

Comparison of development prospects between silicon solar cells and perovskite solar cells

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Abstract: The development history, preparation process, structure and working principle of silicon solar cells and perovskite solar cells are introduced. The main parameters and production processes of the two kinds of solar cells are compared. The advantages and disadvantages of perovskite solar energy compared with existing solar cells in market application are analyzed and summarized, including good light absorption, high energy conversion efficiency and simple process flow, The problems of cost, size and stability of perovskite solar cells in market application are pointed out and the solutions are given. Perovskite solar cells have an excellent development prospect. Short circuit voltage, open circuit current and efficiency exceed those of silicon solar cells and are expected to gradually replace silicon solar cells in the market.

Keywords: Silicon solar cell, Perovskite solar cell, Development prospect

1. Introduction

Because of the traditional energy shortage, solar cells have been developed. As an inexhaustible renewable energy, solar energy has the advantages of no pollution to the environment, convenient energy conversion, economy and environmental protection.

In 2022, the global PV installed capacity will reach 200GW, most of which are traditional solar cells. The new solar cells represented by thin film cells and perovskite cells have a small market share. At present, the research focus is on thin film batteries and perovskite batteries. The main raw material of the new generation of solar cells is perovskite. How to develop a new material perovskite is a subject that many people pay attention to at present. What are the advantages of perovskite compared with silicon in the solar energy manufacturing process, and what is the future development direction of perovskite solar cells? These are future research goals.

After a long period of development and technical innovation, silicon solar cells have become a very mature type of solar cells and occupy a large market share. The research of perovskite solar cells is still at an initial stage, but it has great potential in the future development, with broad development prospects and good commercial value. At present, the research of this kind of solar cell is changing rapidly, and research results based on perovskite solar cells have emerged in large numbers.

This paper introduces and compares the characteristics of solar cells made of silicon and perovskite materials, and analyzes the development prospects of the two kinds of solar cells.

2. Silicon solar cell

2.1 Development of silicon solar cells

In 1839, E. Becquerel discovered the photovoltaic effect of liquid. Since then, solar energy can be converted into electric energy in this theory. This theory has become the basis of the field of solar cells.

In 1954, Chapin et al researchers of Bell Laboratory, discovered the monocrystalline silicon solar cell, and a few months later, the photoelectric conversion efficiency reached 6%. This is the first solar panel in the world. During the development of solar cells, the photoelectric conversion efficiency is an important indicator, which has been improved to 26% [1].

Silicon is a natural solar cell material. When silicon is doped with other impurities, such as boron, phosphorus, etc., excess holes or electrons will be generated in silicon crystals to form

semiconductors. Silicon dioxide is a kind of insulator. Silicon dioxide has good insulating property and is easy to form insulating layer. Silicon has good physical properties and mechanical strength and is not easy to be damaged.

At present, solar cells made of silicon occupy a large number of commercial market shares. Photoelectric conversion efficiency is the development focus of silicon solar cells. The highest efficiency of crystalline silicon solar cells does not exceed 30%, but the efficiency of new multi junction cells can exceed 30%. Therefore, the future development trend will be to replace crystalline silicon solar cells with new solar cells.

2.2 Preparation of materials

The preparation steps of silicon raw materials are as follows: (1) Pull single crystal of silicon to obtain silicon column. (2) Cut the obtained silicon column into monocrystalline silicon chips. (3) Remove the damaged layer of silicon wafer. (4) Pile making and cleaning [2]. (5) Diffusion. (6) Edge Etching Cleaning. (7) Passivation. (8) Printing and sintering

At a suitable temperature, silicon atoms will be arranged to form regular crystals into single crystals, which can be pulled into single crystal silicon pillars by Czochralski method, and single crystal silicon chips can be obtained by cutting. The Czochralski method is widely used in actual process production. Removing the damaged layer can reduce the surface defects, and this step usually adopts the method of acid or alkali corrosion. Pile making and cleaning can remove mechanical damage and oxide layer. The purpose of flocking is to form suede on the surface of silicon chip to reduce the reflectivity of battery chip and to improve the efficiency. Diffusion is used to manufacture PN junction of solar cells, usually by thermal diffusion method. Edge etching cleaning is mainly used to remove PN junction at the edge of silicon chip to prevent short circuit. Passivation is mainly used to passivate the solar cell surface, reduce the reflection coefficient. Printing determines the structure of solar cells. Sintering improves the performance of materials and makes the performance better.

