Scientific Research Publishing

Energy and Power Engineering, 2022, 14, 541-549
https://www.scirp.org/journal/epe
ISSN Online: 1947-3818
ISSN Print: 1949-243X

Review of Photovoltaic Cell Technology Development

Ruiheng Yang

The Barstow School, Ningbo Campus, Ningbo, China
Email: 3083281780@qq.com

How to cite this paper: Yang, R.H. (2022) Review of Photovoltaic Cell Technology Development. *Energy and Power Engineering*, **14**, 541-549.
https://doi.org/10.4236/epe.2022.1410029

Received: September 14, 2022
Accepted: October 14, 2022
Published: October 17, 2022

Abstract

China has pledged to peak its carbon footprint by 2030 and become carbon neutral by 2060. According to the future energy demand and the requirement to achieve "carbon neutrality", the new energy represented by photovoltaic power generation will become the main force to achieve "carbon neutrality". It is great strategic significant to increase the proportion of non-carbon energy gradually and build a new energy supply system with multiple complementary energy. According to the current situation of domestic energy development in recent years and the development trend of new energy in China, the author reviewed the development of photovoltaic cells technology. As the head industry of photovoltaic industry, photovoltaic cells were applied in multy prospects, such as agriculture and public transportation. Two feasible solutions toward the disadvantage of photovoltaic cell were discussed, including the appropriate geographical location of photovoltaic cells and the superhydrophobic coating on the surface of the cell.

Keywords

Carbon Neutrality, Photovoltaic Power Generation, Photovoltaic Cells

1. Introduction

Carbon neutrality refers to the processes of offsetting by total emission amount of carbon dioxide or greenhouse gas directly or indirectly produced by a country, enterprise, product, activity or individual within a certain period of time with planting trees, saving energy and reducing emissions. This achieves positive and negative offset and achieves relative "zero emission" [1]. Facing the global climate crisis, China had pledged to become carbon neutral by 2060. Achieving peak carbon emissions and carbon neutrality is a commitment China has made to the world [2]. This is also a wide-ranging and profound transformation of the

economic and social system. The 9th meeting of, the Financial and Economic Commission of the Communist Party of China(CPC) Central Committee promoted and deployed the follow-up construction of carbon peaking and carbon neutrality by a new power system based on new energy. Our country had a clear follow-up plan [3]. Ecological civilization construction entered the strategic direction with the core of carbon reduction. It not only provides a great strategic opportunity for China to accelerate the green and low carbon transition, but also a very serious challenge.

Photovoltaic (PV) is a kind of photovoltaic effect using semiconductor materials for solar cells. It is a new type of power generation system that directly converts solar radiation energy into electric energy [4]. According to the World Energy Transition Outlook: the 1.5˚C Path, carbon neutrality means that the renewables would become the dominant energy source. Electricity generation by renewables will increase to 90 percent with 63 percent of PV power generation and wind power. Governments around the world are supporting and developing the PV industry. They promote the development of the PV industry chain by promoting the "affordable access" policy. It is expected that by 2050, global PV installations will exceed 14,000 GW (equivalent to 635 new Three Gorges power stations) [5].

The proposal of the goal of "double carbon" also brings a lot of space to our PV industry development. As the expansion of domestic demand becomes the strategic basis point of the country's long-term development, the impact of domestic consumption on carbon emissions will continue to increase. The degree of low-carbon lifestyle will become an important factor affecting the process of national low-carbon development. The scale of the renewable energy market was expanding and the technology was improving. The cost of renewable energy was gradually reducted in by the popularization and application of PV power generation. In 2011, the installed PV capacity in China was only 6% in EU. Since 2013, as the country stepped up efforts to save energy and reduce emissions, China's photovoltaic industry has boomed as a clean energy source. National statistics from 2016 to 2020 shown that the cumulative newly installed PV capacity in China exceeded 200 million kW. In 2017, it exceeded combined of the European Union. In 2020, China's installed PV industry was 253 million kW, with an increase of 24.1%. In terms of industrial scale, production and manufacturing, technological level and enterprise strength, it has comprehensively led the world [6].

