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Review of ways to improve the working efficiency of solar cells

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Abstract. Since the fossil energy is depleting day by day, the development of renewable energy is urgent. Solar energy is one of the most potential clean energy sources, and the efficiency of solar cells still has a lot of room to improve, which leads to their application scope not being wide. This paper aims to summarize the views of different scholars on ways to improve the efficiency of solar cells. Through experiments and numerical simulations, people try to overcome this problem, and they find that the material selection and surface treatment of solar cells can be optimized so that the efficiency of solar cells can be improved.

Keywords: Solar energy, solar cells, efficiency, renewable energy.

1. Introduction

Since the industrial revolution, the rapid development of science and technology has driven economic growth, which not only improves people's quality of life but also means that people's needs for consumption are rapidly increasing day by day. From 1960 to 2000, the world's population doubled from 3 billion to 6 billion. However, the growth rate has never slowed down, and by 2020, the world's population have exceeded seven billions. The explosive growth has resulted in an increase in food and energy consumption and a doubling of pollution. The shortage of energy will further affect the population[1]. Global energy demand has increased significantly, from 8.588 billion tons in 1995 to 13.147 billion tons. Unfortunately, the imminent depletion of fossil fuels means that we must look for and make fantastic use of other kinds of energy wisely in order to meet our growing energy needs with as little pollution producing as possible. We've made great progress in harnessing clean energy — wind power, hydropower, solar energy, and so on. Solar energy, giving meaningful value to human daily life, is one of the most widely used sources of sustainable energy. The utilization of solar energy includes solar power generation system, solar heating system, solar cells and so on. Among them, solar cells can convert light energy into electricity, which can be used in a various variety of fields of industry, such as daily electronic products, grid-connected power generation, to provide electricity resources for areas without electricity and so on. The utilization of solar energy includes solar power generation system, solar heating system, solar cells and so on. Among them, solar cells can convert light energy into electric energy, which can then be applied in various fields of industry, such as daily electronic products, grid-connected power generation, power resources for areas without electricity, and so on. However, the working efficiency of the solar cells currently remains to be improved, which leads to the application of solar cell is not very wide, make the daily life or industrial, agriculture and other areas, people still rely more on fossil energy, which means that such problems as environmental pollution, energy depletion will aggravate, so it is very urgent to improve work efficiency of solar cells.

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This article will focus on the methods proposed by different scientists to improve the work efficiency of solar cells.

2. History of the development of solar cell

Solar cells rely on the photovoltaic effect, in which light falls on photovoltaic materials and photons are converted into electrons, thus converting light energy into electricity. The photovoltaic effect was first discovered by the French physicist A. E. Becquerel in 1839[2]. He found that when a light beam hit the silver plate in the electrolyte, the voltage of the electrolyte increased. At this point, solar power is too inefficient for industrial use. Since then, Chapin and others have developed the first practical monocrystalline silicon solar cell, using a semiconductor material to greatly improve the efficiency of power generation. After a year of constant optimization, the efficiency reached 6%, a milestone in the development of solar cells. Solar cells reached 14% efficiency in 1958, the year solar cells were first used in satellites. The VANGUARD 1 in the United States was loaded with monocrystalline solar cells that powered small radio transmitters for eight years. Since then, solar cells have been widely used in space engineering. In 1960, soyuz-1, a soviet-designed manned spacecraft powered by solar cells, flew for the first time and is still in use today. It is the world's longest service time, the highest launch frequency, but also the best reliability of manned spacecraft. The first commercial communications satellite, Telstar, was launched in 1962 using 14 watts of solar cells. In 1970, research institutes represented by IBM and the Ioffe Institute of Technical Physics of the former Soviet Union developed the first high-efficiency GaAs solar cell, whose efficiency reached 16%. In 1980, the Energy Conversion Institute at the University of Delaware developed the first thin-film solar cell with an efficiency of more than 10 percent by optimizing its structure and performance.

3. Theory and application

As mentioned earlier, solar cells generate electricity from the photovoltaic effect. They generate electricity through the photovoltaic effect of semiconductor P-N junctions in them. When a photon hits the P-N junction, it produces the following energy:

$$E = h\nu$$

Where h is Planck's constant and ν is frequency. Solar cell produces electronic — hole pair. Inside the semiconductor P-N junction near generates no composite carrier, and then reach the space charge region, inside the battery produces by the area of N to P in current, the internal electric field, electrons flowing into N area, the hole into the P area, therefore N area to store excess electrons, P area has excess cavitation. Thus, the P region accumulates a positive charge and the N region accumulates a negative charge, and the thin layer between the N region and the P region produces an electromotive force, which is the photogenerating volt effect. When the battery contacts the external load, the P region acts as the positive electrode, and generates the current from the P region to the external load to the N region, so as to realize the function of battery generation. Solar cells are not as widely used as fossil energy, but because they can convert the sun's energy directly into electricity, they don't produce harmful gases[3], they have played a significant role in people's daily lives. Solar cells can be used to generate electricity in places without much electricity, such as remote areas for daily use, mountains, islands, troops and so on. Remote areas often have unstable electricity, so they have to rely on solar power and other energy sources to generate electricity for themselves. Many areas have established signal base stations that rely on solar cells. These signal base stations can generate electricity stably and provide great convenience for the people around them. In addition, solar cells are also used in daily electronic products such as chargers and street lamps. With the continuous improvement of performance and efficiency, solar cells play an important role in the field of aviation. In the past few decades, solar cells have been used in aircraft because they do not require self-contained fuel, reducing the load and space consumption of aircraft. What's more, the head of Swedish solar company Midsummer revealed that they will be working with Hypatia to use thin-film solar cells for future stratospheric space missions. Permutation and combination by multiple solar cells

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and solar array, the efficiency is very high. NASA has proposed that can be placed on the tall masts, making the loading more compact, lighter. After further improvement in the future, solar cell arrays can also be used to power communication satellites and even explore other planets, such as Mars or the surface of the moon in the future. In a word, the application prospect of solar cells is very broad. As one of the renewable energy sources, solar energy is not only easy to obtain, but also does not produce polluting gases in the process of working. But up to now, the efficiency of solar cells still has a lot of room to improve, which is one of the problems that need to be solved.

4. Factors affecting efficiency and measures to improve it

The efficiency of solar cells is affected by the selection of materials, temperature, light intensity, band gap, doping concentration, surface recombination efficiency and many other factors. There are several ways to improve its working efficiency, such as optimizing the way of producing the battery, optimizing the material surface, etc. For solar cell, whether block cell or thin film cell, the ways to improve their working efficiency are always the same.

4.1. Surface treatment of monocrystalline silicon cells

When sunlight hits a solar cell, it will be reflected due to its reflectivity. The higher the reflectivity, the less energy the solar cell can directly capture and the less efficient it will be. Therefore, solar cells can be made by flexibly selecting materials with low reflectivity, or by processing the surfaces of material, such as coating the surface and surface texture with antireflection film, so as to increase the effective area of solar cells. Take monocrystalline silicon cells for example, the reflectivity of silicon is around 30%. When dealing with this problem, any wet or plasma etchant.can help texturing of silicon surface. Joseph J.D. measured the current and voltage of different types of solar cells by changing the SF_6/O_2 gas ratio and etching time through the method of Reactive Ion Etching(RIE) in his research, and determined the optimal scheme within a certain range[4]. Joseph J.D. believed that the maximum power and efficiency of solar cells could be achieved when the ICP-RIE texture was carried out with DRE for 3 minutes under the SF_6/O_2 ratio of 1:2.7.

4.2. Measures to improve the efficiency of perovskite cells

4.2.1. Changing battery materials. Monocrystalline silicon solar cells are one of the most widely used types of solar cells. Silicon is chemically stable, but it is not easy to produce, so scientists are also developing solar cells made of other materials in recent years. Solar cells made of other materials, such as hybrid perovskite cells, become unstable under the influence of moisture and temperature, and their working time is affected. Naveen Kumar believes that by using $CsPbBr_3$ perovskite material instead of mixed perovskite, the stability of the material is improved and the life of the solar cell is prolonged, thus improving the efficiency[5]. Although the working efficiency of perovskite solar cells is not ideal, $CsPbBr_3$ has great potential in photovoltaic power generation and has high research value.

4.2.2. Improving the preparation method. In the preparation of solar cells, the processing of the electron transport layer also affects the efficiency of solar cells. The preparation materials of perovskite cell films, such as SnO_2, are often used to make electron transport layers due to their stable chemical properties and excellent electrical and thermal conductivity. However, during the preparation, holes and defects will be formed on the interface, which accelerates the dissolution of materials and greatly reduces the working efficiency. Zhangwen Ye et al. believe that the use of low boiling point solvents is not conducive to improving the surface properties of SnO_2, so they choose the low-temperature solution method to prepare SnO_2 film[6]. By comparing the changes in the film properties of dimethoxide ethanol, isopropyl alcohol and other solvents, they finally find that the use of dimethoxide ethanol to prepare SnO_2 film can improve its photovoltaic performance. Improving the surface defects of SnO_2 improves the working ability and efficiency of solar cells. Yinghui Wu et al. also improved the preparation method of thin films[7]. By using the HBPC passivation method, thin

