The importance of renewable energy sources

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Abstract

Today’s political considerations to move the world’s energy consumption away from fossil fuels such as oil, coal and gas has increased the focus on renewable energy . Renewable energy is perceived as a sustainable solution to ensure future energy supply as well as being carbon dioxide emissions free or neutral. Solar energy is by far the renewable energy source with the greatest potential . It has the ability to cover the world’s energy demand several thousand times over and, unlike fossil fuels, solar energy is readily available world-wide. solar cells are commonly used in remote regions with no access to the power grid or in private homes as a green alternative to fossil fuels. As a result a mere 0.04 % of the world’s energy supply came from solar photovoltaics in 2006 [10]. Solar cells are generally divided into two categories: 1- conventional, 2- dye-sensitized and polymer. In this article, an attempt is made to introduce solar cells as a clean and renewable energy in order to take a positive step towards more use of this new energy.

Keywords: electron, organic-inorganic solar cells, photon

1. Introduction

The growth of global energy consumption in the last century and the accompanying increase in greenhouse gas emissions have been associated with more environmental pollution and irreparable damage to vital resources. In order to reduce the global dependence on natural resources that are exhaustible and environmentally destructive fuels, many scientific efforts have been made to reduce the costs of energy production from renewable sources. Attempts to produce electrical energy using sunlight, which has been made using the inherent properties of semiconductors. The first solar cells based on semiconductors, whose efficiency reached more than 10%, were made in 1950-1960. Currently, 85-90% of solar photovoltaic components worldwide are made on the basis of thin crystalline silicon tablets and the use of semiconductors has created a huge transformation in the optical and electronic industries. Today, since a major part of energy is made up of fossil fuels such as oil, coal and natural gas, therefore, the expansion of diverse and renewable energy sources is necessary to reduce the emission of carbon dioxide, methane and other harmful substances. In recent years, the use of this energy source has led to the creation of furnaces and energy-converting solar cells. A solar cell is a device that converts the sun's energy into electricity through the photovoltaic effect (direct conversion of solar energy into electricity) without connecting to an external voltage source [1].

2- Spectrum of the sun and photons

The colors of the spectrum show that sunlight can be divided into different colors. Also, the use of very close parallel lines, as a diffraction grating, shows that colors can be related to line spacing. This means that each wavelength corresponds to each color. Therefore, light is an electromagnetic wave and a wavelength can be attributed to it. Light, on the other hand, travels as tiny packets of energy, which behave like particles and are called photons. The solar spectrum is shown in figure (1) [2]. In a solar cell, electric force is created as a result of absorbing photons, producing electron-hole pairs and passing them through a voltage. Semiconductors inherently have a threshold absorption energy that determines the voltage an electron sees in the semiconductor. For example, in figure (1), the absorption threshold energy for silicon is 1.1 eV, which is equal to 1.1 micron. Photons with energy less than 1.1 eV are not absorbed and solar energy with wavelength greater than 1.1 micron is wasted .

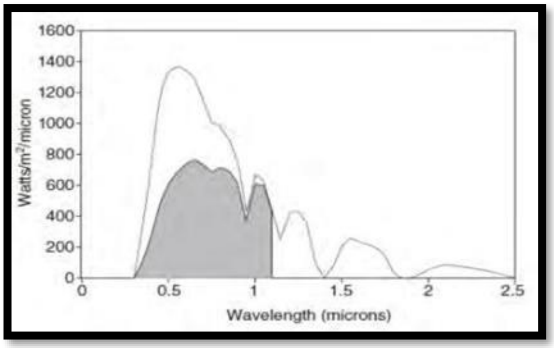

Figure 1- The spectrum of the sun at 1.5 AM, the gray area is the usable photon energy for the silicon solar cell [2].

Photovoltaic phenomenon occurs only with some wavelengths, because light packets (photons) must have a minimum energy to excite the electrons of matter. Part of the photons that do not have enough energy to excite the electron in the molecule or semiconductor are not absorbed by the photovoltaic material. On the other hand, if the energy of the photon is greater than the energy required to excite the electron, the excess energy is wasted. These two phenomena cause 70% of the sun's energy to remain unused [3]. Among the applications of hematopoietic cells, the following can be mentioned [4]

• Providing the necessary power for the movement of cars and small boats

• Providing electricity to the city by photovoltaic power plants

• Providing the necessary energy for devices that require low voltages (such as calculators and clocks)

• Providing power for the movement of satellites and spaceships

Figure2- Images of the use of solar cells [5]

3- Some properties of semiconductors

In order to generate electric power, a solar cell needs to generate flow and voltage. flow generation requires mobile charge carriers and voltage generation requires a gap between electron energy levels. Free charge-carrying metals and insulators have a band gap between electronic energy levels, but semiconductors have both properties. In order to increase the conversion efficiency of the cell, effective charge separation should be done, which depends on factors such as the diffusion length of electrons and holes [6].

