Review on the Development of Photovoltaic Power Generation System of New Energy

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Abstract. As the representative of new energy sources, the photovoltaic power generation technology is the foundation of energy development and utilization in our country. In recent years, photovoltaic power generation system has broken the traditional mode, and possesses the value of large-scale promotion. In this review, we summarize the characteristic, composition, working principle and development of photovoltaic power generation system.

1. Introduction
New energy usually refers to the energy that has not been extensively utilized and is being actively researched and developed. Therefore, coal, oil, natural gas and large and medium-sized hydropower are regarded as conventional energy, and solar energy, wind energy, modern biomass energy, geothermal energy are used as new energy. With the progress of technology and the establishment of the concept of sustainable development, the industrial and living organic wastes, which have been regarded as garbage in the past, have been rerecognized. Compared with traditional energy, new energy has the characteristics of less pollution and large reserves, which is of significant important to the serious environmental pollution problems and resource exhaust in the world [1]. According to the study of International Energy Agency (IEA), non-water renewable power generation will grow faster than any other fuel in the next 30 years. The annual growth rate is nearly 6%, and its total electricity generation will increase by 5 times in 2000–2030. By 2030, non-water renewable power generation will provide 4.4% of the total power of the world, in which the biomass energy will account for 80% [2]. Solar energy is one of the great energy sources that the natural world endows to mankind. Wind energy, water energy and fossil fuel on the earth all come from solar energy. The annual solar radiation energy on the surface of the earth is enormous, which is equivalent to the energy released by combustion of $1.3 \times 10^{14}$ t of standard coal. At present, the utilization of solar energy is mainly to collect, transform or store the radiation energy, in which the photovoltaic power generation is the use of photovoltaic conversion [3]. The solar photovoltaic power generation system of new energy has characteristics of sustainability, safety, cleanliness and pollution-free. It is the direction of energy development in the future and has been drawing more and more attention by researchers in China and abroad.

2. Principle and system structure of photovoltaic power generation
The main principle of photovoltaic power generation is the photovoltaic effect of semiconductor. When the photon is irradiated to the metal, its energy can be fully absorbed by a certain electron in the metal. If the absorbed energy of the electron is large enough to overcome the work of the gravitational force inside the metal, the electron escape out of the metal surface and become an optoelectron [4]. Silicon
Atoms have 4 outer layer electrons. If atoms that have 5 outer layer electrons, such as phosphorus atoms, are added into pure silicon, they will become N-type semiconductors. If pure silicon is doped with atoms that have 3 outer electrons, such as boron atoms, the P-type semiconductor will be formed. When the P-type and N-type semiconductors are combined together, the contact surface will form a potential difference that will become a solar cell. When sunlight is irradiated to the P-N junction, the hole moves from the P-polar region to the N-polar region, and electrons move from the N-polar region to the P-polar region that will form the current [5]. Polycrystalline silicon is made into silicon wafers to be processed after casting, breaking, slicing and other procedures. The P-N junction will be formed by doping and diffusing trace boron and phosphorus on silicon wafer. Then using the screen printing to print the fine silver pulp on the silicon chip to make into a grid line. After sintering, the back electrode was also made, and a layer of anti reflective coating is coated on the surface of the grid that a battery sheet will be made. In this process, as the thickness of the silicon wafer thins gradually and the area of the battery becomes larger, the cost of production is increased. Therefore, several new welding processes have been born, such as laser welding, semiconductor laser welding, ultrasonic metal welding, etc. [6]. A large circuit board is formed by arranging the battery pieces into a battery assembly. The general assembly is usually around with the aluminum frame, and the front covers with glass, the back mounts electrode. With battery components and other auxiliary equipment, the power generation system can be made. In order to convert direct current (dc) into alternating current (ac), a current converter is needed. Therefore, the photovoltaic power generation system is mainly composed of three parts: solar panels (components), controllers and inverters, and the main components are composed of electronic components. The solar cells are connected in series to form a large area of solar cell components, and then the photovoltaic power generation device is formed with the power controller and other components [7].

