}\,\frac{A}{cm^2}$
D. $33 \times 10^{-4}\,\frac{A}{cm^2}$

(2 marks)

Q26 Given a silicon one-sided IMPATT diode has $N_D = 10^{15}\,cm^{-3}$ and $E_m = 2 \times 10^3\,\frac{V}{cm}$, the depletion width would be

A. $1.29 \times 10^{-5}\,cm$
B. $2.59 \times 10^{-5}\,cm$
C. $1.29 \times 10^{-3}\,cm$
D. $2.59 \times 10^{-3}\,cm$

(2 marks)

Q27 A Read IMPATT diode that has $W_D = 4b$ produced breakdown voltage of $7 \times 10^{-2}\,V$. If another Read IMPATT diode has $W_D = 8b$, the breakdown voltage would be

A. $14 \times 10^{-2}\,V$
B. $15 \times 10^{-2}\,V$
C. $28 \times 10^{-2}\,V$
D. $30 \times 10^{-2}\,V$

(2 marks)

Q28 A thyristor produces punchthrough voltage of $6 \times 10^4\,V$ when its depletion width is $16 \times 10^{-6}\,cm$. If the depletion is increased to $24 \times 10^{-6}\,cm$, the punchthrough voltage would be

A. $7.5 \times 10^4\,V$
B. $9.0 \times 10^4\,V$
C. $13.5 \times 10^4\,V$
D. $15.0 \times 10^4\,V$

(2 marks)

Q29 A thyristor with $W = 2W_{n1}$ produced current gain of 0.266. If another thyristor has $W = 4W_{n1}$, the current gain would be

A. 0.037
B. 0.074
C. 0.133
D. 0.532

(2 marks)

Q30 In forward breakover mode, a thyristor with $V_2 = 5 \times 10^{-2}\ V$ produced total voltage drop of $20 \times 10^{-2}\ V$. As the thyristor turns into forward conduction mode, the total voltage drop would become

A. $10 \times 10^{-2}\ V$
B. $15 \times 10^{-2}\ V$
C. $25 \times 10^{-2}\ V$
D. $30 \times 10^{-2}\ V$

(2 marks)

Q31 Suppose a thyristor has punchthrough voltage of $1\ mV$. To keep $\frac{W}{W_{n1}}$ in positive ratio, the maximum of possible anode-cathode voltage would be

A. $0.9801\ mV$
B. $0.9604\ mV$
C. $0.9409\ mV$
D. $0.9216\ mV$

(2 marks)

For questions **Q32 – Q50**, select **ALL** correct answers (multiple correct answers)

Q32 The device conditions when base width modulation occur in BJT are

A. Base region size is inversely proportional with base depletion region size
B. Base-collector voltage directly proportional to base depletion region size
C. Injection current increases as base region size becomes smaller
D. Majority carriers movement from emitter to base reduced as base-collector voltage increases
E. Number of minority carriers per unit area is increasing as base-collector voltage increases
F. Recombination process in the base region reduced as base region size becomes smaller

(2 marks)

Q33 The device conditions when BJT is in high injection are

A. Base-emitter voltage increases number of excess minority carriers in base region
B. Number of both majority and minority carrier are similar in base region
C. Number of excess minority carriers in base region increases due to diffusion process
D. Number of thermal equilibrium minority carriers are increased in base region
E. The emitter efficiency factor is reduced
F. Total number of minority carriers in base region is increased

(2 marks)

Q34 Device conditions of BJT when experiencing current crowding are

A. Centre area of emitter region receives more current than other emitter areas
B. Current going into emitter region is not uniformly distributed
C. Current movement trend is due to the location of physical base terminal
D. Current is more likely to flow through the edge of emitter region
E. Heating issue is one of the consequences of this phenomena
F. Position of collector terminal affects the pattern of current going into the emitter

(2 marks)

Q35 Common device conditions that are **NOT** related to JFET

A. Both top and bottom gate terminals control the channel size
B. Both source and drain terminals are at the same potential
C. Carriers can flow in the channel even when depletion region covers whole channel near drain region
D. Depletion region is not necessarily exist between p-well and substrate
E. Saturation current value is higher for more negative gate voltage
F. Source voltage is not necessarily at ground level

(2 marks)

Q36 The device conditions of MESFET when it is in saturation mode are

A. Depletion region could extend inside semi-insulation substrate
B. Drain and source terminals are separated by depletion region in substrate
C. Drain current is constant until the device breakdown
D. Metal contact of source, drain and gate terminals are similar
E. Saturation current values are similar for different gate voltages
F. The pinch off points are similar for different gate voltages

(2 marks)

