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PHOTO VOLTAIC CELLS, EFFICIENCY AND OPTIMIZATION.

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ABSTRACT

A specific review of the five principal types of wide bandgap photovoltaic materials are described with interest in their band diagram (a time independent kind), activities of charge carriers in valence and conduction bands for solid base and electron transfer in electrolytic and dye-sensitized photovoltaic cells. Various types of photovoltaic activities and average efficiencies are identified. Detailed studies on each cell type thence provide information on the photovoltaic activities to be optimized and suggestions are advanced in the fabrication of the ecologically-friendly and renewable photovoltaic cells.

KEY WORDS: Photovoltaic, Generation, Recombination, Diffusion, Cells.

INTRODUCTION

In the renewable solar energy utilization for production of photovoltaics, the cells considered are Homojunction, Heterojunction, Buried junctions, Schottky barriers and Semiconductor electrolytes and dye sensitized nanocrystalline solar cells. Due to the importance of finding alternatives to longtime expensive, non-renewable hydrocarbon fuel and non-mobile hydroelectric energies (Sayigh, 1977 and Rapp, 1981), detailed study of the available solar cells is important for higher solar-electric energy conversion.

According to Stambolis, (1980), Fahrenbruch and Bube, (1985), the major areas of concern for utilization and production of electricity from photovoltaic are:

(a) Productions of long life span and low-cost solar cells from semiconductor junctions.

(b) Use of concentrators such that more solar radiation is focused on photovoltaic cells.

(c) Optimization of solar cell produced from various junctions.

Fig. 1a

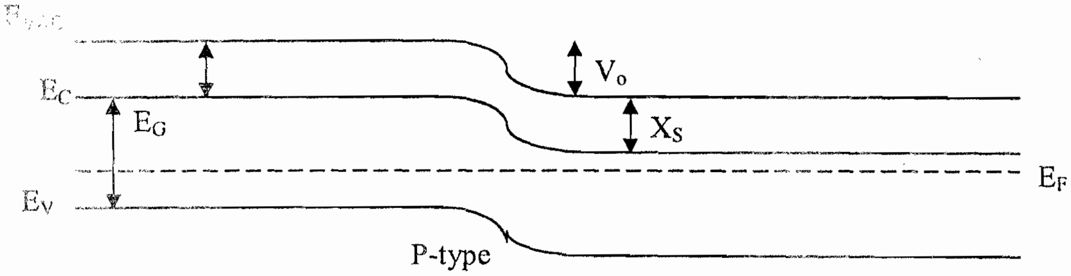

Fig 1b

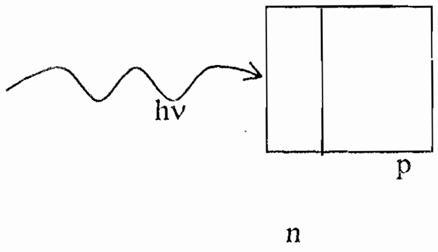

Fig. 1 Band diagram for homojunction structure

Figure 1 shows the different energy boundaries and electronic parameters in an homojunction solar cell, E_{VAC} is the vacuum energy level, V_o is the diffusion voltage, X_S is the electron affinity, E_C is the conduction band, E_F is the Fermi energy level, E_G the energy gap, E_V the valence band and the n- type which is exposed to light.

