類組：電機類　科目：固態電子元件(300G)　　共 7 頁 第 1 頁

一、單選題，每小題 2 分，倒扣分數為 0.5 分，倒扣至本大題(即單選題)0 分為止。

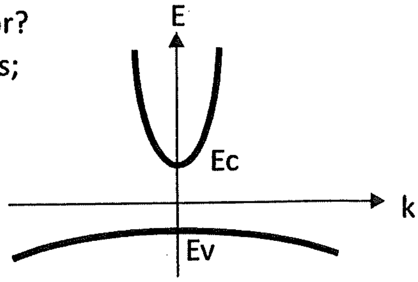
For **Questions 1-4**, considering a piece of semiconductor, where E_V is the valence band edge energy, Eg is the bandgap of the material, E_C is the conduction band edge energy and E_f is the Fermi-level.

1. Which one of the followings gives the "electron affinity"?
(A) $E_{VAC} - E_C$; (B) $E_{VAC} - E_V$; (C) $E_{VAC} - Eg$; (D) $E_C - E_V$.

2. Which one of the followings gives the "ionization energy"?
(A) $E_{VAC} - Eg$; (B) $E_C - E_V$; (C) $E_{VAC} - E_V$; (D) $E_{VAC} - E_C$.

3. At room temperature, which one of the following statements is correct?
(A) In an intrinsic semiconductor, Fermi-level is between Ec and Ev;
(B) Valence band is fully occupied;
(C) Eg will widen in heavy doped samples;
(D) The probability of an electron with energy higher than E_f is zero.

4. The E-k diagram of a material is shown below, where. N_C is the density of states in the conduction band, while N_V is the density of states in the valence band. At thermal equilibrium, which is true for this intrinsic semiconductor?
(A) Effective mass of electrons is larger than that of holes;
(B) Electon density higher than that of holes;
(C) Nc > Nv;
(D) $E_f = (Ev+Ec)/2$.



5. At room temperature, a few electrons are excited into the conduction band, which eventually fall back down to a vacant state in the valence band, re-emitting the excess energy as heat or light, generating "X", and "Y", respectively.
(A) X are photons, Y are phonons.
(B) X are photons, Y are photons.
(C) X are phonons, Y are phonons.
(D) X are phonons, Y are photons.

6. In a material with a bandgap of 1.55 eV, an electron in the conduction band falls back down to the valence band without any heat loss. What is the closest wavelength of the emitted light?
(A) 400 nm; (B) 800 nm; (C) 1000 nm; (D) 1500 nm

7. Which is closest to the energy gap between conduction band and valence band of a semiconductor which emits light of 400 nm wavelength at room temperature?
(A) 0.7 eV; (B) 1.1 eV; (C) 2.3 eV; (D) 3.1 eV.

注意：背面有試題

8. Which statement is correct?
(A) In an isolator, the valence band is empty of electrons, while the conduction band is filled with electrons.
(B)In a metal, the valence band is filled with electrons, while the conduction band is empty of electrons.
(C) For an intrinsic semiconductor at 0 degree Kelvin, the valence band is filled with electron, while the conduction band is empty
(D) In an intrinsic semiconductor, electron density raises faster than that of holes with increasing temperature.

9. Under low electric field, the electron's mobilities in n-type material are affected by? (i) impurity concentration. (ii) electric field. (iii) temperature. (iv) mean free time between collisions.
(A) (i), (ii), (iii), (iv);　(B) (i), (iii), (iv);　(C) (ii), (iii), (iv);　(D) (i), (ii).

10. For a piece of p-type silicon with a doping level of 10^{18} cm^{-3}, when temperature increases from 300K to 350K, which is correct?
(A) Hole density decreases drastically;
(B) Electron density is independent of temperature;
(C) Majority carrier density remains almost the same;
(D) None of the above.

11. Which of the following is **false** in describing a degenerately-doped p+ Silicon?
(A) Fermi-level is inside conduction band;
(B) Energy bandgap narrows;
(C) Acceptor states fold into bands;
(D) Density of electron is much lower than that of holes.