Q37 Unique features that exist in MODFET device structure are

A. Both Schottky barrier and ohmic contact exist at device terminals
B. Depletion region under gate terminal assist electron flow from source to drain terminal
C. Device channel forms outside heterojunction area
D. Diffusion of carriers occurs at heterojunction
E. Source and drain contacts should coincide with device channel
F. Type of metal determines either Schottky barrier or ohmic contact formed at device terminal

(2 marks)

Q38 Features in FinFET as a viable alternative device to MOSFET

A. Both device width and length are arbitrary
B. FinFET on SOI substrate is more popular
C. Its fin can be either shorted or isolated
D. Its structure is in planar configuration
E. Less short channel effect than MOSFET
F. Single gate voltage for both gate terminals

(2 marks)

Q39 Conduction band in double gate transistor is in dome shape due to

A. Band diagram is not in thermal equilibrium
B. Fermi level of source/drain is moving downward
C. Fermi level of source/drain is moving upward
D. Fermi level of substrate is moving downward
E. Fermi level of substrate is moving upward
F. Quasi Fermi level of source regions inside conduction band

(2 marks)

Q40 Conduction band of drain region is positioned below the conduction band of source region due to

A. Band diagram is not in thermal equilibrium
B. Drain region is applied with positive bias
C. Fermi level of substrate is moving upward
D. Source region has lower potential than drain region
E. The effect of semiconductor work function
F. Unstable band level at both source and drain regions

(2 marks)

Q41 Features of a varactor that enable it to store charge are

A. Both anode and cathode terminals act as parallel plates
B. Charges are partly involved in recombination process inside the device
C. Charges are pushed away from pn junction inside the device
D. Forward bias is applied for charge capacity larger than 1000 μF
E. It is applied with reverse bias
F. Some extra charges are produced from generation process inside the device

(2 marks)

Q42 The importance of a wide intrinsic layer in p-i-n diode is to produce

A. High breakdown voltage
B. High switching time
C. High thermal voltage
D. High RF resistance
E. Low current conduction
F. Low carrier saturation velocity

(2 marks)

Q43 Possible reasons the ionisation process occurs in avalanche region of IMPATT diode are

A. Additional carriers from outside coming in to fill in the blank space
B. Carriers are pushed away from pn junction
C. Depletion area covers the whole avalanche region
D. Existing carriers are being swept away by high electric field
E. Forward biased being applied on the pn junction
F. New carriers produced as existing carriers colliding

(2 marks)

Q44 Factors that enable carrier movement in drift region of IMPATT diode are

A. Carrier collision is involved in drift process
B. Carrier drift velocity created by force inside the drift region
C. Depletion area created ease the carriers drifting process
D. High electric field pushing carriers up to saturation velocity
E. Wide area to enable carriers achieve saturation velocity
F. Wide area to help carriers achieving consistent transit time

(2 marks)

Q45 Breakdown voltage profiles of IMPATT diode are

A. Capacitance plays significant role in the breakdown process
B. Carrier saturation velocity speeds up breakdown process
C. Electric field is a direct proportional factor
D. Forward bias enables high breakdown voltage to occur
E. In majority cases, lower substrate dielectric constant is more desired
F. The larger depletion area, the higher breakdown voltage produced

(2 marks)

Q46 Possible reasons that enable thyristor producing high breakdown voltage are

A. Cathode contact placement on n_2 layer
B. Equal width area of both p_1 and n_2 layers
C. Extremely high doping concentration of p_1 layer
D. Gate voltage application on p_2 layer
E. Low doping concentration of n_1 layer
F. Wide area of n_1 layer

(2 marks)

Q47 Options of action that could change thyristor operation into forward conduction mode are

A. Apply gate voltage
B. Force avalanche breakdown
C. Initiate punchthrough breakdown
D. Keep increasing the forward bias voltage
E. Maintain the thyristor in reverse biased
F. Remove gate current immediately

(2 marks)

Q48 Proper indications that could differentiate if a thyristor experiences either avalanche breakdown or punchthrough breakdown are

A. Doping concentration of n_1 region
B. Operating temperature of device
C. Range of gate voltage values
D. Total width of n_1 region
E. Width of depleted n_1 region
F. Width of neutral n_1 region

(2 marks)

Q49 Possible reasons that could stop thyristor in forward conduction mode are

A. Allowing avalanche breakdown to occur
B. Increasing forward biased anode-cathode voltage
C. Letting anode-cathode voltage drops below holding voltage level
D. Maintaining existing forward biased anode-cathode voltage
E. Removing gate voltage immediately
F. Reducing anode current below holding current level

(2 marks)

Q50 Features in power MOSFET structure that made it suitable for power application are

A. Additional gate terminals
B. Deeper junctions
C. FinFET-like structure design
D. Longer channel lengths
E. Semi-insulating material layer
F. Thicker oxides

(2 marks)

- END OF QUESTIONS -