2.3 Structure and working principle

Power can be generated by solar energy, depending on the photoelectric effect of semiconductor. There are many types of semiconductors, which can be divided into P-type and N-type according to the doping type. There are many materials and processes that can meet the power generation needs of photovoltaic cells. However, in the power generation process, semiconductor materials containing p-n junction are indispensable. Electrons are most carriers in N-type semiconductors and the holes is the same state in P-type semiconductors. Connecting the PN junction with the external circuit will generate photogenerated current under the continuous illumination of light. This is the basic principle of solar cell power generation.

Figure 1 shows the cross section structure of the solar cell. Crystalline silicon cells include five parts: front contact, antireflection coating layer, emitter, base and rear contact. Silicon solar cells often have protective films, the main component of which is silicon dioxide. Silicon dioxide is an insulator with stable chemical properties, which can protect solar cells.

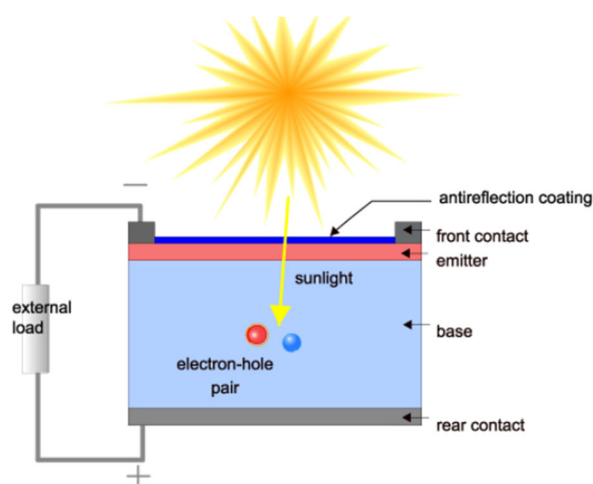


Figure 1. Cross sectional structure of solar cells

3. Perovskite solar cell

3.1 Introduction to perovskite

In 1978, German scientist Weber first formed an organic-inorganic hybrid three-dimensional perovskite structure material. As perovskite has excellent light energy absorption, it is mainly used in the light absorbing layer of perovskite battery.

The structure of Perovskite is shown in Figure 2, which is ABX₃ structure. It refers to a class of substances, not specific materials. Perovskite used to make solar cells usually contains organic groups. The existence of organic groups makes the material soluble in ordinary organic solvents, and its properties can be easily adjusted. Therefore, organic-inorganic perovskite is very suitable for use as the light absorbing layer of solar cells. In the early stage of perovskite photovoltaic research, scientists mainly focused on lead methylamine iodide [3,4]. So far, many different organic materials can be used to manufacture this kind of solar cells and can be used in practical production.

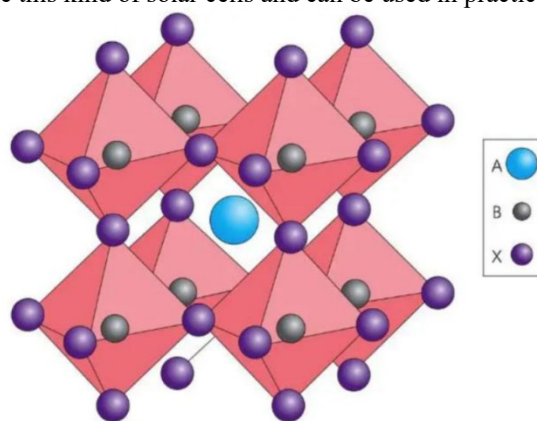


Figure 2 Structure of perovskite

Perovskite has two kinds of structures: mesoscopic structure and planar heterostructure. Both structures can be used to produce solar cells. The mesoscopic structure refers to a multi-stage structure, which has low cost and simple manufacturing process. Planar heterostructures have simple structures, and the preparation process is not complicated, and the cost is very low. These two structures are good choices for manufacturing solar cells.

This kind of materials can provide many advantages, including low electron hole pair binding energy [5], high light absorption coefficient [6], and long carrier diffusion length, which also make perovskite more suitable for making solar cells

3.2 Development and preparation

In 2009, Miyasaka et al. of Japan prepared the first perovskite structure solar cell using $CH_3NH_3PbBr_3$ and $CH_3NH_3PbI_3$ as solar light absorption layers in the laboratory for the first time [3].