12. Which is **true** on the describing the carrier mobilities in Silicon?
(A) Comparing to that at 300K, mobilities of both carriers increase in cryogenic state;
(B) Mobility of the minority carriers is always lower than that of the majority carriers;
(C) At high temperature regime, impurity scattering dominates;
(D) In heavily doped sample, phonon scattering dominates.

Suppose the intrinsic carrier concentration of Si at T=300 K is n_i=1.5x10^{10} cm^{-3}.
Silicon has a relative dielectric constant of 11.7.
The permittivity of free space ε_0 is 8.85x10^{-14} F/cm.
For **Questions 13-15**, an abrupt Si pn junction under zero bias at T=300 K has doping concentrations of N_a=N_d=2x10^{16} cm^{-3}. Find the following quantities:

13. The built-in potential barrier V_{bi} of the junction is

(A) $\frac{kT}{e} ln\left(\frac{N_a N_d}{n_i^2}\right)$ eV; (B) $\frac{kT}{e} ln\left(\frac{N_a N_d}{n_i^2}\right)$ V; (C) $\frac{kT}{e} ln\left(\frac{N_a N_d}{n_i}\right)$ V; (D) $\frac{kT}{e} ln\left(\frac{N_a N_d}{n_i}\right)$ eV.

14. The depletion region width of the junction is
(A) larger on the p-side;
(B) larger on the n-side;
(C) twice the depletion width on each side;
(D) undetermined.

15. The electric field in the depletion region is
(A) uniformly distributed;
(B) parabolically distributed;
(C) linearly distributed with a single slope;
(D) linearly distributed with two slopes.

For **Questions 16-18**, suppose a metal is deposited on n-type Si (N_d=5x10^{15} cm^{-3}) to form a Schottky junction whose Schottky barrier height ϕ_{B0} is 0.65 V at T=300 K. The effective density of states in the conduction band of Si at T=300 K is N_c=2.8x10^{19} cm^{-3}. Answer the following questions.

16. What is the value of the built-in potential barrier V_{bi} of this Schottky junction?
(A) 0.724 V; (B) 0.426 V; (C) 0.654 V; (D) 0.65 V.

17. If the doping concentration of the Si is doubled, what does the value of the built-in potential barrier become?
(A) 0.414 V; (B) 0.65 V; (C) 0.444 V; (D) 0.654 V.

18. And how does this concentration doubling make the value of Schottky barrier height change?
(A) Doubled accordingly; (B) Increased a little; (C) Decreased; (D) Unchanged.

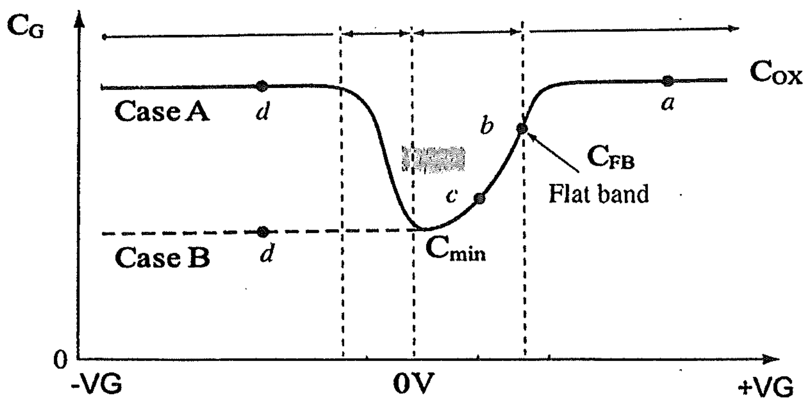
For **Questions 19-21**, Two diodes of the same area value are manufactured on an n-type Si wafer. One of the two diodes is a one-sided (p^+n) junction diode and the other is a Schottky diode.

19. Which diode has a larger built-in potential barrier?
(A) The p^+n diode; (B) The Schottky diode; (C) Same value;
(D) Unable to judge without further information.