3. Study and Development of solar panels

3.1 Introduction of solar panels
Solar panels are made up of one or more solar cell films. A solar cell is a semiconductor device that possesses characteristic of converting light into electrical. It can convert solar radiation energy on its surface into DC [8]. Solar panels are the most basic components of photovoltaic systems or products, and they are also the core part of solar photovoltaic systems. The biggest role of solar panels is to convert solar energy into electrical energy stored in batteries. The solar panels are composed of toughened glass, EVA (used to bond fixed toughened glass and main body of power generation ), back plates, aluminum alloy protective laminates, junction boxes, and silica gel.

3.2 Development of a new type of solar cell
However, due to the high manufacturing cost and high energy consumption of its main component, solar panels are not widely used, and the recent solar cells as a new type of photovoltaic power generation, paper solar cells and flexible perovskite solar cells have the advantages of low cost and low pollution.

3.2.1 Paper solar cells. A Japanese research team developed a new type of solar panel with wood pulp, and this “paper paste” solar cell is green, cheap, thin and flexible. To ensure the light transmittance, paper solar panels usually adopt transparent glass or plastic. The research group led by Yoshiki Masaya, an associate professor of the Institute of Industrial Science, Osaka University, has developed a transparent material with a thickness of only 15 nanometers by compression processing using the plant fiber in the wood pulp. Then, this transparent material are used as substrate to embed the optoelectronic conversion organic materials and wires to produce paper solar cell [9].

Because the size of the wood pulp fiber is only 1/3 of the normal material, the transparent paper sheet can be made by using this material, Then the thin plate is printed on the sheet by high temperature printing technology. Finally, the organics with power generation function and conductive silver wiring are printed on the sheet through high temperature printing technology.

Scientists of Massachusetts Institute of Technology (MIT) have developed a new printing technology.
Recently, in several methods used in solar cell manufacturing, the conditions required are destructive that the printed substrates must be immersed in liquid or require high temperature. The new printing technology requires only steam and no more than 120 degrees of ambient temperature, so that untreated ordinary paper, clothing and plastic can be used as a manufacturing material for the battery [10].

In addition, the technology has only used a very simple method of vapor deposition, which is low in cost and widely used in commercial applications [11]. However, this technique is slightly more complex than ordinary paper printing. The five layers of conductive material are repeatedly deposited in the same position of a sheet of paper through the pattern of the surface of a paper-based mask fixed on the surface of the battery, and the whole process must be carried out in vacuum.

Using the new printing technology, wood pulp is used as the substrate of the battery board, and then the power generation device is printed on the substrate. If these two technologies are combined together, the wood pulp is used as the substrate of the battery board and then printing the power plant onto the substrate by using the new printing technology, thus the combination of the paper substrate and the new printing technology can be realized, which is more conducive to the production of the paper battery board.

Paper solar cells have many advantages. In recent years, solar battery industry has developed and expanded rapidly in our country. During the production of solar panels, hydrofluoric acid, nitric acid, three phosphorus oxychloride, isopropanol and other chemical substances are widely used, which will cause serious pollution to the environment [12]. In comparison, the power generation efficiency of the paper battery board is basically the same as that of the same kind of glass panel. But the practical manufacturing cost of the paper solar cell is only one of ten thousand of the glass material. And paper solar cell is more portable, easy to use, easy to manufacture, and very low in cost.

However, paper solar cells also have some disadvantages. It has been proved that this battery can supply power for electric lamps, but the optical conversion efficiency is only 3%, which is far below the current mature solar power generation technology, and far less than the conversion rate of 10% to 20% of solar cells for general power generation. Moreover, this technology has not been developed and utilized on a large scale, mainly because the fabrication technology is relatively difficult. In particular, there is no similar technology development in China, and the research on paper battery has not been technically supported.

