Energy Materials　Mid-term exam (Chapter 1-4)

Department of materials science and engineering, National United University　Oct. 28, 2025　9:00 – 11:00

(A) True or false question (15%)

1. (　) p-n diode is a minority carrier device.
2. (　) The electric field in an unbiased p-n junction is zero.
3. (　) In an unbiased diode, the direction of the electric field is from the p region to the n region.
4. (　) In an ideal diode, recombination-generation is neglected in the depletion region.
5. (　) In an unbiased p-n junction diode, the hole diffusion current is equal in magnitude but opposite in direction to the electron diffusion current in the depletion region.

(B) Select the correct answer from the list (60%)

6. Which of the following band structure exhibits a large electrical conductivity? (a) The bandgap is larger than 6 eV (b) The bandgap is between 3-6 eV (c) The bandgap is between 0-3 eV (d) Overlapped conduction and valence bands (e) Partially full band
7. At room temperature a semiconductor material is (a) perfect insulator (b) conductor (c) slightly conducting (d) any one of the above (e) none of the above
8. Holes are available in (a) valence band (b) forbidden gap (c) conduction band (d) vacuum level (e) none of the above
9. You've got a semiconductor material. Which of the following can increase the carrier mobility? (a) increase temperature (b) increase doping concentration (c) reduce impurities (d) increase electric fields (e) select carrier with high effective mass
10. This net movement of charge due to an electric field is called (a) drift current (b) diffusion current (c) tunneling current (d) dark current (e) Eddy current
11. A hole and electron in close proximity would tend to (a) repel each other (b) attract each other (c) have no effect on each other (d) all of the above (e) none of the above
12. The distribution law that describes the distribution of electrons among available energy states is (a) Maxwell-Boltzmann distribution (b) Bose-Einstein distribution (c) Fermi-Dirac distribution (d) Cumulative Distribution (e) Gaussian distribution.
13. The intrinsic carrier concentration is a very strong function of (a) Fermi energy level (b) ionization energy (c) effective mass (d) pressure (e) temperature
14. For a metal and an n-type semiconductor, an Ohmic contact is formed when (a) $\Phi_M > \Phi_S$ (b) $\Phi_M < \Phi_S$ (c) $\Phi_M = \Phi_S$ (d) $\Phi_M > \chi_S$ (e) none of the above
15. Solar cell, any device that converts (a) thermal energy to electrical energy (b) photon energy to electrical energy (c) electrical energy to chemical energy (d) electrical energy to photon energy (e) chemical energy to electrical energy through the photovoltaic effect.
16. Which region of a solar cell consists entirely of an electric field? (a) emitter (b) base (c) junction (d) antireflection coating (e) passivation layer
17. In the (a) first (b) second (c) third (d) fourth (e) zero quadrant, the positive photovoltage and the negative current result in the negative power dissipation in the device, indicating the flow of power from the device into the external circuit.
18. For most solar cell measurement, the spectrum is standardized to the (a) AM0 (b) AM0.5 (c) AM1.0 (d) AM1.5 (e) AM2.0 spectrum.
19. Which of the following descriptions is not true? (a) An ideal solar cell can be modeled as a current source in series with a rectifying diode to represent its electrical behavior. (b) The collection probability of the solar cell, which depends chiefly on the surface passivation and the minority carrier lifetime in the base. (c) When comparing solar cells of the same material type, the most critical material parameter is the diffusion length and surface passivation. (d) In the case of very high series resistance ($> 10\,\Omega \cdot \mathrm{cm}^2$), I_{sc} is less than I_{ph}. (e) The short-circuit current depends strongly on the generation rate and the diffusion length.
20. Which of the following statements about ideality factor is not true? (a) The ideality factor of a diode is a measure of how *closely* the diode follows the ideal diode equation. (b) The ideality factor is a measure of the junction quality and the type of recombination (c) For the simple recombination mechanisms, the ideality factor has a value of 1. (d) A high ideality factor degrades the FF. (e) A low ideality factor indicates high recombination, and it gives low open-circuit voltages.
21. Which of the following statements about series resistance is incorrect? (a) The key impact of series resistance is to reduce the fill factor. (b) Series resistance reduces the open-circuit voltage. (c) Series resistance changes the slope of the $I{-}V$ curve at the open-circuit voltage point. (d) Series resistance reduces the fill factor. (e) One source of series resistance in a solar cell is the contact resistance at the metal–silicon interface.
22. Which of the following statements about shunt resistance is not true? (a) Shunt resistance is a measure of leakage current in a solar cell. (b) A high shunt resistance is desirable for good performance, as it indicates minimal leakage. (c) The leakage current is caused by defects, impurities, or surface imperfections. (d) Shunt resistance changes the slope of the $I{-}V$ curve at the short-circuit current point. (e) The negative impact of shunt resistance becomes more significant at higher light intensities.
23. 1 sun corresponds to standard illumination at (a) $1\,\mathrm{W/m^2}$ (b) $1\,\mathrm{kW/m^2}$ (c) $1\,\mathrm{MW/m^2}$ (d) $1\,\mathrm{GW/m^2}$ (e) $1\,\mathrm{TW/m^2}$

24. Which type of light is strongly absorbed by silicon? (a) Blue light (b) Green light (c) Yellow light (d) Red light (e) Infrared
25. Which of the following descriptions about collection probability is not true? (a) Carriers generated more than a diffusion length from the junction have a low collection probability. (b) The collection probability is spectrum-dependent. (c) At the surfaces, the collection probability is higher than in the bulk. (d) The collection probability depends on the surface properties of the device. (e) The collection probability of carriers generated in the depletion region is the highest.

(C) Answer the following questions (50%)

26. Two processes for carrier flow in semiconductors are drift and diffusion. What are the key dependencies of the drift current and diffusion current? (10%)

27. (a) How the depletion region is formed when a p-type material and an n-type material are joined together? (5%) (b) What is the role of the depletion region in the p-n diode? (3%) (c) Define the built-in voltage. (2%)

28. (a) Illustrate the ideal I-V curve of a p-n junction in the dark and under illumination. (4%) (b) Show the equation of the I-V curve under illumination. (2%) (c) Indicate the open circuit voltage and short circuit current in the figure. (2%) (d) Show the definition of fill factor. (2%)

29. Describe the temperature effect on the efficiency of solar cells. (10%)

30. The Figure shows the typical I-V characteristics for a p-n junction diode. Five regions are labeled on the I-V profile. From the list given, pick the number that best describes each of the regions and briefly explain it. (10%)