Some properties of semiconductors include:

● Strip structure

● Direct and indirect band gap in semiconductors

● Carrier transfer in semiconductor

● Recombination

For a solar cell, the processes of production of electrons and holes and their recombination are of the greatest importance, so we examine them.

3-1- Intrinsic and non-intrinsic semiconductors

When the electrons and holes produced by impurities in the semiconductor are much less than the electrons and holes produced by heat, it is called intrinsic semiconductors. In semiconductors, the band gap is in the range of 0.5-3, which leads to the creation of electrons in the conduction band and holes in the valence band. In intrinsic semiconductors, where the electrons and holes produced by impurity are much less than the electrons and holes produced by heat, the Fermi level is located close to the middle of the band gap. In non-intrinsic semiconductors, where the electrons and holes produced by impurity are negligible, the Fermi level is controlled by the concentration of donor or acceptor atoms.

2-3-Optical absorption processes

When the photon energy is greater than the band gap, the incident photon will be absorbed in various ways. The probability of photon absorption with energy is determined by the absorption coefficient (it is a property of the material and is independent of the geometry of the object) [2-3]. Figure (2) shows a diagram of different processes of absorption of electromagnetic radiation in solids and the range of their effect according to the absorption coefficient of the material and the frequency of light. If an equation is longer than 82 mm, it should be broken into two or three lines. To adjust the length of the equation, never reduce it using the mouse [7].

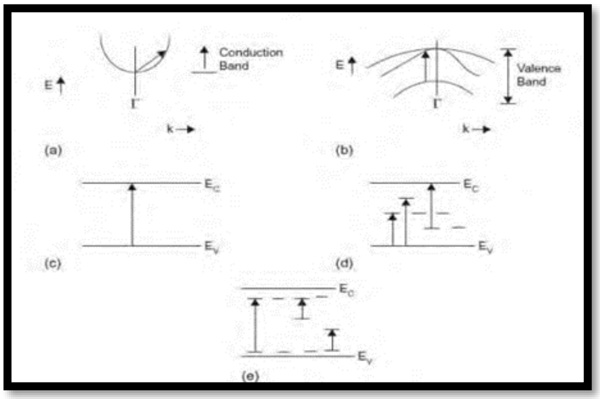

Figure 3- Diagram of electron transition between single electron states as a result of light absorption [7].

4- Separation of charge carriers in semiconductors

For a solar cell to work, it needs free charge carriers. First, with light irradiation, electrons are excited to the conduction band and corresponding holes are formed in the valence band, which is called the separation of excitons (electron-hole pairs). However, the excited electrons return to their ground state, which can be done in several ways. When an electron makes a transition from the conduction band to the valence band, an electron-hole pair annihilates. The process of electron and hole annihilation is known as recombination. If the energy released through recombination is in the form of a photon, the process is known as radiative-recombination and is most common for electrons moving fully from the conduction to the valence band. Recombination may be accompanied by the emission of a photon. This type of recombination is called non-radiative.

5- Types of solar cells

Solar cells can be divided into two distinct categories: conventional solar cells, such as silicon p-n junctions, and excitonic solar cells (XSCs). Most of the solar cells based on organic materials, including dye-sensitized solar cells (DSSC and Polymer-Inorganic Hybrid Cells), are classified as XSCs. In these cells, electron excitation due to light absorption produces bound electron-hole pairs, which are called excitons [8].

