

Through analysis of three-generation solar cells, predict the future potential for solar-powered cars

Haoyu Xu *

University of Toronto Scarborough, Toronto, On, Canada

* Corresponding Author Email: haoyuu.xu@mail.utoronto.ca

Abstract. In today's world, the problem of global warming is becoming increasingly serious, leading to natural disasters. One of the main causes of global warming is the emission of carbon dioxide. There are hundreds of millions of cars worldwide that contain a lot of carbon dioxide in their exhaust emissions, and in the future more and more. So now mankind needs a way to solve this problem. The development and promotion of solar cars is a good way to reduce car exhaust emissions. The role, market size and prospects of solar vehicles are presented in this article. By summarizing the different types of solar cells in different literature, the working principles of the first, second and third generation solar cell, as well as their advantages and disadvantages, are analysed. By studying the properties of these batteries, the performance of the fourth generation of new solar cells is predicted and some individual opinions are presented.

Keywords: Solar cars; batteries; efficiency; scale of the market.

1. Introduction

Since the 21st century, worldwide car production and sales have continued to grow, and the problem is that the total oil reserves that car energy may face may be inadequate in the future. Simultaneously, substantial quantities of vehicle emissions are contributing to global warming, leading to a rise in the frequency of extreme weather patterns. So, in order to mitigate the global extreme climate problem, we have to tackle the problem of car emissions. Firstly, solar cars can replace conventional fuels with photovoltaics, thereby saving limited oil resources. Secondly, the solar electric vehicle has no pollution and noise, because it does not consume fuel and emit harmful gases, nor does the noise of the internal combustion engine. Solar cars basically do not need daily maintenance, while traditional cars must frequently replace engine oil, add cooling water and face other regular maintenance trouble. Solar cars can generate electricity themselves as electric vehicles, thereby saving people's cost of using cars. It is estimated that the carbon dioxide emissions of each vehicle could be halved if replaced with solar vehicles. Studies have shown that the power required for different speeds of solar cars varies, with a 20km/h vehicle requiring 642W, 40 km/h requiring 1990W, 60km/hr requiring 4142W and 80km/H requiring 7197W [1]. At present, solar cars mainly use photovoltaic cells, such as thin-film cells and crystalline silicon cells. The conversion rate of monocrystalline silicon cells is 19.5%, and the cost per watt is less than 0.5 yuan; the conversion rate of polycrystalline silicon cells is 18.2%, and the cost per watt is 18.2%. The cost is less than 0.5 yuan; the conversion rate of amorphous silicon cells is 6.8%, and the cost per watt is less than 0.3 yuan [2]. This article will analyze the representative types of data in each generation of solar cells, summarize the development direction and improvement methods of solar cells, predict the properties and efficiency of the next generation of solar cells, and thereby analyze the possibility of popularizing solar cars.

2. Working Mechanism

For solar cars, there are currently two main ways of researching and developing them. One is to replace conventional fuels with solar fuels, which differ greatly from conventional vehicles in terms of design and functionality. During lengthy trips, traditional electric cars need to stop frequently to recharge the battery; however, solar cars can be charged while in motion. Solar cars are made up of

motors, electrical storage, and panels instead of an engine, chassis, drive, gearbox, or other parts. The car is powered by solar energy that is directly converted into electrical energy by the solar panels. The electrical energy is then used to propel the vehicle. Output can be adjusted to change the vehicle's speed. Currently, this kind of solar car has a top speed of over 100 km/h and a maximum driving range of over 100 km in the absence of sunshine. The limited utility of fully solar-powered cars is caused by the low intensity of solar radiation, the high cost of producing photovoltaic panels, and the effects of weather and battery capacity. Although composite-energy vehicles resemble conventional vehicles in appearance, they are equipped with solar absorber components on their outside, including the roof battery board, which can be utilized as a power source or to charge batteries. These cars are equipped with both an electric motor and a gasoline engine. The electric motor powers the back wheel while the gasoline engine powers the front wheels. The electric motor is powered by a battery. Low speeds are driven by the electric motor. The electric engine disconnects from the drive axis and the gasoline engine fires up when the vehicle reaches a predetermined speed, allowing it to operate like a standard car. Today's market is divided into two main categories of utility solar cars as those with 2 to 3 square meters of solar cells charged on lightweight, compact-structured private cars and 5 to 9 kilowatts of battery cars, and those with 5 to 7 square meters of batteries and 3 to 5 kilowatt-hour batteries loaded on private cars like racing cars. Furthermore, a utility solar car is a compact passenger car that is available on the market that has been adapted to run on electricity and has 1.5 to 2 square meters of sun cells and 14 to 18 kilowatt-hour batteries installed. Apart from adapting to variations in the weather, the solar battery can also function in tandem with solar cells in the event of inadequate electricity.

