Social Issues Caused by Lithium-ion Batteries

Peisen Zhang *

RCF Experimental School, Beijing, 100028, China

* Corresponding author: zhangpeisen@rdfzcygj.cn

Abstract. Human civilization is often intertwined with natural resources, and with the progress of human civilization, the demand for resources continues to increase. For centuries, oil, gas and coal mines have been the main resources for industrial production. However, while bringing vigorous productivity to human beings, it also brings irreversible harm to the environment. The letting of the carbon dioxide causes the global warming, the using of oil produce much toxic gas which cause the atmosphere pollution, and so on. Battery is a major new energy source invented by human beings, and safety, cost and work efficiency are worth considering. Thus, this paper is focus on summarizing the working principle, the application, the main issues and the future forecast of the lithium-ion batteries. This paper firstly introduces the battery itself. Then this paper will talk about the advantages and disadvantages, which is followed by several main issues. Finally, I am going to dope out the of the lithium-ion batteries. All in all, the research significance of this paper is to summarize the social problem and sort out its solution and application feasibility.

Keywords: Lithium-ion batteries, new resources, electricity vehicles, electrode material, security issue.

1. Introduction

In recent years, the new energy vehicles especially the electricity energy vehicles gradually become a main role in the market. It took nearly a decade for lithium-ion batteries to reach their current market dominance [1]. In addition, the target of this paper is to explore the social issues caused by the lithium-ion batteries. The reason why the lithium-ion should be focused is that the lithium-ion batteries have reached a very main stage in the electricity or new resources region, which have mentioned before.

Meanwhile, just because of its significance, many scholars and scientists have researched this issue before. That builds the history of the lithium-ion batteries. In the 1970s, scientists found titanium sulfide and chose it to be the positive electrode material, and used lithium as the negative electrode material. This process made a foundation was laid. Then in 1982, R.R. Agarwal and J.R. Selman found that there are security issues in the lithium battery. In order to solve this, they tried to use the characteristics of lithium-ion embedded in graphite to make rechargeable batteries. The first lithium graphite electrode which can be really used was trial-produced. Next year, scientists found the manganese spinel which is a new material of the positive electrode which is cheaper and more stable. The cost issues firstly have been found and solve. Finally, in 1996, the cycle life issue has been solved as well. Padhi and Goodenough found the Lithium iron phosphate whose overcharge resistance far exceeds that of traditional lithium-ion battery materials. The process is considered successful. The history of lithium-ion batteries can be traced back to the 1970s, but the important progress has been made since the 1980s, and the first lithium-ion battery was produced for commercial use in 1991, which has given researchers, laboratories and industrial production considerable time. Michel Armand was very important in the creation and development of negative, positive electrodes, and electrolytes for lithium-ion batteries. He is one of the "grandfathers of modern batteries", which motivates many researchers and designers to invent materials and electrolytes with higher energy densities, longer life cycles, and inexpensive materials. As a result, electric vehicle batteries emerged as the times require, and the technology is more mature, regulating the electricity generated by intermittent power sources before being integrated into the smart grid [2].

However, unlike these highly specialized scientific studies before, this paper focuses on the scientific basis that has been summarized to discuss the problems of lithium-ion batteries in daily life.

Firstly, this paper briefly explains how lithium-ion batteries work, and then list some of its common applications. Afterwards, this paper will elaborate on cost issues, safety issues, environmental issues and recycling issues. Thus, the limitation and disadvantages are the main part of this paper and there is also a short outlook and conclusion at the end of this paper.

2. Lithium-ion Batteries

The Ordinary batteries have two electrodes, which are a place to convert different types of energy into chemical energy and store it. The lithium-ion battery needs the lithium ions to move between two different electrodes in order to work. After the charging and discharging process, the lithium ions enter and exit from two electrodes. When it is charging, the ions exit from the positive electrode and move into negative electrode through the electrolyte, and the negative electrode is in a state of plenty of lithium ions.

2.1. Structure of Battery

At the beginning of social issues, this paper will firstly introduce the principle of the lithium-ion batteries. The batteries are consisted with 4 parts: positive electrode, negative electrode, electrolyte and the separator. The lithium-ion batteries often use alloy of lithium or lithium oxide as the positive electrode and use graphite as the negative electrode. The electrolyte is a kind of electrolyte which does not contain water. The table 1 shows four kinds of lithium-ion batteries and their data of the voltage and energy density.