In the future, with the advent of the PV parity Internet era, green energy would be integrated with residents' lives [7]. The PV industry refers to the production of solar cells from raw materials such as silicon through various technologies and technological routes, and the packaging and protection of solar cells through series and parallel to form large-area solar cell modules. By cooperating with the power controller, the industry chain of PV power generation device was formed [8]. This paper reviews the technology development and application of photovoltaic cells as the leading PV industry. The feasible solutions were discussed to

avoid the disadvantage of PV cell.

2. The Development of PV Cells Technology

The rapid development of PV industry requires the progress of relevant technical equipment and technology. PV cells are the storage medium of photovoltaic energy. Its replacement trend was toward to the development direction of high conversion rate, low cost and harmless material. According to the sequence of technology development, photovoltaic cells were mainly divided into three types:

2.1. Silicon Based Photovoltaic Cells

Crystal silicon cell was the first generation of solar cell technology which was researched and applied first. It was also the most commonly used photovoltaic cell. According to the shape of the material, it was divided into monocrystalline silicon cells and polycrystalline silicon cells. For silicon-based photovoltaic cells, the improvement of conversion efficiency required the increase of the light absorption rate of the cell and reduce of the cell surface recombination. Monocrystalline silicon photovoltaic cells are the earliest silicon based photovoltaic cells. It is based on silicon and has a high conversion rate. Because of the complex process and high cost in the early stage, it is not conducive to mass market use. As a result, polysilicon PV cells with cheaper price were soon available. Polysilicon is a form of elemental silicon. When the molten elemental silicon solidifies under the condition of supercooling, the silicon atoms were arranged into many crystal nuclei in the form of diamond lattice. These nuclei grown into grains with different orientation of the crystal faces and combined to crystallize into polycrystalline silicon. Astor's German ISFH research Institute reported that the highest conversion efficiency of the polycrystalline silicon PV cell was 22.8% in laboratory. However, the actual conversion efficiency of polysilicon PV cells used in the PV market is around 18%. The transfer efficiency of polysilicon was lower than that of monocrystalline silicon photovoltaic cells (26.8%) in both research environment and daily environment. After the significant cost reduction of monocrystalline silicon cell, the development of polysilicon photovoltaic cells was hindered [9].

2.2. Thin Film Photovoltaic Cells

After silicon-based PV cells, the thin film PV cells as a new generation of cells were born. Thin-film PV cells made by glass, stainless steel or plastic with a very thin photosensitive material used less material than silicon-based PV cells. Theoretically, the advantages of thin-film PV cells was higher conversion efficiency, stable performance and low cost. The emergence of thin film PV cell materials provides the possibility for the organic combination of building technology and PV power generation technology. The texture of the material presents the characteristics of translucency and flexibility, which can well meet the needs of PV buildings and ensure aesthetic. At the same time, thin-film PV cell materials can

also be used in the car roof, car body and other fields. This greatly reduces carbon emissions, help our "double carbon" work. Therefore, thin-film PV cells have developed rapidly in recent years.

In order to promote the application of thin film PV cells, it is necessary to further reduce the cost and potential harm of the cells. Copper indium gallium selenium (CuInGaSe, GIGS) is one of the most important photovoltaic cells in China. The main reason is that In element, the key material in the battery, is relatively scarce in the world. China's reserves of In is the lagestin the world. It can provide a good material base for the development of CIGS battery. At present, In order to reduce the cost, cheaper elements can be used to replace the more expensive elements In the original thin-film photovoltaic cells, for example, the expensive In and Ga In CIGS cells can be replaced by cheap Zn and Sn [10].

The Te element in cadmium telluride (CdTe) cells, another thin-film PV cell, is also rare. Its natural reserves are limited. At present, the main development trend of the battery is to reduce the use of Te by reducing the thickness of the film. In addition, Cd element is also a toxic element, which requires corresponding recycling measures to reduce the environmental pollution caused by batteries [11].