20. Which diode has a larger reverse current before breakdown?
(A) The p^+n diode; (B) The Schottky diode; (C) Same value;
(D) Unable to judge without further information.

21. Which diode has a slower switching speed?
(A) The p^+n diode; (B) The Schottky diode; (C) Same value;
(D) Unable to judge without further information,

Consider a CV of MOS capacitor with n+ Si gate and Tox=5 nm as shown the figure below, answer **Questions 22-26**:



22. Which region is at inversion state?
(A) region a; (B) region b; (C) region c; (D) region d.

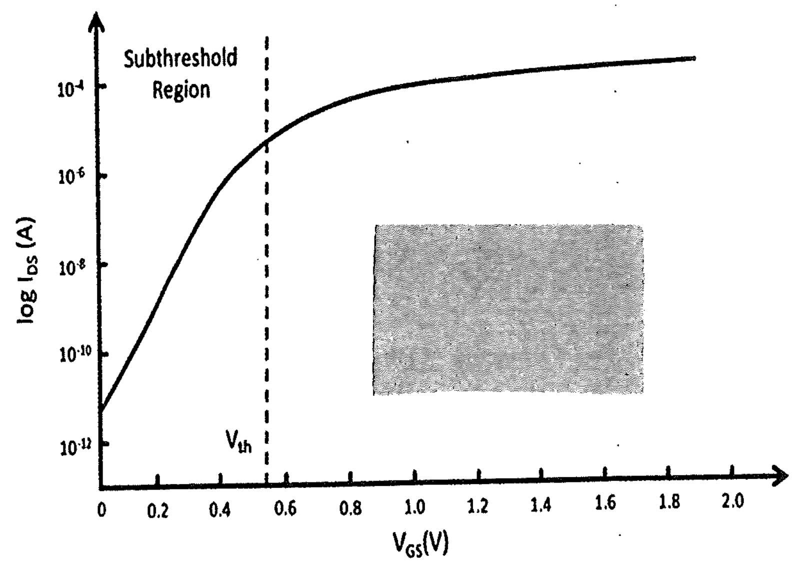
23. What is the substrate type?
(A) n-type; (B) p-type; (C) intrinsic (D) cannot decide in the CV curve

24. Increase the substrate dopant concentration, what happen to C_{min} and C_{FB}?
(A) C_{min} becomes larger and C_{FB} slightly shifts to left;
(B) C_{min} becomes larger and C_{FB} slightly increases;
(C) C_{min} becomes smaller and C_{FB} has no change;
(D) C_{min} becomes smaller and slightly shifts to right.

25. Use p+ Si gate instead of n+ Si gate, what will be the CV curve?
(A) CV curve is left and right reversed: region a to d and region d to a;
(B) CV curve has no change;
(C) CV curve is shifted toward left;
(D) CV curve is shifted toward right.

26. Add fixed positive charges in gate oxide, what happen to the CV curve?
(A) CV curve has no change, but C_{FB} shifts to right;
(B) CV curve has no change, but C_{FB} shifts to left;
(C) CV curve becomes flatter, and C_{min} slightly larger;
(D) CV curve becomes flatter, and C_{FB} shifts to right.

For **Questions 27-30**, the subthreshold I_{DS}-V_{GS} curve of n+ gate nMOSFET with Tox=5nm at 300K is shown in the figure below,



27. What is the subthreshold swing (mV/dec)?
(A) 200;　(B) 30;　(C) 60;　(D) 90.

28. Increase the Tox to 8nm, what will be the subthreshold swing (mV/dec)?
(A) larger;　(B) no change;　(C) smaller;　(D) cannot decide.

