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Investigation Factors In Nano-Structure Photovoltaic System Design

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Abstract: Nano science and technology are proposing new and interesting ways to deal with current challenges in making solar cell nano structures. Large-scale production requires not only designing some devices for creating high efficiency and sustainability, but also requires the ability to produce uniform and orderly films in great area. For this purpose, in the first phase, a process is required for economic production of semiconductor nano-structure arrays in large-scale. In recent years, the dye – sensitized nano-structured solar cells (DNSC) based on nano- structured metal oxide films have attracted much attention to themselves. These cells are promising of the photovoltaic energy conversion with spending low costs. By using these cells, the efficiencies of converting solar energy into electrical energy have been obtained as more than 10%

Key words: photovoltaic Cells, Nano-Structure ,Electricity, Radiation, Solar, Power

INTRODUCTION

Photovoltaic systems are energy-generating systems that are produce electricity from the sunlight radiation without taking advantage of moving and chemical mechanisms. In other words, these systems produce a clean and reliable energy without using fossil fuels.

Research related to photovoltaic technology has begun since one hundred years ago. In 1873, "Vilogbi Smith" (1973), an English scientist, realized the Selenium sensitivity to the light. He concluded based on his own experiments that the ability of selenium to conduct electricity has a direct relationship with the amount of light radiated to it. In 1880, "Charles Fritz" (1883) could build the first electric solar cell by using selenium. This product was generating electricity without the use of raw materials and without generating heat and noise. However, this research remained stagnant until 1905, when "Albert Einstein" (1905) presented his theory about the photovoltaic effect. Einstein's theories created an evolution in the electricity production process. But due to high costs and low production efficiency, slow progresses were obtained in this field. Then, until the early 1950s, the "Bell" (2003) laboratory scientists during their investigations on telecommunications systems and discovering the new energy sources realized the sensitivity of silicon, the second abundant element on earth, to the sunlight and found that when this matter is used with a given impurity, will generate energy with significant voltage against the light radiation. In 1954, they produced the first silicon solar cell with 60% efficiency and for the first time, this technology was used in the rural telecommunication station in Georgia State. In NASA, in order to generate abundant, light, reliable and appropriate energy in outer space, the scientists installed a system comprises 108 solar cells on the "Vanguard" (United States Naval Research Laboratory, 1960) satellite in the early 1960s. Since then, the photovoltaic systems have been used on most of the satellites and spacecrafts. After then, the photovoltaic systems were used in a widespread area of needs. The silicon cells, which are made from 1 ton of sand, can produce an amount of electricity equivalent to burning of 500,000 tons of coal during their lifetime.

The solar cell usually produces peak voltages that are roughly equivalent to the two third of the semiconductor energy gap. The optimal energy gap is equal to 1.0 e.v. and 1.7e.v. In a clear day and when the sun is overhead, the sunlight intensity is approximately as 1000 w/m^2. The solar module with an efficiency of 10% can produce a power about 100 volts on a sunny day. With solar radiation and no cloud, 6 hours per day on average, a number of solar modules with an area of 60 square meters produce approximately 1000 kWh of electricity per month, which is approximately the same electricity that the families in countries like United States of America use monthly.

The Advantages Of Photovoltaic Technology (Richard, M., 2009):

A. Durability: The durability of these systems has been about 10 years in the past, but the average useful life of these systems has reached to 25 years.

B. Low maintenance costs: In non-renewable resources system, the costs of material transportation and labor are very high. But in photovoltaic systems, there are no such costs in the production cycle. Since, the system needs periodic inspections and occasional low-cost maintenance. C. No need for fuel materials D. Reduced noise pollution E. Ability to install and launch photovoltaic systems in various capacities: a few milliwatts to several megawatts of energy F.lack of dependence on urban electricity network

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Disadvantages Of Photovoltaic Technology (Mohring, H.-D., D. Stellbogen, 2008):

A. Set up costs B. Strong dependency to solar radiation C.Need for energy storage D. lack of people's familiarity with photovoltaic system

The Advantages Of The Solar Cells' Nano-Structures:

Nano science and technology are proposing new and interesting ways to deal with current challenges in making solar cell nano structures. Large-scale production requires not only designing some devices for creating high efficiency and sustainability, but also requires the ability to produce uniform and orderly films in great area. For this purpose, in the first phase, a process is required for economic production of semiconductor nano-structure arrays in large-scale. This process must have the following conditions.

A. The size and composition of the nano-structure materials can be changed.

B .It can use a variety of substrate with more advantage.

C .It should be compatible with methods of manufacturing based on standard silicon carbide.The key aspects, which increase the efficiency of nano-structured solar cells, include:

A .Increasing the amount of light collection B. Increased charge transmission from free carriers

In this context, the nano-structure layers create three important advantages in thin layer solar cells:

A. Due to scattering, the effective optical path to attract is larger than the actual thickness of the film.

B. The electrons and holes produced by light need to move on a shorter path to prevent the charge recombination greatly. For example, the thickness of the absorbent layer in nano-structures can be as thin as 150 nm, while in the conventional thin layer solar cells, this thickness is a few micrometers ()[19-20].