2.3. New Type Photovoltaic Cell

The main characteristics of the new PV cells include thin-film, high theoretical conversion efficiency, abundant raw materials and no toxicity. At present, the hot new PV cells include dye-sensitized cells and perovskite cells [12]. Perovskite PV cells was used perovskite-type organometallic halide semiconductors as light absorbing materials. Dye-sensitized solar cells (DSSCs) are a new type of photochemical cells that mimic the principle of photosynthesis on large clusters. It is a new type of photovoltaic device developed in the process of exploring new technology, new materials and thin-film battery preparation [13]. Since Pt electrodes of dye-sensitized cells are expensive, this increases the production cost of dye-sensitized cells. Some researchers have found that Pt metal electrodes can be replaced by carbon materials to reduce the cost of battery preparation [14].

2.4. The Application of Three Kinds of Batteries in the World

From the current analysis of the global PV market, monocrystalline silicon and polysilicon cells with high cost performance, still dominate the market. However, thin-film PV cells or new PV cells have good development prospects due to their high theoretical conversion efficiency and low preparation cost. Although there are many kinds of new PV cells at present, only perovskite PV cells can be industrialized and applied to civil fields.

3. Application of Photovoltaic Cells

Transportation and agricultural planning are basic, leading and strategic industries in the national economy, while the PV industry is a rising sun indus-

try based on the integration and development of semiconductor technology and new energy demand. The effective combination of the two will promote Green and low-carbon transformation of transportation and agriculture planning to make transportation and agriculture more environmentally friendly and low-carbon.

3.1. Application in Agriculture

The major application of PV cells with agriculture is mainly about to build combinations between agricultural production and photovoltaic energy generation. The photovoltaic cell is capable for working with both terrestrial crops and aquatic creatures with the purpose of maximizing the utility of the land and increasing the income of corresponding farmers [15].

Some of crops, both terrestrial and aquatic, do not require sunlight in order to grow. In some extreme cases, the production of those crops is even possible to decrease with unnecessary sunlight. In this case, covering the top of water or farmland by photovoltaic cells will be a win-win strategy for farmers. Therefore, these farmers not only do not need to endure more cost for their crop, but also they can gain electricity supply for their basic necessity, such as machine used to spray pesticides and light bulbs for chasing insects. For farmers with huge farmlands, they can even sell additional electricity generated back to the country, which significantly increase their income.

Besides that win-win strategy, another significance of applying photovoltaic cell with agriculture is that it maximize the utility of the land even for farmers who plant regular crops with demand on sunlight. The fertility of the land will decrease as farmers plant crops on top of it. Therefore, normally, the lands are actually under rotation of utility instead of continuous utility. As a result, there are always some farmlands being left alone without any crops. With implementation of photovoltaic cells, these farmlands can be put into utility again even if there are none of crops being cultivated there [16].

"Photovoltaic+" in the countryside is not simply to build a power station on wasteland. In addition to analyzing the rate of return of photovoltaics, it also considers the input and output of agriculture, and adds the design and optimization of ecological governance during project review. The Inner Mongolia Photovoltaic Eco-Industry Demonstration Base is an excellent example of a diversified "photovoltaic+" integrated development model. In 2014, it covers an area of 30,000 acres with an investment of 4.9 billion yuan and plans to develop and construct a solar photovoltaic project with an installed capacity of 500 MW. At present, the base has begun to take shape, and many enterprises have settled in. After the base is fully completed, it will form a photovoltaic ecological industry governance demonstration base integrating photovoltaic power generation, modern animal husbandry, sand and grass industry, and ecological tourism, which can save 78,000 tons of standard coal and 780 tons of sulfur dioxide emissions every year.

3.2. Application in Transportation

The application of photovoltaic cell on transportation is mainly about to deduce the demand on traditional source of energy, mostly fossil fuels such as coal and oil. There are numerous amount of photovoltaic cells planted on train station or airport, in order to generate electricity for the travelers to use. Normally, these electricity will be used for supplying the station itself, such as sustaining air condition system and light bulbs in the station. As a result, less fossil fuel is required by the station (Clark, 2022). Besides the train station or airports, signal lights on the road is also utilizing photovoltaic cells as their source of energy.

Implementation of photovoltaic cells not only decrease the demand of fossil fuels, but also decrease the eternal costs associated to the electricity, such as wires and inverters. Since generation of electricity by photovoltaic cell will not require a system of wires connecting lights as a whole. Thus, this is another win-win strategy achieved by advancement on photovoltaic cells [17].

