ME4252

AY2022-23

Additional problems for your practice:

1. A specimen of germanium is doped with 0.1 atomic percent of arsenic. Assuming that at room temperature all the arsenic atoms are ionized, find the electron and hole concentration in germanium. The intrinsic carrier density in germanium at room temperature is $2.37\times10^{19}\,m^{-3}$. The number density of germanium atom is $4.41\times10^{28}\,m^{-3}$.

   Answer:

   $n = 4.41 \times 10^{25}\ m^{-3}$

   $p = 1.27 \times 10^{13}\ m^{-3}$

2. InSb is a semiconductor with a band gap of 0.2 eV and mobilities of 80,000 $cm^2\,V^{-1}\,s^{-1}$ for electrons and 750 $cm^2\,V^{-1}\,s^{-1}$ for holes. The effective masses are $0.001m_o$ for electrons and $0.1m_o$ for holes. $N_c = 10^{18}\ cm^{-3}$ and $N_v = 10^{19}\ cm^{-3}$. Assume the temperature to be 300K.

   (a) What intrinsic carrier concentration would you expect in *undoped* InSb?

   (b) For *doped* InSb (with $N_D = 10^{18}\ cm^{-3}$) what conductivity would you expect?

   Answer:

   $n_i = 6.5 \times 10^{16}\ cm^{-3}$

   $p = 4.3 \times 10^{15}\ cm^{-3}$

3. Consider a silicon *p-n* junction at *T*=300 *K* with the following parameters:

   $N_d=10^{16}\ cm^{-3}$ $\quad N_a=5\times10^{18}\ cm^{-3}$

   $D_p=10\ cm^2/sec$ $\quad D_n=25\ cm^2/sec$

   $\tau_{n0}=5\times10^{-7}\ sec$ $\quad \tau_{p0} = 10^{-7}\ sec$ $\quad$ & $n_i =1.5\times10^{10}\ cm^{-3}$

   Assume that excess carriers are uniformly generated in the solar cell and for one sun, J_L=15 mA/cm^2. Calculate the open circuit voltage.

   Answer:

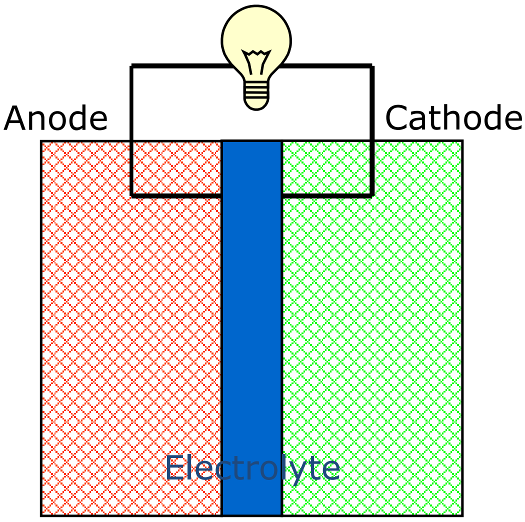
   $V_{OC} = 0.514V$

4. A Silicon solar cell of size 2 *cm* x 2 *cm* with I_0 = 32 *nA* has an optical generation rate of 10^{18} EHP/cm^3-sec within $L_p = L_n$ = 2 μm of the junction. If the depletion width is 1 *μm*, calculate the I_{SC} and V_{OC} for this cell at room temperature (300K).

Answer:

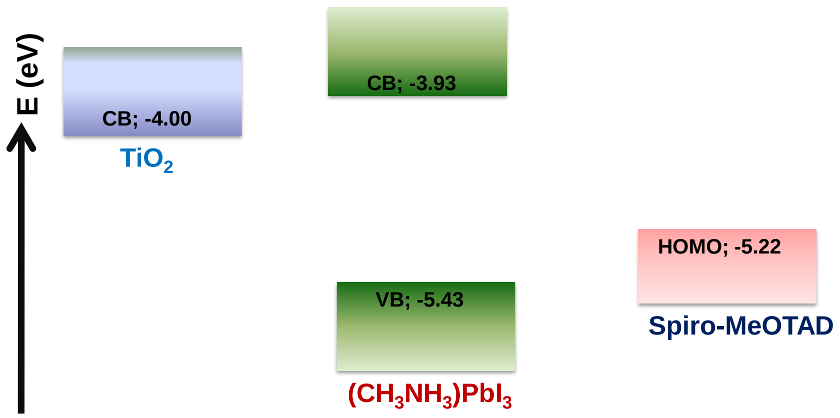
V_{OC} = 0.24V

5. Consider schematics of a proton exchange membrane fuel cell (PEMFC) shown in Figure below. Explain the principle of operation of PEMFC.



6. A lithium-ion battery designed using $LiCoO_2$ cathode versus Si anode is expected to have high energy density (~400 *Wh/kg*) but less cycle life (< 200). Explain the reason.

7. Figure below shows the energy diagram of a TiO_2 based perovskite solar cell:



Using above diagram, show all electron and hole transfer processes. Also indicate all possible recombination processes. Mention which one is the predominant recombination process.

8. Describe briefly each of the following recombination mechanisms using schematic diagrams.
   (i) Band-to-Band recombination in direct band gap material
   (ii) Shockley-Read-Hall recombination in indirect band gap material
   (iii) Auger recombination in indirect band gap material

9. Using schematic diagrams, describe four possible loss mechanisms in silicon solar cell (each in one or two sentences).

10. Multiple Exciton Generation (MEG) is a well-known phenomenon in quantum dot solar cells.
    (i) Describe MEG process in quantum dot solar cells using schematic diagram.
    (ii) We do not observe a similar MEG process in bulk Si solar cells. Explain the reason using schematic diagram.