5-1- Conventional solar cells

Conventional solar cells, epitomized by the silicon p-n junction cell, were invented in the 1950s and first commercialized in the 1960s for use in the space program.1 Since then, there have been rapid advances in the efficiency and reliability of these cells, along with substantial decreases in cost. The nascent photovoltaic industry has been growing rapidly as a result of these advances. Nevertheless, the price of solar power is still greater than the price of power from the electrical grid in industrialized nations, partly because the costs of the pollution generated by conventional power sources are not included in their prices. There is an increasing amount of research devoted to potentially less expensive types of solar cells such as those based on organic dyes and pigments;2-5 these have been studied since the late 1950s,6-8 albeit at a fairly low level until recently. One of the great promises of organic electronics is that, once the physical requirements for a certain application are clearly understood, synthetic chemists can produce compounds having these characteristics. For the moment, however, the primary challenge is still to understand the physical requirements. A fundamental difference between organic solar cells and conventional solar cells was recognized almost immediately: light absorption results in the formation of excitons in organic materials rather than the free electron-hole pairs directly produced in inorganic semiconductors, such as silicon.8-10 An exciton in an organic semiconductor (usually a Frenkel exciton)11 is sometimes considered to be a bound electron-hole pair. However, because of its electro neutrality and the strong binding between the electron and the hole, it is often better characterized as a mobile excited state.12 Although the distinction between the photo generation of excitons in organic semiconductors and of free electron-hole pairs in inorganic semiconductors was made early on, the consequences of this distinction are just beginning to be fully appreciated.12-15 This paper examines the fundamental changes in photo conversion mechanism caused by this difference. With minimal oversimplification, I believe it is possible to separate existing solar cells into two distinct categories on the basis of their charge generation mechanisms: conventional solar cells and excitonic solar cells. The latter category, XSCs, consists of cells in which light absorption results in the production of a transiently localized excited state that cannot thermally dissociate (binding energy . kT) in the chemical phase in which it was formed. Examples of XSCs include molecular semiconductor solar cells,16-19 conducting polymer solar cells,2,3,20-27 dye-sensitized solar cells (DSSCs),4,5,15,28-31 and probably also the proposed, but not yet realized, quantum dot solar cells.32 In all these cases, charge generation via interfacial exciton dissociation results in a photo conversion mechanism that is fundamentally different from that in conventional solar cells .

5-2- Dye-sensitized solar cells (DSSC)

Dye-sensitized solar cells (DSSCs) have become one of the most promising low-cost alternatives for the photovoltaic conversion of solar energy compared with the conventional solid p–n junction photovoltaic devices [1], [2]. The heart of a DSSC system is a mesoporous oxide layer composed of nanometer-sized particles anchored by a monolayer of the charge transfer dye such as Ru-poly pyridyl-complex [2]. High performance and good stability of DSSCs based on Ru dyes had been obtained in the literatures [5]. However, the Ru dyes are facing the problem of costs and environmental issues.
Metal-free dyes, which have many advantages such as large absorption coefficients (attributed to an intramolecular π–π* transition), easily molecular design for desired photophysical and photochemical properties, inexpensive and environment friendly [6e,6g], are also adopted as sensitizers for DSSCs. But the efficiencies of DSSCs based on metal-free dyes are much lower than that of Ru dyes based solar cells. Recently, DSSCs performance based on metal-free organic dyes has been remarkably improved by several groups [5]. A much higher solar-to-electric power conversion efficiency of up to 9% in full sunlight has been achieved by Ito et al. using an indoline dye [14]. This result suggest that smart designed metal-free organic dyes are also highly competitive candidates for solar cells due to their low costs and easy synthesis.

5-3- Polymer solar cells

Polymer solar cells are typically comprised of a photon absorbing active layer sandwiched between two electrodes and placed on a substrate of glass or clear plastic foil [3]. One of the electrodes is transparent in order to allow photons to penetrate into the absorbing layer. Indium tin oxide (ITO) is commonly used as transparent electrode and metals like aluminum, calcium or magnesium as the other electrode [7] (cf. figure ٤). The absorbed photons excite electrons in the active layer and thereby promoting them from the highest occupied molecular orbital (HOMO) to the lowest unoccupied molecular orbital (LUMO) within the polymer.[7] The excitation of an electron leaves behind an empty electron space in the HOMO level called "a hole".[14] The hole and the excited electron are not totally independent but associated to one another in a form called an exciton.[2] In most organic molecules excitation is followed shortly by relaxation, typically in the form of recombination when the excited electron falls back into the hole.[10] This releases the absorbed energy as either radiative or non-radiative energy which cannot be utilized for electricity. In polymer solar cells recombination still occurs but not right away.[9] Instead the exciton is separated into a free hole and a free electron which are then transported to different electrodes due to differences in the electrodes' ionization energy.[7] The electron is then forced to travel from one electrode through an external circuit to the other electrode in order to recombine with the hole. The absorbed energy can then be utilized in the external circuit.[8]