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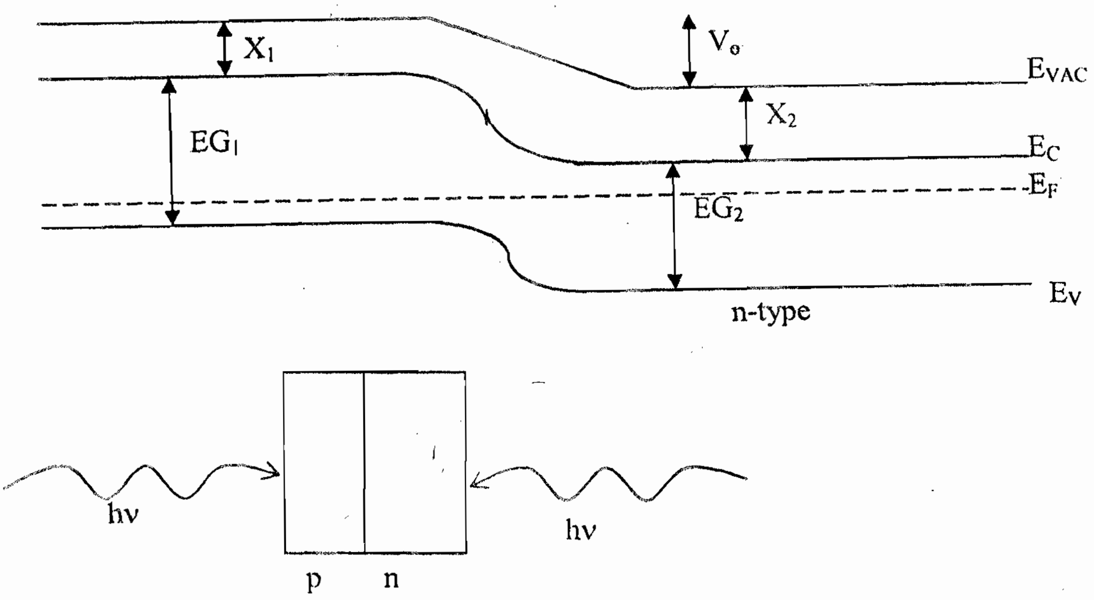

Fig. 2 Energy band diagram of a p-n semiconductor heterojunction.

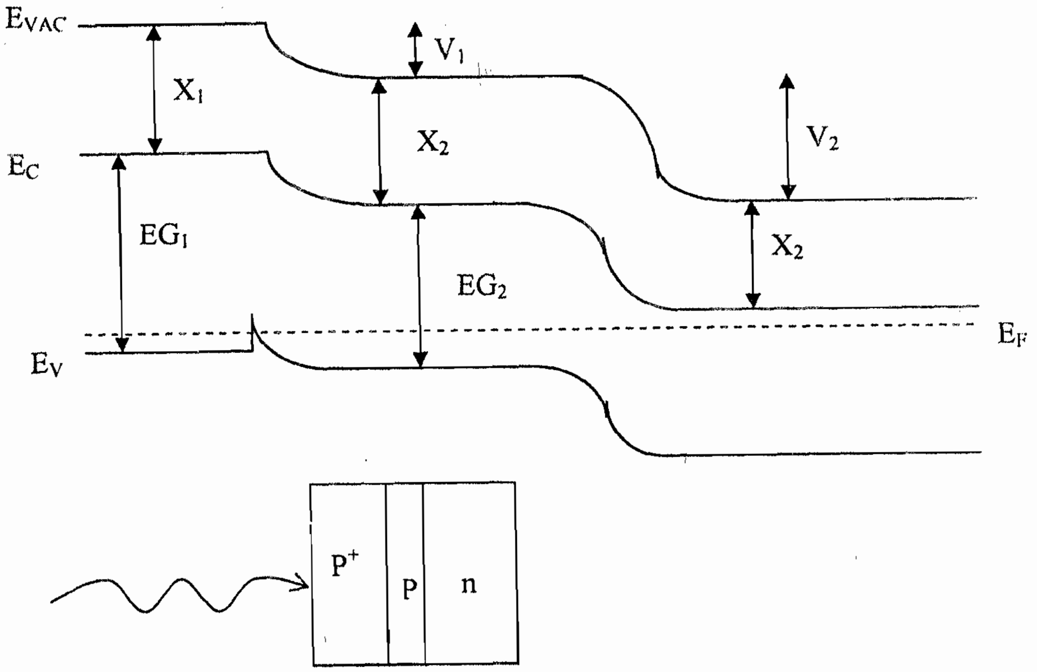

Fig 3 p^+-p-n semiconductor buried junction.

This present study is based on properties and efficiency of each solar cell as this will show what is to be optimized in a particular kind of cell and which cell to produce in large quantity thereby lowering the utilization cost of solar cells.

THE PHOTOVOLTAIC CELLS

Homojunction Solar cells.

A homojunction solar cell is formed between two portions of the same material, but with one portion dominated by n-type conductivity while the remaining portion is dominated by p-type conductivity. A typical example is the Silicon solar cell with band diagram as shown below in fig.1 (Fahrenbruch and Bube, 1991). The n-type region should be thin approximately equal to diffusion length of Silicon (Si) or Gallium Arsenide (GaAs) so that recombination of light generated electrons do not occur before they are collected in the hole of the p-type region where recombination takes place. Nanocrystalline Silicon or gallium arsenide can also be used for increased efficiency from that of Single crystal silicon of efficiencies 15-17% for air mass 0

AM0) radiation or GaAs with 19% efficiency at sunlight oncentration ratio 1700.