Table 1. The voltage and energy density of different positive electrode material.

Lithium-ion battery	$LiCOO_2$	Li_2MnO_3	$LiFePO_4$	Li_2FePO_4F
Voltage	3.7 V	3.7 V	3.2 V	3.6 V
Energy Density	140 mAh/g	100 mAh/g	130 mAh/g	115 mAh/g

2.2. Function of Electrodes

After the battery charging process, there are lithium ions are existed on the anode, and these lithium ions transfer from electrolyte to cathode. As the negative electrode, the carbon has a layer structure which has many pores. These ions which arrive at the negative electrode will enter the pores. The more entered lithium ions, the better the charging quantity. On the other hand, when the battery is discharging, the ions which entered the pores will be separated and come back to positive electrode. Same as before, the more the ions come back, the higher the discharging quantity.

Anode material mostly is graphite. The research has showed that titanium may be a proper material. The negative reaction is that the lithium-ion insertion during charging, lithium ion is removed during discharge. There are several materials which can be used as the negative electrode, such as graphite, tin and alloy.

2.3. Electrolyte

The material of the electrolyte often chooses the lithium salt. Because the working pressure of the lithium-ion battery is much higher than the separated pressure of water, the lithium-ion battery usually uses the organic solvent. However, the process of charging the organic solvent will destroy the structure of the graphite and make it fall off. The surface will generate the solid electrolyte, thereby cause the electrode inactivated. In addition, the organic solvent will bring security issues such as explosion and burn.

3. Social Issues

The lithium-ion battery has many advantages compared with the others. The energy ratio is relatively high, it has long service life, the rated voltage is high, it has high power endurance, the self-

discharge rate is very low and very light. Although the battery is good in many applications, it has some challenge and problem as well. Taking the new resources vehicles as the example, in recent years, plenty of lithium-ion batteries are applied to these vehicles in order to diminish the pollution which are produced by the vehicles which were using fossil fuels. Whereas, there are many accidents which are because of the battery burnt or even explosion. There are some issues behind these accidents. In addition, the cost of the lithium-ion battery also affects the application.

3.1. Cost Issues

According to Fig. 1, it can be easily found that the demand for the lithium-ion batteries both on electricity vehicles and consumer using are increasing rapidly from 1998 to 2018. Especially for the electricity vehicles, without the fossil fuel, the limitation of pollution produced by the vehicles can be improved obviously [3].

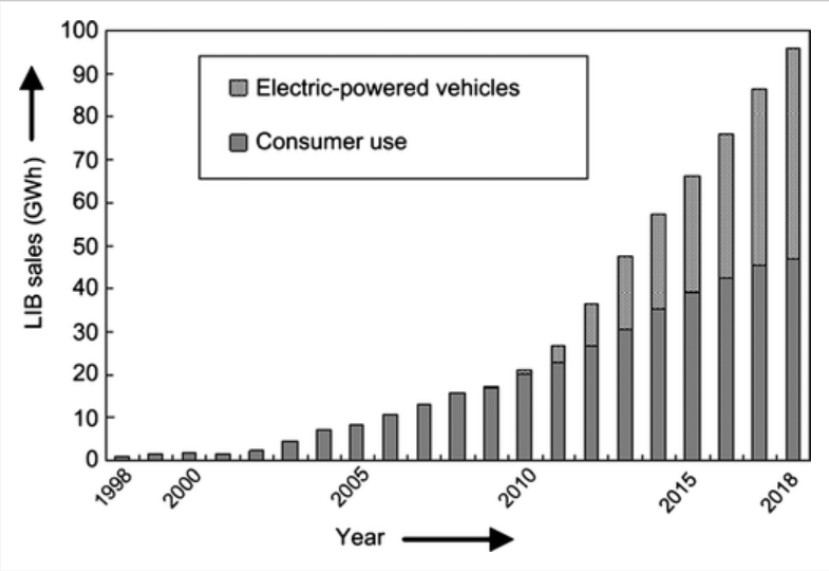

Figure 1. The trend of the lithium ion battery sales from 1998 to 2018. https://onlinelibrary.wiley.com/doi/full/10.1002/ese3.95

Da Deng said in the "Li-ion batteries: basics, progress, and challenges" that the degree of commercialization and technology of lithium-ion batteries are very mature, and the main use of batteries is currently in electronic items, such as phones and laptops, and it has an increasing importance in new energy vehicles. Lithium-ion batteries can also be used as a storage site to store new energy converted from renewable energy. However, the requirements for energy storage are getting higher and higher, and lithium-ion batteries also need to be upgraded to upgrade. Especially the cost issue, the cost needs to be reduced. Therefore, it is still very difficult to invent a new generation of lithium-ion batteries to replace current lithium-ion battery [4].