3. Types and Development History of Batteries

Now there are four generations of batteries. The first generation is crystalline silicon batteries, such as monocrystalline, multicolor silicone batteries. Thin film batteries of the second generation can be widely divided into three categories: CDTe thin film batteries, CIGS thin film batteries and non-microcrystalline silicon thin film chargers. GIGS has the highest conversion efficiency, followed by CDTe and the least efficient non-microcrystalline batteries. However, from the point of view of raw material availability, silicon is the most common raw material in non-microcrystalline batteries, while rare element compounds are present in the raw materials of the other two batteries and are therefore less readily available.

The third generation of solar cells aims to reduce costs, increase application convenience and improve energy conversion efficiency. These, known as new solar cells, include calcium-mineral solar cell, dye sensor, organic thin film solar cell and quantum-point sensor cell. These batteries have high theoretical energy conversion efficiency, relatively low production costs and fast development time, which makes them very promising for future development. The fourth-generation solar cells are thin-film solar batteries that paint very thin layers on glass floors by mixing "nanoparticles" of 10 to 100 nanometers in diameter into transparent liquids. Specific information on these generations of batteries can be found in the Table 1.

Table 1. Four Generations Solar Cells

| Generation | Production Technology | Advantage | Disadvantages |
|------------|--|--|--|
| First | Monocrystalline silicon solar cells: Float Zone Method and Czochralski Method [3]; Polycrystalline silicon solar cells: Chlorosilane reduction method [4]. | The production process is mature, stable, easy to obtain raw materials, and low cost. Efficiency reached 25% [5]. | The conversion efficiency is not high enough and difficult to improve. Poor high-temperature performance, poor luminosity. |
| Second | 1. CIGS: Technology of the CIGS solar cells [6]. 2. a-Si: plasma-enhanced chemical vapour deposition (PE-CVD) [7]. 3. Manufacture of CdTe solar cells[8]. | 1. Low pollution, good light performance and efficiency [2] 2. Low power consumption, short energy recovery time; easy to manufacture on a large scale [9]. 3. High theoretical efficiency, stable performance, and easy to manufacture. | 1. Complex manufacturing, high investment costs; insufficient supply of critical raw materials; inability to produce on a large scale. 2. Conversion efficiency slightly lower than crystalline silicon photovoltaic batteries. 3. Conversion efficiency slightly lower than crystalline silicon batteries [8]. |
| Third | 1. Produced by organic materials with photosensitive properties as semiconductor materials [10]. 2. Combination of natural dye as a photo sensitizers [11] 3.Sensitization of anode [12] 4.Structure of solar cells in calcium uranium ore [13] | 1. Rich in sources and inexpensive, obtained by artificial synthesis. 2. Works well in darker environments. 3. High absorption efficiency, wide range, adjustable belt gap, low cost [13] 4. Almost the same performance as conventional batteries, and a lower price [13]. | 1. Low efficiency and service life under prolonged sun exposure conditions 2. Limits of the increase in battery efficiency, and poor stability 3. Relatively low photoelectric conversion efficiency 4. Large cost of organic hole transmission material, complex synthesis process, difficulty in the purity, and the low stability [13] |
| Fourth | These nanoparticles, when exposed to sunlight, release hot electrons and generate electrical impulses. | Low cost for the ability of the material sprayed on any | Currently used only in vacuum devices |

The first-generation solar cell industry is very mature and is widely used globally. Second generation solar cells and the first generation have made a change in the direction of the production principle, leading to the development of solar panels in a thinner direction. Third generation solar batteries continue to develop in terms of materials and production methods, reducing production costs and improving the efficiency of photovoltaic conversion. The direction of research of the fourth-generation Solar cells is an entirely new field with a clear advantage over the previous three generations, as long as the surface is smooth, spraying material can produce a layer of coating,

converting solar energy into electric energy, which allows it to be very conveniently applied in various scenarios, without the impact of the equipment volume.