4. Solutions for Potential Disadvantage of Photovoltaic Cells

As a form of renewable energy, there are some disadvantages of utilizing photovoltaic cell. Photovoltaic cell is mainly dependence on weather, relatively low efficiency on generating energy, fragile structure and inability on independent work. As a form of renewable energy, the disadvantage is always unavoidable. There are some possible solutions in order to minimize the disadvantage of photovoltaic cells. In this article, two feasible solutions toward the disadvantage of photovoltaic cell are discussed, include planting photovoltaic cells based on the geographical location and employing superhydrophobic coating on the surface of the cell.

4.1. The Appropriate Geographical Location of the PV Cell

To begin with the essential function of PV cell, there are layers of silicons being pressed into different shapes, leading to the photovoltaic effect which enable photons to separate electrons from atoms in order to generate electrical currents. Therefore, it is impossible for PV cell to work during the time without sufficient sunlight. As a result, the utility of photovoltaic cell actually is actually encountering numerous restrictions. The utility time and build place for PV cell is severely limited. Compared with other renewable energy sources, such as wind energy or thermal energy, the efficiency of energy generation by PV cell is relatively lower. According to National Renewable Energy Laboratory, the percentage of electricity generation from photovoltaic cell is estimated to be around 10%, which is also comparatively low in contrast to traditional sources of energy [18].

In order to generate electricity, the photovoltaic cell must be illuminated by the sunlight. If the daylight is extended, then the total work time of photovoltaic would be significantly increased. For China, Northern Ningxia, northern Gansu, southern Xinjiang, western Qinghai, western Tibet and other places are the most

abundant solar energy resources in my country. Northwestern Hebei, northern Shanxi, southern Inner Mongolia, southern Ningxia, central Gansu, eastern Qinghai, southeastern Tibet, and southern Xinjiang are also abundant. Thus, PV cells planted there are guaranteed with sufficient supply of sunlight. However, because these areas are located inland, the altitude is high, the temperature difference between day and night varies greatly, and the four seasons are also very distinct. In order to achieve that plan, the capability of photovoltaic cells under low temperature need to be enhanced. Factory might employ a transparent heat-preventing layer on top of the cell in order to ensure their function in the poles, which will finally lead to improvement on efficiency of energy generation.

4.2. Superhydrophobic Coating

The most important component of the system, solar panel, have a fragile surface. A tiny crack on the surface can lead to severe damage to the entire system. Therefore, the photovoltaic cell must be isolated and protected in order to decrease the possibility of being damaged.

Rain water is capable for conducting electricity and deducing penetration of photons. Adhered water relics might lead to deduction on the efficiency of receiving photons from the sunlight. In most cases, therefore, it is important to ensure that the photovoltaic cell is not wet as it works. In this case, implementation of superhydrophobic coating effectively ensure an arid surface of the cell. Since under the assistance of super hydrophobicity with typical Cassie-Baxter's state, none of water can access the bottom of the surface of the cell. Therefore, the durability of the cell and the efficiency of the cell are both improved [19].

5. Conclusion

In the process of China's "carbon neutrality", the efficient use of renewable resources would play an important role in the future. The development of photovoltaics in China is getting faster, and efficiency market penetration rate of photovoltaics are getting wider. In the future, experts need to expand the advantages, reduce the disadvantages, solve some problems, and improve the battery life and storage capacity of photovoltaics. A low-carbon and intelligent multi-energy integrated and complementary energy supply system will be a powerful tool to promote the realization of the "dual carbon" goal, and will certainly make great contributions to building a beautiful China. In the process of China's "carbon neutrality", the efficient use of renewable resources will play an important role in the future.

Conflicts of Interest

The author declares no conflicts of interest regarding the publication of this paper.

References

[1] Yu, J., Ye, H.R., Xu, T.J., Chen, Y., Qian, C., Chen, T. and Huang, Y.L. (2022) New

Opportunities for Photovoltaic Development and Application in Energy Networks under the "Double Carbon" Goal. *Globalization*, **34**, 5-18.