3.2.2 Flexible perovskite solar cell. Perovskite solar cells have been a research hotspot in the field of solar cells for several years [13]. After several years of development, its energy conversion rate has increased from the initial 3.8% to 22%. Because of low material and manufacturing cost, Perovskite solar cells are considered as a new generation of solar cells that may replace silicon solar cells. Such batteries have two types, one type is n-i-p and the other type is p-i-n.

The n-i-p structure is a traditional perovskite solar cell structure that is simple and energy conversion efficiency is high. But the n-i-p structure needs the dense layer of TiO2 as the electron transport layer. And the preparation process needs annealing at high temperature of 450~500℃, thus obtaining anatase with good crystalline form. But the PET or PEN substrate commonly used by flexible batteries can withstand temperatures of not more than 150℃ [14]. Therefore, the perovskite solar cells with n-i-p structure can not be used directly for the fabrication of the flexible batteries. The related research is mainly focused on the low temperature preparation of the electron transport layer. A direct idea is to replace TiO2 for other electron transport layer materials that can be prepared at low temperature. ZnO has been widely studied in flexible perovskite solar cells because of its higher electron mobility and easier preparation at low temperature [15]. Except the way of replacing by other electronic transport materials, the researchers also tried to reduce the preparation of the dense layer, so that the traditional materials could be used in flexible perovskite solar cells.

The structure of p-i-n type solar cell is the basic structure of organic matter battery (OPV). In 2013, the Snaith project group first applied this device to the perovskite battery, and the efficiency of the device on the flexible substrate could reach 6%. The materials and preparation processes used in OPV can be easily transferred to the preparation of perovskite batteries. The experience about flexible solar
cells in OPV also makes the flexible perovskite solar cells develop rapidly. Because p-i-n type perovskite batteries no longer require TiO2 and other metal oxides as electron transport materials, PEDOT, PSS, PCBM and other organic compounds are widely used. Therefore, the sintering process under high temperature is no longer required, making the p-i-n structure is more suitable for the preparation of flexible perovskite batteries [15].

Flexible perovskite solar cells have been developing rapidly since their appearance in 2013. The device efficiency and stability have been greatly improved, laying a solid foundation for the next step in practical application. Flexible solar cell is a new form of solar cell. The characteristics of perovskite materials that can prepare at low temperature endows them inherent advantages in preparing flexible solar cells, which has drawn widespread attention. However, compared with the energy conversion rate of 22% of the rigid perovskite solar cell, the efficiency of the flexible perovskite battery still has a large gap, and the stability of the devices that is not encapsulated is not good enough. Therefore, it must continue to improve the energy conversion efficiency and the device stability of the flexible perovskite solar cells, and the flexural stability of the device also needs to be further enhanced.

4. Prospects
In the past 5 years, the cost of photovoltaic power has fallen by 1/3, and photovoltaic power in South America and other countries have been equal, even lower than retail prices. The cost of photovoltaic power will be further highlighted in future. Thermal power generation will bring extremely high cost of environmental control, so the cost of coal power generation will be higher than that of photovoltaic power generation. The cost of investment of photovoltaic power generation has been dropped to less than 8 yuan / watt, and the electricity cost has been dropped to 0.6-0.9 yuan / kWh. The rise of this new material has further reduced manufacturing costs, and it is a new development in terms of cost and environmental protection. Of course, new solar cells is low in efficiency, so there still have big developing spaces.

With the rapid development of economy, the shortage of energy is becoming more and more serious. Solar photovoltaic power generation, as a representative of new energy power generation, has been formally applied to production practice. Photovoltaic power is different from traditional power that its power output changes drastically with the change of environmental factors such as light intensity and temperature, and it is uncontrollable. Therefore, photovoltaic power generation can replace traditional energy to achieve large-scale grid connected power generation that impact on the grid can not be ignored [16].

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