C. By changing the size of the nanoparticles, the band gap energy can be changed to the desired size to achieve the optimal cell (quantum limitation). This allows the nano-structured solar cell design engineers to provide the valve and absorber layers in a more appropriate way.

To achieve the above three ways, which cause the increased efficiency of nano-structured solar cells, we will physically and technically study the nano-structured solar cells in this project.The method by which nano-dots with uniform sizes can be created and a controlled separation would be established between these points includes a form or a pattern that is applied on the surface and will be used as a guide for the next precipitant on the surface. In this regard, the technique of using a porous nano-film of alumina as a "negative template" can be mentioned to prepare the nano-dots and nano-wires. This technique is an ideal one to create metal or semiconductor nano-dots within the insulated matrix. The semiconductors and metals can be deposited into the alumina holes. In order to develop an analytical model for heterogeneous photovoltaic junctions in nano-scale, their optical- electronic properties and their electron transfer would be studied. The unique advantage of such an insulated mold or format allows us to achieve the followings:

A. Performing the annealing reactions without loss of crystallization at nano-scale.

B. Study of single nano-scale junction within the hole.

Also, if the thicknesses of the deposited material are as a few nanometers, a quantum dot (a structure that is in all three dimensions at nano-scale) will be obtained. It can be said that this method is economically a cost effective technique for preparing nano-structures in an extensive scale. In summary, the main features of this technique include:

A. Regular and uniform distribution of microscopic holes with several micrometers to several nanometers in diameter

B. Holes arrangement in the vertical direction with a high "depth to diameter" ratio in the almost identical intervals than to each other

C. The ability to control cells and holes diameter by changing the electrolyte composition and electrochemical processes

D. Reproducibility of making films for samples with large size (large films)

Silicon Carbide Nano-Structures For Solar Cells:

Today, nano-materials and nanostructures are not only the forefront of the hot researches on the fundamental material, but also have entered slowly and intrusively into our daily lives (Zhang, L.D., *et al*., 2007). The structures that have at least one dimension in the range of 1 to 100 nm are called nanostructure. They have attracted steadily a growing interest to themselves due to their attractor properties, the properties that emanate from their geometry (Yang, P.D., *et al.*, 2002; Sun, G., *et al.*, 2006). Depending on their shape, the nanostructures can be classified into several groups:

- 0-dimensional nanostructure (when they are uniform)
- One-dimensional nanostructures (when they are stretched and extended)
- Two - dimensional nanostructures (when have been flattened)

In recent years, the dye –sensitized nano-structured solar cells (DNSC) based on nano- structured metal oxide films have attracted much attention to themselves (Gao, Y.H. and Y. Bando,). These cells are promising of the photovoltaic energy conversion with spending low costs. By using these cells, the efficiencies of converting solar energy into electrical energy have been obtained as more than 10% (Xia, Y.N., *et al*., 2003) and long-term stabilities have been achieved (Yugang Sun and John A. Rogers, 2007). The function mechanism of the dye –sensitized nano-structured solar cells is completely different from the functioning of the conventional solar cells with p-n junction. But after several years of research, their mechanism has not been completely known yet.

Table 1: shows the comparison of physical and fundamental properties of silicon carbide with some others.

	Crystal structures	Band gap/eV	Exciton binding energy/meV	Work function/eV
ZnO	Hexagonal wurtzite	3.37	60	5.3
ZnS	Cubic zinc blende/hexagonal wurtzite	3.72-3.77	39	7.0
Si	Face-centered (diamond-like) cubic	1.12	15	3.6
WO3	The crystal structure of tungsten trioxide is temperature dependent	2.5-3.5	-	5.7
AlN	Hexagonal wurtzite	6.2	75	3.7
SiC	b-SiC (similar to diamond and zinc blende or aphalerite) is the general structure for 1D SiC nanostructures	2.30	27	4.0
CdS	Hexagonal wurtzite	2.42	29.4	4.2

The depletion area in solar cells (Salavati-Niasari, M., M. Sabet, 2010)]:

The empty depletion is ionized by the donor and acceptor ions depletion has charged, while the area beyond the depletion is electrically neutral.

We want to calculate the width of the depletion layer of a p-n junction with the sharp slope whose p-type semiconductor layer is doped with N_A for x<0 and the n-type semiconductor layer is doped with N_D for x<0 (Figure 1).