4. Bottleneck and perspective Conclusion

The fourth-generation solar cells are still in the experimental phase and are still faced with the high cost of materials and the high industrial cost. And if such a battery can really be covered like a film on other objects, will it have a short lifetime; if part of the film is broken, will the overall efficiency be affected, and how to repair it. If a fourth-generation battery can be mass-produced, then a layer of transparent media on a future solar car will not affect its structure at all, saving space on the solar panels of today's solar cars, reducing the weight of the car and reducing electricity consumption while driving. If the efficiency of the fourth-generation battery exceeds 25 percent or even 30 percent, then it is very likely that cars that rely entirely on solar power will be massively promoted.

5. Conclusion

This article concludes that the development of the first generation of solar cells has almost reached its limit, and it is difficult to make any major improvements. The second generation of batteries has improved the manufacturing method, making them smaller and thinner. Although the photoelectric conversion efficiency is not as good as the first generation of batteries and faces many key problems, the second generation of batteries still has a lot of room for development. The third generation of batteries is developed in the direction of raw materials, using various new materials to replace traditional materials. It has unique advantages in many fields, but the use of new materials also means facing many problems. Although there is very little information about the fourth generation of batteries, it can be seen from this information that it is very powerful. Although it still takes a long time to develop, when it is successfully developed, the field of solar cells will surely achieve a major breakthrough. This article summarizes and analyzes various types of solar cells to a certain extent and provides some of my personal insights into the development of solar cells. I hope that it can provide certain convenience for scholars who study solar cells in the future so that they can get the information they need faster. However, there are still some omissions in the various detailed details of each battery, such as more specific parameters. I hope that other scholars can add more data based on the text in the future, update the production cost of various solar cells, photoelectric conversion efficiency, and other data, so as to conduct in-depth research in the field of solar cells.

References

- [1] Esmaeili S E, Aldandan A, Dallol L, et al. Design and implementation of a one-seater solar car[J]. *Journal of Sustainable Development of Energy, Water and Environment Systems*, 2024, 12(1): 1-14.
- [2] Zhang Wenjie. A brief discussion on the application of solar energy technology in the field of new automotive energy [J]. *Technology and Market*, 2021, 28(12):96-97.
- [3] Ballif C, Haug F J, Boccard M, et al. Status and perspectives of crystalline silicon photovoltaics in research and industry[J]. *Nature Reviews Materials*, 2022, 7(8): 597-616.
- [4] Hou Yanqing, Xie Gang, Tao Dongping, et al. Solar grade polysilicon production technology[D], 2010.
- [5] Chen Junfan, Zhao Shengsheng, Gao Tian, et al. Latest progress and development trends of high-efficiency monocrystalline silicon solar cells [J]. *Materials Herald*, 2019, 33(1): 110-116.
- [6] Tang Y. Copper indium gallium selenide thin film solar cells[J]. *Nanostructured solar cells*, 2017, 10: 65291
- [7] Shah A. Amorphous silicon solar cells[J]. *Solar Cells and Modules*, 2020: 139-161.
- [8] Romeo A, Artegiani E. CdTe-based thin film solar cells: past, present and future[J]. *Energies*, 2021, 14(6): 1684

- [9] Zhao Zhiming. Technology development status and trends of amorphous silicon thin film solar cells and production equipment[J]. Science and Technology Information Development and Economics, 2009, 19(34): 136-138
- [10] Chen Zhonghai, Zhou Ying. Working principle and application prospects of organic solar cells[J]. Physical Bulletin, 2020, 39(3): 123-125.
- [11] Francis O I, Ikenna A. Review of dye-sensitized solar cell (DSSCs) development[J]. Natural Science, 2021, 13(12): 496-509.
- [12] Li Ling, Ma Zeyuan, Li Zixiang, et al. Research progress on quantum dot sensitized solar cells [J]. Journal of Hebei University (Natural Science Edition), 2020, 40(5): 469.
- [13] Li Bo, Zhao Jianhong, Zhao Xinbo, et al. Research progress and development trends of new solar cells [J]. Energy Research and Information, 2021, 37(1): 32-39.