Methods and analysis of factors impact on the efficiency of the photovoltaic generation

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Abstract. First of all, the thesis elaborates two important breakthroughs which happened in the field of the application of solar energy in the 1950s. The 21st century the development of solar photovoltaic power generation will have the following characteristics: the continued high growth of industrial development, the significantly reducing cost of the solar cell, the large-scale high-tech development of photovoltaic industries, the breakthroughs of the film battery technology, the rapid development of solar PV buildings integration and combined to the grids. The paper makes principles of solar cells the theoretical analysis. On the basis, we study the conversion efficiency of solar cells, find the factors impact on the efficiency of the photovoltaic generation, solve solar cell conversion efficiency of technical problems through the development of new technology, and open up new ways to improve the solar cell conversion efficiency. Finally, the paper connecting with the practice establishes policies and legislation to the use of encourage renewable energy, development strategy, basic applied research etc.

1. Introduction

Solar energy is the most important basic energy in all sorts of renewable energy, biomass, wind, and water are all from the oceanic solar energy etc. Through converting equipment change solar radiant energy into electricity, the photoelectric convert device is using photoelectric principle of semiconductor devices, to achieve the conversion between the sun light and the electric power. In the field of solar energy utilization, in the 1950s, there were two big technology breakthrough: one is the bell LABS developed 6% practical monocrystalline cells in 1954, the second is Tabor in Israel put forward the selective absorption surface theories and successfully developed the selective absorption coating the 1955. These two breakthroughs established technology base for solar energy utilization to enter the modern development period. With the development of the material and spiritual in people’s life, the energy resources is exhausting and environment is worsening, in addition to induce political and economic disputes in a lot of national and regional, even conflicts and war. In the 21st century, the world is facing the challenges of limited fossil fuels resources and higher requirements of environmental protection, so adhering the priority of energy conservation, improving energy efficiency, optimizing energy structure, relying on scientific and technological progress, the exploitation and utilization of new energy are particularly important. Based on the analysis the energy
crisis of the world is facing in 21st century, the influence factors of improving photovoltaic energy efficiency, this paper research the new technology in the efficiency of solar cells converting, and opening a new way to improve the efficiency of solar cells.

2. The development characteristics of solar photovoltaic power generation in 21 century

Solar power has the following features in 21st century: the first one is the industry will be developed with a high speed. The development of photovoltaic industry is one of the highest growth rate and most stable for many years, the prospection of photovoltaic energy has been recognised by more and more governments and finance circles, many developed countries and regions have set pv development planning, and photovoltaic energy is expected to be mankind's basic energy the middle of this century, the second one is the component costs will decrease, photovoltaic energy system’s installation cost is decreasing by 9-10% rate per year, by expanding scale, improving the level of technology and automation technology, improving the efficiency of the cells approach to reduce the cost. The third one is photovoltaic industry develop to larger scale and higher technical level. The fourth is film battery technology will obtain breakthrough. The fifth is the rapid development of solar building integrated and grid-connected generation system.

3. Analusis of working principle and producting material of solar cells

3.1 The principle of solar cells

Solar cells work principle is pv effect of p-n knot in semiconductor. When the object is irradiated by light, the charge distribution state is changed and produce emf and current. When the sun or other illumination irradiate semiconductor p - n knot, both sides of p - n knot will appeare the voltage. Every atom outer electron have fixed position, and is constrainted by the nucleus, after stimulated by the energy in the outside,it get rid of the nucleus, and become a free electron,and at the same time , its original place will leave a space (named cavity), electron is negative electricity, while cavity is positive electricity. Combine p-type and n-type semiconductor together which are mixed with two different type impurities. Because the diffusion of electron and cavity in the interface, p-n knot will be formed, and electric field will be formed too. When the sun light to p-n knot, the electron in semiconductor will releasing electron. Accordingly to produce electron - cavity, and under the potential field electron is drived to n area, the cavity is drived to p area, thereby n area have excess electron, p area have exceed hole, then, the Photo-electric is born near p-n knot which is opposite to the barrier electric field. Part of the Photo-electric offset potential field, the rest let p area have positively charged , n zones have negatively charged, which makes EMF on the thin layer between n area and p area. This is named the pv emf, when switching the external circuit there is electricity output. If dozens or hundreds of solar battery series connected or parallel connected to composite solar modules, in the sun radiation, considerable power output of electric power can be gained. Figure 1 gives a solar cells energy level.