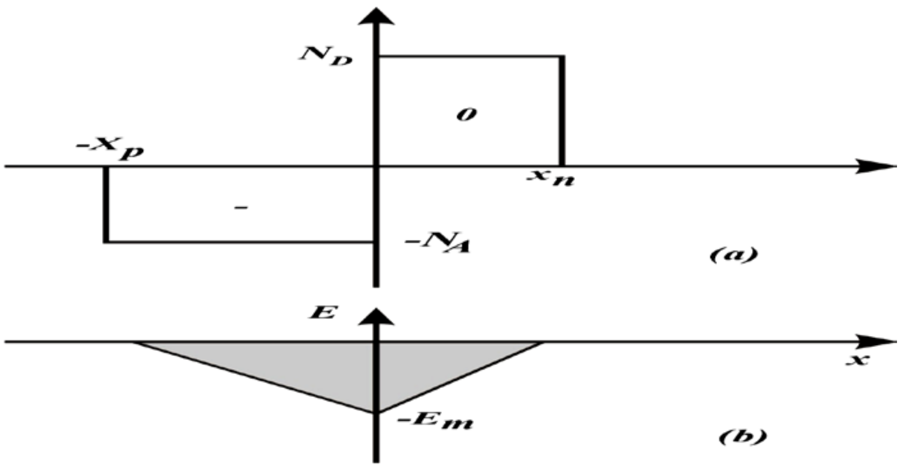

Fig. 1: a.The rectangular spatial charge estimation b. Distribution of electric field in junction

Ignoring the transition zone, xn and xp determine the width of the depletion layer in the p and n, respectively. According to the Poison equation, the electrostatic potential should be as follows:

$$\frac{d^2\varphi}{dx^2} = \frac{q}{\varepsilon} N_A \qquad (-x_p \le x < 0) \tag{1}$$

$$\frac{d^2\phi}{dx^2} = -\frac{q}{\varepsilon} N_D \qquad (0 \le x < -x_n) \tag{2}$$

The electric field is expressed as follows:

$$E = \frac{d\phi}{dx} = -\frac{qN_A(x + x_p)}{\varepsilon} \qquad (-x_p \le x < 0) \tag{3}$$

$$E = \frac{d\phi}{dx} = -\frac{qN_D(x + x_n)}{\varepsilon} \qquad (0 \le x < x_n) \tag{4}$$

$$E_m = {}^{qN_D}\!/_{\varepsilon x_n} = {}^{qN_D}\!/_{\varepsilon x_p} \tag{5}$$

$$V_b = -\int_{-x_p}^{x_n} E dx = \frac{qN_A Xp^2}{2\varepsilon} + \frac{qN_D Xp^2}{2\varepsilon} = {}^{1}\!/_{2} E_m w \tag{6}$$

It is equal to the area of a triangle (Figure 1-a). Total depletion width is equal to:

$$W = \sqrt{\frac{2\varepsilon}{q}\left(\frac{1}{N_A} + \frac{1}{N_D}\right)V_b} \tag{7}$$

Width of the depletion layer is increased when donor or acceptor concentration is low. When the impurity concentration on one side is more than the other, e.g. in $P^+ - n$, $N_A >> N_D$ the total width of the depletion layer is obtained as follows:

$$W = \sqrt{\frac{2\varepsilon}{qN_D}V_b} \tag{8}$$

Nano-Particles Quantum Size Effects In Nano-Structured Solar Cells:

When moving from the bulk state to the nano, the effects restriction at the nano-scale is partially felt. In nano-sized semiconductors, crystal dimensions for the development of the energy band bending are small and energy band is sensitive to surface conditions (Hagfeldt, A. and M. Gratzel, 1995; Kavan, L., *et al*., 1996). If the particle size is equal to or smaller than the electron spectrum scale (which is measured by the effective mass of electrons), we have to apply the instruction of entering the quantum confinement.

If semiconductor particles are equal or smaller than the Bohr radius, quantum confinement will affect electron spectrum (Bohr Radius in vacuum, a0 through $a_0 = h^2\varepsilon_0/q^2m_e = 0.523A^o$) . Donor electronic structure in the bulk and width semiconductors in which quantum confinement will start to interfere in electron structure is well obtained by the Bohr radius effective bulk from the following equation (Pankove, J.I., 1975):

$$a* = {}^{h^2\varepsilon_r}\!/_{q^2m^*} = \frac{\varepsilon_\infty}{{}^{m^*}\!/_{m_e}} a_0 \tag{9}$$

Quantum size effect can be directly observed for zinc oxide semiconductor particles with a size smaller than the Bohr radius of the material. For these particles (with a diameter less than nm), an increase in band gap energy occurs due to electron state constraints (Brus, L., 1986; Brus, L., 1984).

Coclusion:

Width of the depletion layer is increased when donor or acceptor concentration is low. When moving from the bulk state to the nano, the effects restriction at the nano-scale is partially felt. In nano-sized semiconductors, crystal dimensions for the development of the energy band bending are small and energy band is sensitive to surface conditions

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