In only four years, the efficiency of solar cells has reached 15.4%. At present, the highest battery efficiency has reached 25.7%, and the theoretical efficiency exceeds 30%, which is higher than the crystalline silicon battery.

The theoretical photoelectric conversion efficiency of perovskite materials is higher than that of silicon. As the development of this new material is not yet mature, the main material of solar cells commonly seen in the market is still silicon.

At present, perovskite materials have two technical directions: single junction and lamination. Single junction perovskite technology is similar to thin film technology, but the manufacturing cost is expected to be reduced. Lamination technology generally refers to the technology combining perovskite and crystalline silicon, which can greatly improve the photoelectric conversion efficiency and reduce the manufacturing cost.

Figure 3 shows the technological development history of various solar cells[7]. According to the chart, this kind of materials have caught up with the development of traditional solar cells in just a few years.

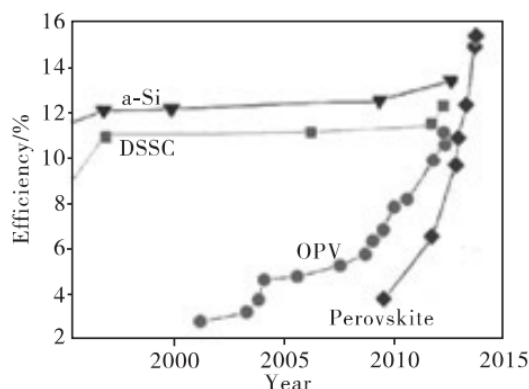


Figure 3 Efficiency of several solar cells [7]

3.3 Structure and working principle

As shown in Figure 4, perovskite solar cells usually include six levels: glass substrate, metal electrode, HTM layer, TiO₂ dense layer, TiO₂ mesoporous layer, Fluorine-doped tin oxide.

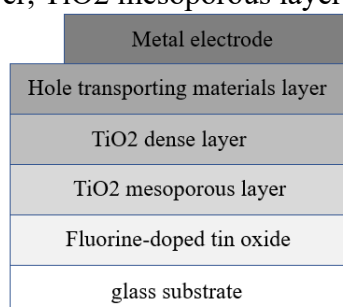


Figure 4 Cross Section of Perovskite Solar Cell

The way of obtaining the materials is as follows: FTO layer is placed on the transparent conductive glass substrate as the anode, TiO₂ is obtained by annealing, then a layer of perovskite is deposited on TiO₂, and then a metal layer is placed on the hole transport layer as the cathode. TiO₂ materials can be replaced, as long as they are insulating materials can be used.

The working principle is still photovoltaic. The work flow of perovskite solar cells is mainly divided into the following five steps: (1) Photon absorption process. (2) Electron hole pair diffusion process. (3) Electron hole pair dissociation process. (4) Carrier transport process. (5) Charge collection process

Compared with the traditional material silicon, the perovskite material has excellent photoelectric properties. The electron hole pair binding energy of the perovskite material is small, and the carrier recombination probability is low and the carrier mobility is high. Therefore, the carrier diffusion

distance and life are long. Compared with the traditional materials, the perovskite material is more suitable for solar cells.

4. Comparison between perovskite and silicon solar cells

4.1 Performance comparison between two types of solar cells

The basic performance parameters of solar cells are shown in the following table:

Table.1. Comparison of Performance Parameters of Perovskite Solar Cells [8] and Amorphous Silicon Solar Cells [9]

Battery type	short-circuit current(mA/cm ²)	Open-circuit voltage(V)	Fill factor	Energy conversion efficiency(%)
Perovskite solar cell	21.5	1.070	0.67	15.4
Amorphous silicon solar cell	19.4	0.887	0.74	12.7

It can be seen from the comparison in Table 1 that, except for the fill factor, all parameters of perovskite solar cells are higher. Because the development of this kind of material is far from the peak, its performance parameters still have a lot of room to improve, and the future development prospects are broad.

The efficiency and fill factor of this kind of material will be greatly improved in the future. In 2020, the Korean Seoul University and the NREL will jointly study to improve the maximum efficiency of PSCs batteries to 26.7% [10]. At present, the maximum efficiency of silicon solar cells has been exceeded by this kind of materials. Therefore, this material is the main direction of future development.