[2] Tian, H. (2020) Progress, Trend and Enlightenment of International Carbon Neutralization. *China Development Observatory*, **2020**, 72-74.

[3] Song, W. and Xiao, R. (2022) The Evolution Path of China's Photovoltaic Industry Policy Tools and Its Enlightenment. *Journal of Intelligence*, **2022**, 177-184.

[4] Lu, C. (2020) Scenarios and Effects after Carbon Peaking in China's Power Industry under the Constraint of 1.5 ˚C. North China Electric Power University, Beijing.

[5] Zhang, S., Qi, M., Lv, X., *et al.* (2021) Prospects for the Development Trend of the Refining and Chemical Industry under the Vision of "Carbon Neutrality". *Oil and Gas and New Energy*, **33**, 18-22.

[6] Zhang, F. and Zou, J. (2022) Difficulties and Countermeasures of High-Quality Development of My Country's Photovoltaic Industry under the "Double Carbon". *Journal of Xichang Social Science Edition*, **34**, 53-57.

[7] Yu, X. and Wu, H. (2021) Photovoltaic Has Gradually Become the Main Body of Power Increment. Multiple Challenges Still Need to Be Overcome. China Reform News, 2021-07-27(5).

[8] Zhang, Y. (2021) Situation and Starting Ideas for Carbon Peaking and Carbon Neutrality Work. *Administrative Management Reform*, **2021**, 77-85.

[9] China Photovoltaic Society (2020) Report on 2020 China PV Technology Development—Research Progress of Crystalline Silicon Solar Cells (1). *Solar Energy*, **2020**, 5-12.

[10] Zhang, S., Zhao, C. and Zheng, Z. (2021) Progress on Building Integrated Thin-Film Photovoltaic. *New Chemical Materials*, **49**, 71-75. (In Chinese)

[11] Qi, P., Xie, C., Wang, K., *et al.* (2021) Application Analysis of CdTe Solar Module in Integrated Photovoltaic Building. *Glass*, **48**, 52-55. (In Chinese)

[12] Cao, S., Zhou, G., Cai, Q., *et al.* (2022) A Review of Solar Cells: Materials, Policy-Driven Mechanisms and Application Prospects. *Acta Materiae Compositae Sinica*, **39**, 1847-1858. (In Chinese)

[13] Hao, A. (2018) Research of the Dye-Sensitized Solar Cells. *Journal of Anyang Institute of Technology*, **17**, 7-10. (In Chinese)

[14] Zhang, Q. and Huang, Q. (2018) Novel Progress on Application of Carbon Materials as Counter Electrode in Dye-Sensitized Solar Cells and Perovskite Solar Cells. *Journal of Materials Engineering*, **46**, 56-63. (In Chinese)

[15] Wang, L. and Chen, J. (2021) Review of Related Research on the Integration of Photovoltaic and Agriculture. *Journal of Anhui Agricultural Sciences*, **49**, 18-21, 29. (In Chinese)

[16] Xue, J. (2017) Photovoltaic Agriculture—New Opportunity for Photovoltaic Applications in China. *Renewable and Sustainable Energy Reviews*, **73**, 1-9. https://doi.org/10.1016/j.rser.2017.01.098

[17] Shao, D. and Li, H. (2021) Decarbonization Benefits and Carbon Peak Goals of Urban Passenger Transport Electrification: Case Study of Shanghai. *Urban Transport of China*, **19**, 42, 53-58. (In Chinese)

[18] BYJU'S (2022) Solar Power—Introduction, Solar Energy, Photovoltaic Cell, Advantages and Disadvantages of Photovoltaic Cells, and Faqs. https://byjus.com/physics/solar-energy-and-photovoltaic-cell/#disadvantages-of-photovoltaic-cells

[19] NREL (2018) News Release: NREL Details Great Potential for Floating PV Systems.

https://www.nrel.gov/news/press/2018/nrel-details-great-potential-for-floating-pv-systems.html#:~:text=National%20Renewable%20Energy%20Laboratory%20%28NREL%29%20researchers%20estimate%20that,10%20percent%20of%20the%20nation%E2%80%99s%20annual%20electricity%20production