29. Increase the substrate dopant concentration, what happen the subthreshold swing (mV/dec)?
(A) larger;　(B)no change;　(C) smaller;　(D) cannot decide

30.Decrease the operation temperature to 77K, what happens to the subthreshold swing (mV/dec)?
(A) larger;　(B)no change;　(C) smaller;　(D) cannot decide

二、多選題，每小題4分，每題每一選項單獨計分，每一選項個別分數為0.8分，答錯一選項倒扣分數為0.8分，倒扣至本大題(即複選題)0分為止。

31. For a intrinsic material with E-k band diagram as below, where E_V is the valence band edge energy , E_C is the conduction band edge energy. N_C is the density of states in the conduction band, while N_V is the density of states in the valence band. Which of the following statements are correct ?(6%)

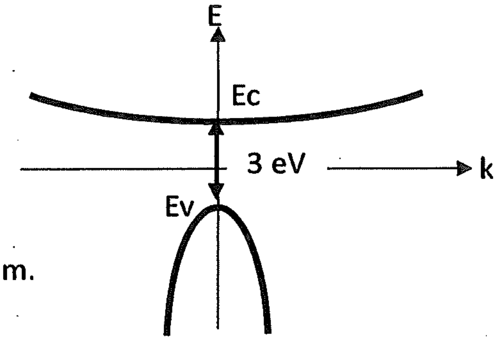
(A) Direct bandgap material;

(B) Fermi level > $(E_V+E_C)/2 >0$;

(C) $N_C < N_V$;

(D) Electron effective mass > hole effective mass;

(E) Can directly absorb light with wavelengh of 700 nm.



32. For a region of Si with compensation doping, its energy band diagram is below, Let n_0 and p_0 be the electron and hole densities at thermal equilibrium, N_D and N_A are the donor and acceptor concentrations, respectively, while n_i is the intrinisc carrier density. Which are true? (6%)

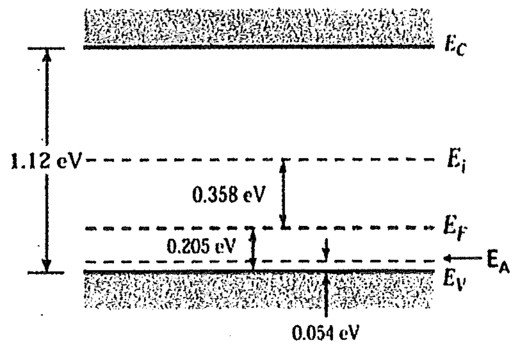
(A) It's considered as degenerately-doped;

(B) $n_0<p_0$;

(C) $N_D>N_A$;

(D) $n_0*p_0=n_i^2$;

(E) $n_0= N_D+N_A$.



33. Which ones of the following items can affect the common-base current gain α of an NPN BJT?

(A) Base doping concentration;

(B) Emitter doping concentration;

(C) Emitter width;

(D) Collector width;

(E) Base width.

34. What will be increased if the base doping concentration of a BJT is reduced by half?

(A) Emitter injection efficiency;

(B) BV_{CEO};

(C) Base transit time;

(D) Current gain;

(E) Base resistance R_B.

35. What will be increased by reducing the base width of a BJT?
(A) Emitter injection efficiency;
(B) BV_{CEO};
(C) Base transit time;
(D) Current gain;
(E) Early voltage.

36. Which in the following are majority carrier devices?
(A) BJT;
(B) MOSFET;
(C) PN junction diode;
(D) MS junction diode;
(E) Semiconductor resistor.

For **Questions 37-40**, consider a n+ Si gate nMOSFET with Tox=5nm at 300K,
37. Which factors will lower the channel mobility?
(A) reduce operation temperature;
(B) add substrate dopant;
(C) rise the gate voltage;
(D) increase the drain voltage;
(E) increase the oxide thickness.

38. Which parameters will increase the body effect?
(A) reduce operation temperature;
(B) add substrate dopant;
(C) use p+ Si gate instead of n+ Si gate;
(D) use SOI (Silicon on Insulator) wafer;
(E) decrease the oxide thickness.

39. Which factors will increase the early voltage
(A) reduce the channel length;
(B) add substrate dopant;
(C) rise the gate voltage;
(D) increase the drain voltage;
(E) use thinner gate oxide.

40. Which factors will increase the drain-induced barrier lowering (DIBL)?
(A) reduce the channel length;
(B) add substrate dopant;
(C) applied negative substrate bias;
(D) increase the drain voltage;
(E) use thicker gate oxide.