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films with stronger light capture ability were prepared. By comparing the spectra and analyzing the perovskite battery films dissolved with different concentrations of HBPC, it was found that the passivation interface of the films was clearer when the concentration of HBPC was 4mg/ mL. The defects on crystal surface were improved and the crystallinity of the perovskite film was also improved. Seckin Akin et al. improved the vacancy and defect of the crystal surface of lead halide solar cells by improving the quality of the perovskite layer and interface in fully the assembled device configuration[8]. In terms of improving the working efficiency of perovskite solar cells, Naveen Kumar et al. optimized the life of solar cells by replacing mixed perovskite with more stable $CsPbBr_3$. Zhangwen Ye et al., Yinghui Wu et al., through different preparation methods, improved the performance of the battery, and thus improved the working efficiency. Seckin Akin minimizes the impact of crystal defects on productivity by improving the quality of the perovskite layer and interface.

4.3. Changing the SnS battery thickness

SnS is also a promising solar cell material, but its efficiency is very low at present. F.J. S´ anchez-rodriguez et al. found in their study that the ion carrier loss of SnS block and the interface between SnS and CdS, as well as the negative impact of series resistance and shunt resistance on the battery, are the main reasons affecting the working efficiency of the SnS battery[9]. Therefore, they optimized for these two factors and observed the change in the efficiency of solar cells when the SnS thickness changed from 400 nanometers to 1 micron, and found that the efficiency increased from 2% to 2.19%, indicating a small increase in efficiency. In this process, Rodriguez found that when the SnS thickness was 1.2 microns, the photon absorption efficiency was higher. In subsequent experiments, it was found that the defect density in the interface was 108 cm^{-2}, and the defect density in SnS was 1012 cm^{-3}. Under the influence of radiation recombination, the efficiency could reach 8.7%, and when the influence of series and shunt resistance on the efficiency was taken into account, the efficiency could be improved even more.

4.4. Improving the absorption layer defects of CZTSSe battery

The lattice defects, such as inversion, vacancy and gap, in the absorption layer of solar cells have a great impact on the efficiency of the work. Mahsa Yousefi used the numerical simulation method to establish the absorption layer model of CZTSSe cells when studying how to improve the efficiency of CZTSSe cells[10]. By changing the acceptor density of various donor defects in CZT and CZTSe absorbants, the working situation of the battery was simulated. Through data analysis, it was found that when the defect density was less than $1 \times 1015I/cm^3$, the efficiency was not significantly affected, so it was also known as benign defect. In the range of 0.6-0.7eV above the valence band of the CZT and CZTSe layers, the defect level of the absorption layer will significantly reduce the working efficiency of the solar cell. However, when the defect level is far away from this layer, the efficiency and working performance of the solar cell will not be negatively affected. Therefore, Mahsa Yousefi proposed that uniform mixing of CN-Zn-Sn-Se precursors or nanocrystals could be used to improve the defect of absorption layer, improve the photoconductivity and improve the working efficiency of the battery.

5. Conclusion

Since fossil energy is increasingly exhausted, the emergence and development of solar cells undoubtedly provides an effective solution to the problem of energy depletion. From the original monocrystalline silicon cells to various block cells and thin film cells, the performance and structure of solar cells have been optimized, and their efficiency has been gradually improved, so they are widely used in many fields. Solar cells are not only used for street lamps and chargers in people's daily lives, but also for communication base stations in recent years to steadily generate electricity for people in those remote areas. In the aerospace field, solar cells are also beginning to play a significant role, being used for spacecraft, satellites, and in the future, may even be used for Mars, the moon and

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other planets surface power. The efficiency of solar cells is affected by many factors, and many people have achieved efficiency improvements through different methods in response to these factors. The effects of various methods on solar energy efficiency can be observed intuitively through experiments. Solar cells made of different materials have different properties. Therefore, solar cells can be prepared by choosing materials with more stable properties and lower reflectivity to minimize energy loss during operation. When the material has been selected, surface treatment, such as surface etching, can also be used to increase the effective area of the battery, improve the performance of the battery, or change the thickness of the material to reduce the ion consumption; In the process of preparing solar cells, the preparation method can also be changed, such as using different kinds of solutions to prepare thin films, so as to improve the photovoltaic performance of thin films, or by using different concentrations of solutions to dissolve thin films, so as to make the light capture ability of thin films stronger. When the experimental cost is too high and the consumption time is too long, the working process of solar cells can also be simulated by the numerical simulation method, and the change in the working efficiency of solar cells can be observed by changing different parameters, so as to improve the working efficiency. It can be seen that there are many ways to improve the efficiency of solar cells, and the efficiency of solar cells still has a lot of room for improvement. In the future, for a long time, its efficiency will be further improved, and more widely used in our life and industrial development.

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