ME4252 Nanomaterials for Energy Engineering

Solution to Quiz-2

AY2022-23

1. Dominated recombination in a quantum dot solar cell is:
   (a) Radiative recombination
   (b) Auger recombination
   (c) Trap-assisted SRH recombination
   (d) Surface recombination

Mention one subsequent impact of this recombination process on the photocurrent of the quantum dot solar cell measured at 1000W/m^2.

Surface recombination predominates due to large surface area.
The photocurrent does not remain constant with time at 1000W/m^2. At this large power, there is substantial surface recombination hence the photocurrent decays with time.

2. Provide two reasons for the presence of shunt resistance in a practical Si solar cell.
The parallel or shunt resistance arises (i) from the leakage of current through the cell-around the edges of the device and (ii) in the junction due to the presence of crystal defects, impurities

3. The maximum power P_{max} extracted from a solar cell with optimal load is always less than the power derived from the product of I_{sc} and V_{oc}. Explain the reasons in 1-2 sentences.

Because the low Fill factor, it is never equal to 1, rather always less than 1.

4. Mention one advantage and one disadvantage of using liquid electrolyte instead of hole transport medium (polymer electrolyte) in a dye-sensitized solar cell.
Advantage of liquid electrolyte in DSSC: it can vet the complete surface of the dye molecules adsorbed on the surface of TiO_2 nanoparticles.
Disadvantage: This can leak in the device, also corrosive due to presence of iodide.
Advantage of HTM in DSSC: This cannot leak in the device, also not corrosive.
Disadvantage: It cannot vet the complete surface of the dye molecules adsorbed on the surface of TiO_2 nanoparticles.

5. Select the fastest process among the following in a perovskite solar cell:
   (a) Electron transport within TiO_2
   (b) Electron transfer from Fermi level of TiO_2 to the valance band edge of perovskite
   (c) Electron transfer from the conduction band edge of the perovskite to the conduction band edge of TiO_2
   (d) Electron transfer from conduction band edge of the perovskite to the HOMO level of the polymer (Hole Transport Medium).

   Give one possible reason for this observed fast process (1-2 sentences).

   (c) Electron transfer from the conduction band edge of the perovskite to the conduction band edge of TiO_2
   Due to the energetic reason. The conduction band edge of the perovskite lies just above the conduction band edge of TiO_2.

6. While designing n-p junction for a Si solar cell (i) n-type Si layer is made (optimally) thin, while (ii) p-type Si is lightly doped ($10^{16}/cm^3$). Provide one reason for each of the above design criteria.

   (i) n-layer is designed thin so that not much light is trapped in this layer but pass through to the p-layer where most of the absorption takes place.
   (ii) p-layer is lightly doped to avoid possible recombination prior to separation of electron and holes at the junction and improve diffusion length.

7. Photovoltaic conversion efficiency of a perovskite solar cell is 25.3% while the conversion efficiency of a dye sensitized solar cell is only about 12.0%. Provide two valid reasons for the observed high efficiency of perovskite solar cell.

   (i) Perovskite materials have high absorption coefficient over the entire visible region
   (ii) The loss is negligible so that one could achieve high open circuit voltage of about 1.1V as compared to dye sensitive solar cells 0.8V.
   (iii) Perovskite materials have high crystallinity hence high diffusion length >1micon.

8. In a dye sensitized solar cell device using TiO_2 nanoparticles (50nm size), micron sized TiO_2 is used as scattering layer (SL). On the other hand, dye sensitized solar cell device using mesoporous TiO_2 (agglomerate of nanograins) we do not use such a scattering layer. Provide one reason (1-2 sentences) for choosing SL in first case and for not choosing SL in the second case.

(i) The scattering layer is used for TiO2 nanoparticle because most of the light pass through the 15-micron thick TiO2 nanoparticle coating.

(ii) While using mesoporous TiO2 due to morphology of 1-2 micron size particle comprised of 15-20nm nanograins, the light almost get trapped hence there is no need to use additional SL.

9. Multiple exciton generation is observed in a quantum dot solar cell while it is not observed in a monocrystalline Si solar cell. Describe the reason (1-2 sentences).
Quantum dot solar cells have discrete energy level in both conduction and valance bands as a result the thermalization process during high energy light illumination is quite slow hence one could use this lost energy to create additional excitons. However, in monocrystalline Si solar cell, this thermalization process during high energy illumination is pretty fast due to continuum nature of the energy levels in both conduction and valance bands.

10. What causes observed open circuit voltage in a quantum dot solar cell using liquid electrolyte? Provide your answer precisely in 1-2 sentences.

Open circuit voltage is due to difference in the Fermi levels of TiO_2 and the redox (Fermi) level of the liquid electrolyte used.

11. Given ice, water and steam (vapour), which has highest entropy and which has lowest entropy. What is the role of entropy?

Steam has highest entropy. Entropy causes disorder in the system.

12. In the I-V curve of a Fuel cell delivering 1.6 A/cm^2, the fuel cross-over between anode and cathode causes voltage loss at the following current:
    (a) at 0.4 A/cm^2
    (b) at 0.8 A/cm^2
    (c) at 1.2 A/cm^2
    (d) at zero current

    Provide your reason.

    Fuel cross-over between anode and cathode causes voltage loss at zero current, once the cell is formed. Without drawing any current the open circuit voltage drops due to this trace amount of fuel cross over phenomena between anode and cathode.

13. What is the role of triple phase boundary in a solid oxide fuel cell? Provide your answer precisely in 1-2 sentences.

    Triple phase boundary is formed where the fuel is in contact simultaneously with ionic conducting medium (electrolyte) and electronic conducting medium (electrode). This is where the catalytic reaction of fuel is converted to mobile ionic species which flows within the electrolyte and electrons which flows through the external circuit.

14. If you are given PEMFC and SOFC, which one will you use for the EV application? Give one reason for your choice.

    I will choose PEMFC for EV, as it operates ta low temperature.

15. In a dye sensitized solar cell, the overall energy conversion efficiency can be improved by increasing the surface area of TiO_2 which contributes to:
    (a) Electron collection efficiency
    (b) Electron injection efficiency
    (c) Photon absorption efficiency
    (d) Less recombination

    Provide an explanation within 30 words.

    (c) Photon absorption efficiency. Nanoparticle of TiO2 has larger surface area hence large dye molecules adsorbed on their surfaces. Hence more photon absorption resulting in enhanced overall energy conversion efficiency of DSSC.