The main issue is that the balance between the cost and the security of the lithium-ion battery. Taking the cobalt and nickle as the example, the positive ion of these two elements was considered to be chosen as the positive electrode material. However, both two these materials were toxic.

Besides the safety, the energy density should be considered as well. In order to increase the energy density of lithium-ion batteries, electrode coupling with high specific capacity and high operating battery voltage needs to be found. As mentioned earlier, there is a great number of anode materials which can replace that can significantly increase specific capacity, especially silicon and tin-based anodes with high appeal. The large-scale and low-cost preparation of Si nanometer materials still faces challenges [5].

In short, lithium-ion batteries have gradually become more and more related to our lives, which has led to the growing demand for lithium-ion batteries. However, while the technology is becoming more and more mature. The cost of lithium-ion batteries has fallen over time, which makes the future trend of electric vehicles that rely on lithium-ion technology better. The cost price of the battery varies

depending on the source, but inside the EV battery pack, the battery accounts for about 77% of the total cost of the average battery pack. According to Argonne National Laboratory's BatPac model, the cost of manufacturing lithium-ion batteries includes equipment depreciation, labor costs, and plant floor space costs. According to estimates by the Boston Consulting Group, battery prices have been down for a long time and are now around $125 per kWh [6]. The four high-level executives agreed that by 2025, the price of ternary lithium batteries will be about 500 yuan, and the price of lithium iron phosphate batteries will be about 400 yuan, which is more than half of the current price.

3.2. Security Issues

As the other new technologies, the lithium-ion batteries also have the risk of the safety. Among them, battery burnout or even explosion is the main problem.

The article called “Lithium-Ion Battery” public in the Clean Energy Institute states that industry, science and consumer concerns about the safety of lithium-ion batteries focus on whether the battery can produce more energy, more power, and whether it can produce enough batteries. In addition, battery fire accidents are also a point of great concern. The fire of new energy vehicles is the most important example [7].

There are four reasons which can explain why batteries may explode and in short, these are: (i) The reaction between the electrolyte and the nagetive electrodes. Even though the metal lithium and the carbon are separated by the film in order to protect. However, the performance of this protect film reject the plenty reaction between two parts. (ii) There is a heat decomposition in the electrolyte and when the temperature of the battery has reached a certain place. The electrolyte will be decomposed and produced heat. (iii) The reaction between electrolyte and the positive electrode. Because of the difference between the pressure in elctrolyte and the positive electrode, the reacion is rare to be existed. (iv) The enthalpy changes of the organic material on both positive and negative electrode and the thermal decomposition of the material of the positive electrode.

Because the quality depends on the temperature, there are challenges existed in the application of the lithium-ion batteries. The best temperature of lithium-ion batteries usually is from 15℃ to 35℃, and whatever the real temperature is higher or lower. Both of these two situations will affect the quality of the battery, and even bring a change which cannot be repaired. In a low temperature situation, the diminish of the quality is because of the ionic conductivity decreases and the charge transfer resistance increases. The graphite will react with other materials on the positive electrode and generates a special effect, which will lose the quantity of the battery. In addition, when the battery is in a high temperature situation, the battery will age rapidly and decrease the using life of the lithium-ion battery. After the simulation of increasing temperature, the battery will be in a exothermic reaction and produce more heats, which cause the temperature of the system further increase. These uncontrolled heats will cause the heat of the whole system are uncontrolled [8].

3.3. Environmental Issues

The electrolyte of lithium batteries contains heavy metals such as nickel, cobalt, manganese and fluorine organic compounds, which if not handled properly, will cause problems such as heavy metal pollution and organic waste emissions. The pollution of lithium batteries mainly has two aspects, one is heavy metals, such as cobalt, manganese and nickel in ternary battery lithium cobalt oxide materials, and the other aspect is the electrolyte in the battery. There are pollutants such as lead dust, lead smoke, acid mist and other pollutants in the production process of lithium batteries, and waste gas treatment equipment needs to be used to treat the waste gas to safely discharge. The lithium battery itself is less polluting than lead-acid and nickel-chromium batteries, but there is still heavy metal pollution.