3.2 Analysis of solar cells production materials

In principle, almost all the materials have pv effect, can be used as the base material of solar cells. So, in theory, all the semiconductor materials should be solar photoelectric material preparation. But
because of the following three aspects, not all of the semiconductor materials can be used solar photoelectric material in actual: the first one is the physical properties of materials, such as forbidden band width, carriers mobility, and light absorption coefficient, which makes some materials prepared for solar cell’s theory transform is very low, have no development and application value. The Second one is the preparation and purification of the material are difficulty, in the present technical conditions, not all of the semiconductor materials are used for preparation of solar cells which can achieved high purity. The third one is the cost of materials and the preparation of solar battery, if the relevant costs is too high, the development and application will have no meaning. Therefore, although there are many types of semiconductor materials, but the real actual application semiconductor materials in solar cell industry is short. In the 19th century, the researchers had found the semiconductor solar effect in selenium, that is to say in sunshine illuminate, semiconductor materials would appear current, but has not been widely studied and applied. Until the 1950s, due to the invention of silicon and germanium, the transistor of solar energy conversion is applicated. In 1954 monocrystalline silicon solar cells are developed, the photoelectric conversion efficiency soon more than 10%. Then, amorphous silicon, cast polysilicon, film polysilicon are all researched and applicable as solar photovoltaic material. In this period, compound semiconductor film materials, since it has appropriate forbidden band width and light absorption coefficient, therefore it is the important solar photoelectric material and is researched extensive.

Organic materials have strong light absorption ability, absorpt spectra is narrow, material energy gap can decreases with the increasing of conjugate length. When radiation of sunlight is AM1.5, after comparison between different maximum absorption curve of different energy gap, we know that narrow gap material (absorption peaks 600nm) is good to the absorption of sun energy. Organic materials’ absorption is usually in the visible region, most materials absorbs on the sunlight is no more than 40%, therefore improving molar absorption coefficient of the active material, reducing energy gap, letting material have a wide absorpt spectrum is the useful method to improve the sunlight absorption. To increase the problem of sun absorption, except through changing the molecular structure function design to improve the active material’s absorptipn, but also strong absorpt
characteristics materials can be introducing the device structure. Using them to absorb part solar energy, then through exciton diffusion to transferred it to active material, in active material occur exciton disintegrate process and induced current.

3.3 Performance analysis of solar cell devices

Solar cells have three important output characteristic parameters: the first one is open voltage, that is to say, when there is no current in the circuate, the produced voltage after lighting. The second one is the short-circuit current density (Jsc), that is to say when the extra electric field is zero, the current in the circuate. The third one is the fill factor (FF), it refers to the specific value between maximum output power (U\text{m}J\text{m}) and the product of open voltage short-circuit current.

When the load resistance of solar cells is zero (RL → 0), can detect short-circuit current of solar cells. When the load resistance of solar battery is infinite (RL → ∞), can detect the open voltage. Solar battery open voltage is relative to the spectral intensity, have no relation with the cells size. Solar cells open voltage is proportional to the incident spectral irradiance. An ideal solar battery have small series resistance Rs, while the leakage resistance Rsh is large. Because Rsh and Rs is respective tandem and parallel in the circuit, so in the ideal circuit, they are negligible, the current through load is

\[ I_L = I_{SC} - I_D \]  \hspace{1cm} (1)

Ideal p-n junction characteristic curve equation is

\[ I_L = I_{SC} - I_0(e^{qV_{OC}/A_kT} - 1) \]  \hspace{1cm} (2)

wherein, I0 saturation current when solar cells in the absence of light; q is electron charge; k\,B is boltzmann constant; A is constant factor. When IL=0, U is U\text{OC}, and can be expressed as

\[ U_{OC} = \frac{A_kT}{Q} \ln \left( \frac{I_{SC}}{I_0} + 1 \right) \]  \hspace{1cm} (3)

So the resulting fill factor (FF) is

\[ FF = \frac{U_{m}J_{m}}{U_{oc}J_{sc}} \]  \hspace{1cm} (4)

In the single-layer organic solar cells, the open circuit voltage value does not exceed the difference value between the two electrodes’ work function. Figure 2 shows the solar cells output three important characteristic parameters.

In the heterojunction between donor and receptors, open voltage have relation with LUMO and HOMO, also have relation with interface between the active material and the electrodes, light current is linear to absorpt light ntensity. Through a series study the characteristics of heterojunction which is formed by different levels of LUMO small molecular materials and donor MEH – PPV. We found that the receptor LUMO significantly affect the open voltage, the lower of LUMO is linear to open-circuit voltage.
Solar cells energy conversion efficiency is have three representations: external quantum efficiency ($\eta_{EQE}$) also is named input photo conversion efficiency ($\eta_{IPCE}$); the second one is internal quantum efficiency, $\eta_{IQE}$, which is named light conversion efficiency ($\eta_{APCE}$); the third one is $\eta$, the total conversion efficiency of the device, which is named power efficiency ($\eta_P$). The solar cells which is based on the dissociation mechanism of donor and receiver. $\eta_{EQE}$ is signified as