Figure 1 shows the different energy oundaries and electronic parameters in an omojunction solar cell, E_{VAC} is the vacuum energy evel, V_o is the diffusion voltage, X_S is the electron ffinity, E_C is the conduction band, E_F is the Fermi nergy level, E_G the energy gap, E_V the valence band nd the n- type which is exposed to light.

eterojunction Solar cell.

In heterojunction cells, the thicknesses of lectron affinities X and energy gaps EG are different on oth sides of the junctions due to the different ompounds of II-VI and III-V groups forming the nultijunctions. The values are chosen so as to eliminate spike formation in the junctions. Examples of such unctions are found in CdS/Cu_2S, $CdS/CuInSe_2$ and Cu_x/CaS photovoltaic cells with efficiencies up to 14%. There are also works going on for production of cheaper (to fabricate) but low efficiency (less than 5%) polymeric semiconductor heterojunctions from (Polythiophenes) PT, (Polyphenylenevinylenes) PPV, poly(3,4-ethylenedioxythiophene) PEDOT and poly(3-(2,5-octylbiphenyl)-thiophene) PTOPT (Bantikassegn and Inganäs, 1997). The mixed junctions allow electron generation possible at both sides with more electrons generated at the predominant n type side. To produce more efficient heterojunction cells, the p-type material should have smaller bandgap such that diffusion lengths of photoexcited electrons are longer than those of holes so that the flow of electrons is more (Landsberg, 1989, Fahrenbruch and Bube, 1991). Band diagram of heterojunction cell is given in fig.2.

Buried Solar cell.

A buried junction photovoltaic cell is made up of a combination of heterojunction and homojunction.

The buried narrow p-type region is between the p^+-p heterostructure through which photons are incident on the n-type region. There are two diffusion voltages V_1 and V_2 as there are two graded junctions in the energy band diagram., the electron affinities and bandgaps also vary providing more avenue to test for higher solar cell's efficiency adjustment. The p-type region in p^+-p heterojunction structure could be replaced with thin n-type or n type placed in between the p^+-p junction so that more electrons are available to flow from n-type to p-type heterostructures for higher photovoltaic efficiency. A major example of buried junction cell is the p^+-GaAlAs/p-GaAs/n-GaAs, with band diagram as shown in figure 3.

Metal-Semiconductor (Schottky barrier) Solar cell.

In a metal and a semiconductor junction solar cell the charge carriers flow from the semiconductor to the metal with the depletion or transition region in the semiconductor. For electron to flow from semiconductor to the metal, the work function of the metal should be more than that of the semiconductor (Kittel 1971, Bube 1985, Fahrenbruch and Bube 1991). More modification of a junction of this nature is possible with introduction of thin insulator or an oxide at the junction to increase its efficiency of about 5.5% for Platinum schottky barrier on amorphous silicon. Fig. 4 gives the energy band diagram of a Metal-Semiconductor junction.