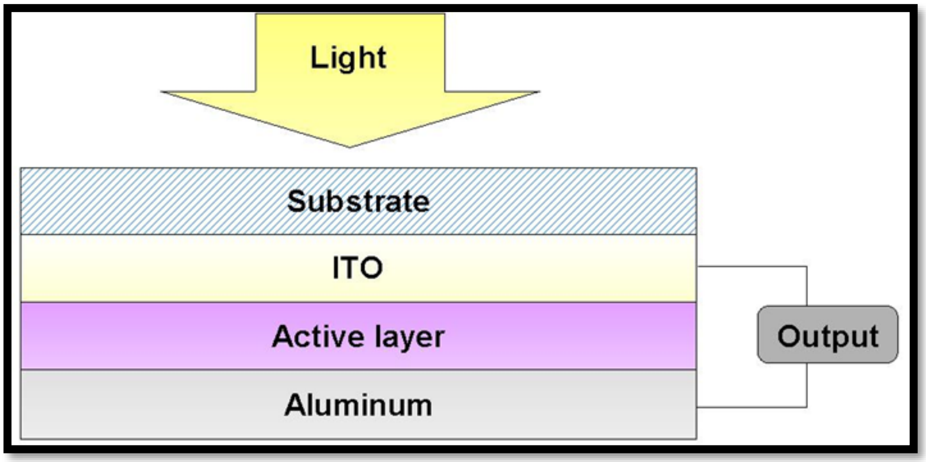

Figure 4. Schematic presentation of a polymer solar cell. The active layer is sandwiched between two electrodes, aluminum and indium tin oxide (ITO) which is transparent. The sandwich structure is placed on a substrate of glass or clear plastic

The separation of the electron from the hole in polymer solar cells is achieved by utilizing an electron accepting material along with the electron donating polymer. The electron donor and acceptor are mixed to form a heterogeneous active layer.[14] This type of device is known as a bulk heterojunction solar cell.[10] The charge separation occurs when an exciton has diffused to the donor/acceptor interface .[3] Here a difference in potential of the two phases pulls the electron into the electron accepting phase leaving behind the hole in the electron donating phase. The electron and the hole are then free to move through their respective phases to the electrodes [9] (cf. figure 5).

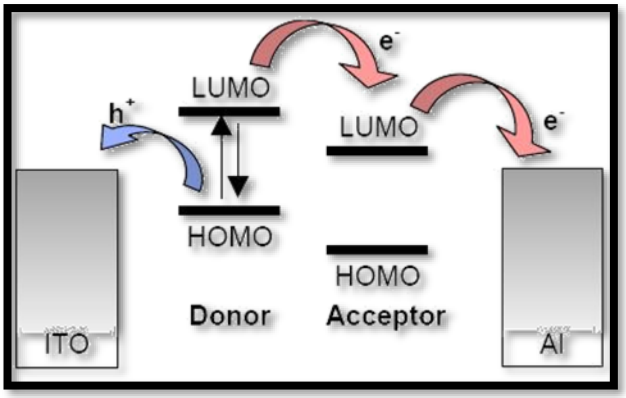

Figure 5. Charge separation within the active layer. Upon excitation the electron is transferred into the electron accepting phase due to an offset in the LUMO levels of the donor and acceptor materials. Charges are then transported to their respective electrodes

6- Technologies of photovoltaic systems

Photovoltaic cell converts sunlight directly into electrical energy. The basic principle in this technology is the "photoelectric" phenomenon, which was first proposed by Einstein. The basis of the work of solar cells can be justified based on the theory of electrons in atomic orbits. On the outer surface of the energy level of the atom, there are two distinct levels. The valence level of the atom (valence), which is involved in chemical operations, and the conduction level of the atom (conduction layer), which plays a role in electrical conductivity. If an electron that is in the valence level is given more energy than the gap energy, it is transferred to the conduction level and creates an electron and a free hole. Therefore, this property is used to make N and P type semiconductors. As a result of the impact of light on the surface of the PN type semiconductor and the acquisition of energy gap, charge carriers (electron-holes) are created that can move inside the semiconductor and generate electricity.

7- Conclusion

Today, we are facing two major crises that are more related to each other than we seem to recognize. On the one hand, industrial societies as well as big cities are facing the problem of environmental pollution, and on the other hand, it can be seen that the raw materials and fuel needed by these machines are running out with increasing speed. Solar energy as a clean and renewable source can be introduced as a suitable alternative to fossil fuels. Renewable energy sources derived principally from solar energy have been gaining ground over the last few years and are now beginning to contribute to the global energy mix. Solar energy in the form of direct electricity conversion (photovoltaics) is already very popular in countries such as the United States, Germany and Japan. Finally useful insight into the performance of the PV systems as a function of the meteorological conditions and location will be highlighted.

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