$$\eta_{EQE} = \eta_A \eta_{IQE} = \eta_A \eta_{ED} \eta_{ET} \eta_{CT} \eta_{CC}$$  \hspace{1cm} (5)

wherein, $\eta_{IQE}$ is internal quantum efficiency, defined as the ratio between the number of carriers and the number of absorbed photons by the device. $\eta_A$ is photon absorption efficiency; $\eta_{ED}$ is exciton diffusion efficiency; $\eta_{ET}$ is Exciton dissociation efficiency; $\eta_{CT}$ is free charge transport efficiency; $\eta_{CC}$ is charge collection efficiency. Cells power conversion efficiency is $\eta_P$

$$\eta_P = \frac{P_m}{P_{in}} = \frac{U_{OC} J_{SC}}{P_{in}}$$  \hspace{1cm} (6)

Defined as the ratio between the maximum output power $P_m$ and radiation power $P_{in}$.

4. Factors of affecting the efficiency of photovoltaic power generation and new technologies to improve efficiency

4.1 Factors of affecting the efficiency of energy conversion and the two major bottlenecks

In recent years, there are many problems in the application of solar energy technologies, especially the conversion efficiency of the battery technology has encountered many obstacles: the shading effects of grating on the surface of solar cell; the loss of surface reflection; the loss of optical transmission; the loss of internal composite; the loss of surface composite. The core of solar energy application is generating electricity, generating electricity system is like a mini power station, which absorbs solar light, and directly changes solar into electrical energy. Not only satisfying their own electricity demand, excess electricity can also be incorporated into the power grid. The key bottleneck of limited solar energy application is technical environment and policy environment. Interconnection model with solar power equipment based on urban and rural power grid, far higher power grid companies may not buying grid type household solar power equipment redundant power. Even if the government subsidies,
still quite difficult. To solve the key technical problems, is to reduce the cost of electricity can, in the true sense of the large-scale promotion.

4.2 New technologies to improve conversion efficiency

To solve these problems, the following new technologies are developed: Single-layer antireflection coating; laser carving groove buried grating technology; rongmian technology; back contact electrode, efficient back reflect technology; light absorption technology. With the application of these new technologies, issuing a series of studies which is focus on solar cell materials, conversion efficiency and stability, inventing many new types of cell, which is greatly enhancing the conversion efficiency of solar cells. In organic solar cells, three primary factors which is decide photoelectric conversion efficiency is the absorption of solar spectrum, exciton dissociation, free charge transfer. So when designing and choosing active material should pay attention to these characteristic to obtain high-performance battery device.

Improving the conversion efficiency of solar cells and reducing the cost of photovoltaic technology are the key. At present the impact of major obstacle to large-scale application of photovoltaic cells is its high manufacturing costs. In many power generation technologies, solar photovoltaic is still one of the highest cost, therefore, the main objective to the development of solar power generation technology is to design new battery structure by improving the existing manufacturing processes, to develop new battery materials, so the manufacturing cost is lower and improve the efficiency of photoelectric conversion. There are two main factors to improve the efficiency of photovoltaic solar cells: the first is how to make electron donor and receptor molecules in the mixture in the separate state; the second is how to expand the contact area between the two. In order to meet these two conditions, after studying the simulated new materials of molecular structure of the biofilm, hydrophobic side-chain and hydrophilic side-chain can be added, then to combine the two types of material to study the arrangement of the molecular structure, in order to form a liquid crystal state layered structure to improve the photoelectric conversion efficiency.

5. Policy support

- To strengthen publicity, improve the consciousness of developing and using solar energy. The potential crisis degree of China's energy and the ecological environment is more serious than the world average level. Strengthening propaganda, improving energy and environmental crisis consciousness and developing renewable energy sources, such as solar industry is necessity and urgency.

- Making the long-term development industry plan of photovoltaic. Organizing pv bounded experts of technical and economic aspects to make the plan, which make photovoltaic technology and industries developed coordinative and healthy.

- Encourage photovoltaic companies actively explore the international market. To reduce the company dilemma due to domestic policy delay, countries should give more capital and technical support. To export enterprises in formulating a policy.
- Develop standards for the production of photovoltaic and policies, regulations of PV industry development.
- Government support policies. Learn from the developed countries started to rely on government support market experience, through the Government's policy orientation and demonstration projects, in a given period, giving appropriate subsidies to the users who using solar photovoltaic products, gradually guiding solar PV products to be used in more fields, cultivating the domestic consumer market.

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