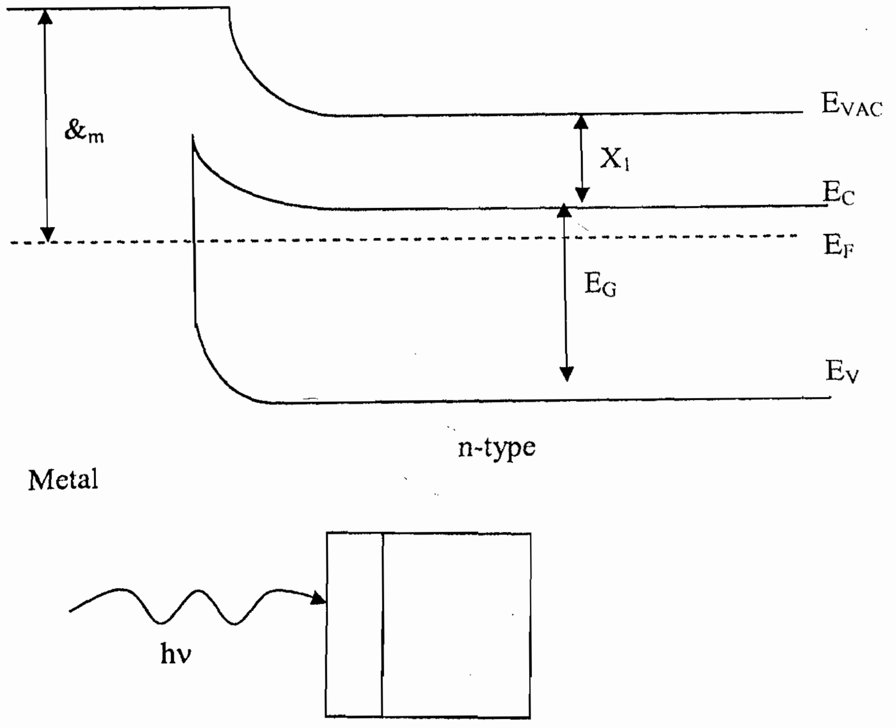

Figure 4. Energy band diagram of a Metal-Semiconductor junction.

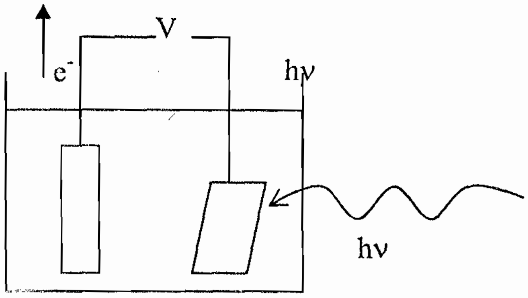

Fig. 5 Semiconductor electrolytic solar cell

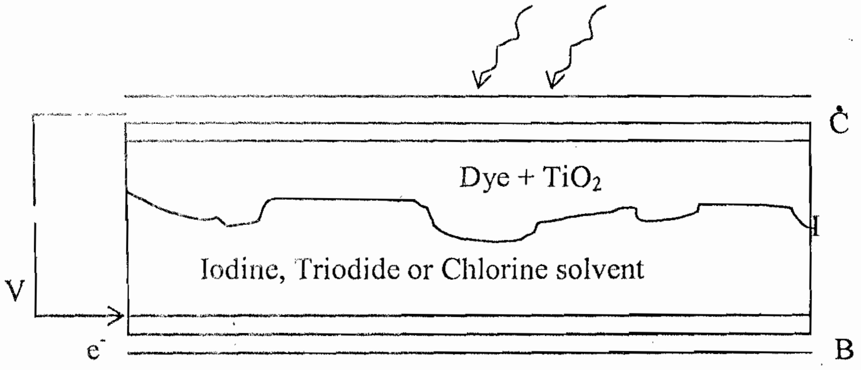

Fig. 6 Nanocrystalline dye sensitized electrolytic solar cell. C is conducting wire mesh, I is the interface while B is glass enclosure.

Semiconductor electrolytic and Nanocrystalline dye-sensitized electrolytic solar cells.

In the semiconductor-electrolyte junction solar cell, the two events or phenomena taking place are the photoelectrolytic and photoelectrochemical cell performances. Cu_x/CaS heterojunctions are rich sources of electrolytic event. A practical set up could involve a large bandgap semiconductor and a copper electrode used in water electrolyte. The semiconductor when exposed to light generates electron hole pairs,

The electron-hole pairs dissociate water and current flows through the copper electrode. Indium phosphide, a wide direct bandgap material, can be used for higher efficiency. A suggested experimental set up is given in figure 5. In a dye-sensitized electrolytic nanocrystalline solar cell, a positive electrode is connected to the layer of about 20 nanometer diameter TiO_2 crystal mixed with dye which is exposed to photons while iodide electrolyte is below the crystal mix where the negative electrode is connected. The efficiency of up to 24% is realizable (Bach et al 1998). The dye-sensitized electrolytic nanocrystalline solar cell constitutes a research success due to its low cost solution processing, robust, lightweight and high photovoltaic efficiency. A suggested experimental diagram is as shown in fig. 6.

CONCLUSION

A material for fabricating solar cells should be cheap to acquire, purify and use, the attempt on polymer based cells is thus a good development. The efficiency of a single cell is low (less than 25 %) hence they do not utilize good proportion of the solar energy incident on them. The dye sensitized solar cells are promising but the dye should be made more sensitive to wider photon energy range (1.3-1.5eV) for increased efficiency. More research on antireflection coatings and stacking of different cells with bandgaps covering the incident energy of the photons would be a good attempt at achieving higher efficiency. Reduction or elimination of interface state recombination loss is also suggested during fabrication of solar cells.

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