4.2 Cost comparison between two types of solar cells

Perovskite as a solar cell has superior material performance, which will have a huge impact on the market of traditional solar cells. Now, crystalline silicon battery has occupied a large number of markets, and it is difficult to be completely replaced by perovskite battery in a short time. But in the long run, perovskite solar cells will gradually replace crystalline silicon cells.

The cost of battery is mainly related to energy conversion efficiency and production process. According to the previous article, the current energy conversion efficiency can already exceed the energy conversion efficiency of the crystalline silicon battery. Some small batch production of perovskite batteries can reach about 1.2 yuan/W, which is lower than the production cost of crystalline silicon batteries. However, there are some problems such as low output power, low efficiency and short life, which can not achieve mass production.

Table.2. Comparison of production processes of perovskite solar cells and crystalline silicon solar cells

Compared items	silicon solar cells	perovskite solar cells
Length of process flow	Long	Short
Thickness of light absorbing layer	About 180 μm	About 0.3 μm
Absorbing layer cost	60%	5%
Purity of light absorbing layer	99.9999% pure silicon	95% pure perovskite
Maximum process temperature	1700°C	150°C

Compared with crystalline silicon solar cells, perovskite has great advantages in production. The process flow of perovskite solar cell is simple, time consuming is short, the thickness of light absorbing layer is small, and the cost is small. Compared with silicon, it has low requirements for ore purity and low process temperature, which can greatly save costs.

Therefore, when the production capacity is high and can be mass produced, the production cost of perovskite solar cells will be greatly reduced. As long as the battery efficiency and life problems are solved, the cost is expected to continue to decline.

5. Development prospect of perovskite solar cells

5.1 Advantages

When perovskite was first discovered in 2009, its battery efficiency was only 3.8%, but ten years later, the efficiency of perovskite has caught up with that of crystalline silicon solar cells. This kind of materials have excellent performance. In the current research, the efficiency has been greatly improved, which has exceeded the traditional silicon solar cells. In particular, the theoretical conversion efficiency of the 3-junction and above perovskite laminated battery can reach about 50%. It is the key development direction of future industrialization to further improve the photoelectric conversion efficiency by laminating with HJT.

The main advantages are: (1) Perovskite has a much stronger light absorption performance than silicon, and its excellent light absorption characteristics make it possible for the energy conversion efficiency of this materials to reach a higher level. (2) The efficiency loss of this materials in energy conversion is less. Because its components are organic compounds, the chemical formula of calcium titanium minerals can be changed by configuration to change its band gap width and other parameters, which can achieve better performance. (3) The industrial chain of this materials is relatively simple. The production process of the silicon solar cell industry chain takes several days to complete, resulting in a long production cycle. The process of perovskite solar cells only takes tens of minutes, which can shorten the production cycle of solar cells, and also has lower production costs.

5.2 Disadvantages

At present, the research of perovskite solar cells is still in the laboratory stage, and there is still a certain gap to reach the market level. However, the research on perovskite solar cells must be the development direction of photovoltaic cells. The disadvantages of perovskite solar cells are as follows: (1) Dimensions. Perovskite manufacturing process includes three steps: film preparation, laser etching and packaging. The current perovskite battery mainly follows the route of flexible devices, and can also be classified as a thin film battery. However, it is difficult for the laboratory to manufacture large perovskite films at present, and the films produced are only a few millimeters in size, which cannot meet the demand for use. The key to the future development is to realize the preparation of large area high-quality films. (2) Cost. Although perovskite is relatively cheap, other structural components are relatively expensive, and the short life of perovskite solar cells will affect the cost per unit time. The future development direction is to find alternative materials to reduce costs. (3) Stability. Perovskite solar cells are easily affected by external factors when applied, which leads to the reduction of energy conversion efficiency. The current solution is to control unstable factors through technological means to make them stable. How to solve the stability problem is also an important way to promote the development of this kind of materials.

6. Conclusions

Perovskite solar cells have broad prospects for development and good commercial value, and are expected to replace the widely used silicon solar cells in the future. It is a kind of solar cells worthy of research. Because of the superiority of perovskite materials, perovskite solar cells have better performance parameters. Moreover, the perovskite material has good light absorption performance, the preparation of the battery is relatively simple, the work flow is fast, the production efficiency is high, the requirement for the purity of the material is low, and the cost is very low. At present, the problems of this materials are that the transport layer materials are expensive, the stability of the cells

is poor, and the size of the cells is difficult to meet the size requirements. This is also the main research direction of perovskite solar cells in the future.

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