The requirement of the lithium-ion batteries rise in a quick rate. Lithium-ion batteries are already a necessity in people's lives, whether it is computers, mobile phones and new energy vehicles used daily, and then to battery energy storage systems. Batteries are also important in the field of renewable energy, which requires an intermittent power supply managed by battery energy storage systems. The application of lithium-ion batteries in electric traction has sparked a revolution in the automotive

industry, aiming to decarbonize the transport sector and reduce local air pollution. In 2009, the lithium-ion battery energy storage capacity put into the global market was close to 25.6 GWh (about 134,000 tons), in 2019 it was about 218 GWh (more than 1.2 million tons), and it is expected that by 2030 there will be more than 2,500 GWh (over 12.7 million tons) into the market, subsequently resulting in a large amount of waste from used lithium-ion battery [9].

3.4. Cycle Life Issues

Anode materials are needed in lithium-ion batteries because lithium metal forms dendrites, which can cause a cutting-out, and cause a thermal runaway reaction on the negative electrode, and cause the battery to catch fire. In addition, lithium metal also has the problem of poor cycle life [10].

One of the problems of the cycle life is the positive electrode overcharge reaction which mainly occurs when the proportion of cathode material is too low, resulting in a capacity imbalance between the electrodes, and then leading to irreversible loss of lithium-ion batteries, and the continuous accumulation of oxygen and combustible gas decomposed by cathode materials and electrolytes, which will bring safety hazards to the use of lithium-ion batteries. During charging, the active material of the positive electrode of the battery is unstable, which will cause reaction with the electrolyte and affect the battery capacity. Among them, the structural defects of the cathode material, the charging potential is too high, and the carbon black content are the main factors affecting the battery capacity.

4. Conclusion

Compared with traditional fossil fuels, lithium-ion batteries have some considerable advantages: high and fast conversion rate, high energy density, fast response, which is why lithium-ion batteries are used in new energy transportation and other fields. However, lithium-ion batteries also have problems worth considering, the safety hazards caused by their positive and negative imbalances, the pollution to the environment during recycling, how to balance costs, and how to improve their cycle life. Lithium-ion batteries face many challenges and an unknown future. The future of lithium-ion batteries must first find more environmentally friendly and cheaper electrode materials, not only to avoid toxic pollution to the environment, but also to allow the public to buy and use in large quantities. not only to avoid toxic pollution to the environment, but also to allow the public to buy and use in large quantities. Secondly, the safety problem inside the battery, the reaction between the positive and negative electrodes and the electrolyte needs to be studied more carefully, so that the generated heat can be discharged in time to avoid explosion, spontaneous combustion and other safety hazards. Finally, this paper mainly summarizes the problems caused by lithium-ion batteries to the current society, and introduces them from four aspects: cost, safety, battery life and environment. And from the electrode material of lithium-ion batteries, the working principle and technical shortcomings of lithium-ion batteries are briefly described.

References

[1] Masataka W., Recent developments in lithium-ion batteries, ScienceDirect, Materials Science and Engineering: Reports, 2001, 33 (4): 109 - 134.

[2] Mogalahalli V., Reddy, Alain M., et al., Brief History of Early Lithium-Battery Development, MDPI, Journals, Materials, 2020, 13 (8): 1884.

[3] Li-ion batteries: basics, progress, and challenges, Energy Science & Engineering, 2015.

[4] Da D., Li-ion batteries: basics, progress, and challenges, WILEY Online Library, Energy Science & Engineer, 2015, 3 (5): 385 - 418.

[5] Nitta P., Wu F., Lee J., Glab Yushin Li-ion battery: present and future, materials today, 2015, 18 (5): 252 - 264.

[6] https: //news.bjx.com.cn/html/20210209/1135654.shtml.

[7] https: //www.cei.washington.edu/research/energy-storage/lithium-ion-battery/.

[8] Kim T., Song W., Son D.Y., Luis K.O., Qi Y., Lithium-ion batteries: outlook on present, future, and hybridized technologies, Royal society of chemistry, 2019, 7.

[9] Wojciech M., Mohammad A.R., Oliver H., Paul C., Environmental impacts, pollution sources and pathways of spent lithium-ion batteries, Royal society of chemistry, Energy Environmental Science, 2021, 14: 6099 - 6121.

[10] Cabrera C., Florian N., Andreas J., Calculation of the state of safety (SOS), ScienceDirect, 2016, 324: 509 - 520.