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Brief Talk about Lithium-ion Batteries' Safety and Influencing Factors

Cheng Jin*

Public Security Fire Force College, Kunming 650208 China

*Corresponding author e-mail: jincheng0521@126.com

Abstract. A brief introduction of the development background, the concept, characteristic and advantages of lithium-ion battery was given. The typical fire accidents about lithium-ion battery in production process, the vehicle with new energy, portable electronic products were summarized. Some important factors for lithium-ion batteries' safety were emphatically analyzed. Several constructive suggestions on improvement direction were given, meanwhile, we have a nice exception on the future of lithium-ion battery industry.

Key words. Lithium-ion battery; lithium-ion batteries' safety; influencing factors.

1. Introduction

As we all know, people's various production and life cannot leave the energy. Energy is an essential element of human social activities. Especially in today's period of rapid economic development, with the rapid increase of population, the demand for energy is increasing and human society is consuming a lot of energy at every moment. In recent years, the quality of air has deteriorated, and the number of reparable particulate in the sky has been increasing. The haze weather has been common, which not only causes serious damage to our health, but also affects and restrains economic progress and development. As a result, almost all countries in the world are looking for an efficient clean energy to solve the problem. With the improvement of industrialization and the continuous progress of human society, the problem of energy scarcity is becoming more and more serious. How to find a new energy material is one of the major development problems that human beings need to solve since the 21st century [1].

Nowadays, people have been trying to solve this problem, and each country's scholars are trying to find and develop a new energy with the feature of environmental protection, high energy, and high security [2]. After continuous research and exploration, a variety of primary and secondary energy and other new energy have been developed and used. Among these energies, chemical energy has been developed rapidly, and has gradually become the focus of attention. The main reason is that it has a high energy density and energy conversion efficiency; can be assembled and moved freely ; cannot cause noise pollution. At present, our emphasis on electrochemical energy research has risen to a very high height [3, 4].



2. Brief of Lithium-ion battery

Lithium-ion battery is different from the lithium battery. It is a secondary battery and can be charged and discharged. Its work principle is to rely on the movement of lithium ions between cathode and anode. In the process of charging and discharging, Li^+ intercalates and DE intercalates between the insulated cathode and anode. During the charging process, Li^+ DE intercalates from cathode and intercalates into anode through the electrolyte. Then the anode is in the lithium-rich state. During the discharge process, Li^+ DE intercalates from anode and intercalates into cathode through the electrolyte. Then the cathode is in the lithium-rich state. Lithium-ion battery is a typical representative of modern high-performance batteries, which electrode in most cases is used with lithium-containing materials.

Compared with the traditional nickel-metal hydride batteries, nickel-cadmium batteries and lead-acid batteries, the lithium-ion battery has many advantages. For example, high average output voltage, small volume and light weight, high energy density and high theoretical specific capacity, low self-discharge rate and long service life, high safety performance, green, no "memory effect" and so on. At present, lithium-ion battery has been widely used in portable consumer electronic products, such as smart phone, notebook computer, digital camera, electric tools, etc. At home and abroad, some research units and manufacturers have begun to study and produce high-capacity large-scale lithium-ion battery and its battery to provide power for electric vehicles, aerospace and aviation, large and medium-sized communication devices.

With the rapid development of electric vehicle technology, lithium-ion battery has become an important source of power for electric vehicles and hybrid vehicles. Governments at all levels, especially in economic developed provinces, have introduced many strategies to support new energy vehicles from the macro-policy level. Seven strategic emerging industry development plan which includes new energy vehicles, will further promote the development of China's electric vehicles from the policy level [5-7].

3. Typical Fire Case of Lithium-ion Battery

With the wide application of lithium-ion batteries, the security problem is more prominent, and people pay more attention to it. Lithium-ion batteries bring the gospel to humans, at the same time, it is also a potential danger. In recent years, there have been many influential fire accidents at home and abroad, resulting in huge economic losses, and lead to a large-scale recall of related products, which caused a huge impact to the lithium ion battery industry and related industries.

3.1. *Lithium-ion Battery Business Fire Once again Caused Concern*

May 31, 2016, at 5:53 pm, Jiangsu Hai SiDa Power Company Limited which located in Jiangsu Nantong Qidong occurred lithium battery fire and explosion. The accident occurred in the company's three-layer warehouse which stored fully charged lithium- batteries in the Nanyuan West Road of Qidong City. Fire officers and soldiers arrived quickly and carried out the rescue measures after the fighting. In the disposal, the scene suddenly exploded. 12 employees and 8 firefighters injured on the spot. Subsequently, the injured were rushed to Nantong and Qigong hospital for treatment. However, eventually a firefighter and an employee died.

After a preliminary investigation, the cause of the accident was that the battery has a short circuit inside, resulting in a rapid rise in temperature and affecting the adjacent battery, which eventually led to the occurrence of e explosion.

3.2. *New Energy Car Fire Caused Deep Thinking*

In recent years, with the progress of scientific and technological, as well as the introduction of various subsidy policies, new energy vehicles ushered in the explosive growth. The production and sales hit record highs repeatedly, which from another aspect seems to explain of the application of new energy gradually is becoming mature and getting better.

The development of new energy vehicles always have inextricably linked with the safety. According to incomplete statistics, there are more than a dozen new energy vehicles fire accidents at home and abroad caused by the battery. Short circuit of battery is one of the major reasons.

3.3. *Lithium-ion Battery in the Field of Portable Electronic Products Accident*

At present, lithium-ion batteries are widely used in notebook computers, portable phones and other electronic products. The explosion and fire of mobile phone lithium-ion battery cause everyone's attention.

Samsung released the new flagship mobile phone Galaxy Note7 in 2016. However, the occurrence of the so-called flagship mobile phone chain explosion made the Samsung Electronics in the storm. Samsung Electronics then carried out a large-scale mobile phone recall, but this measure did not reverse the vicious development of the situation. Security issues are the most important, and no matter how high-tech the smart phone contents, if there is no security to guarantee, it is worthless. The emergence of mobile phone battery explosion is not only seriously damaged Samsung's reputation and brand image, but also lead to huge economic losses. Samsung Electronics shares plummeted, which caused Korea's stock market turmoil. At present, aeronautical bureau of multiple countries has issued the security warning that passengers are strictly prohibited to use Samsung Note7 mobile phone in the plane, and are not allowed to put the Samsung Note7 into checked baggage.

4. **Analysis of Factors Affecting the Safety of Lithium-ion Batteries**

The specific energy of lithium-ion battery is relatively high, and the electrolyte is mostly organic flammable. When the battery heat generation have higher speed than the heat dissipation rate, there may be a security problem [1]. For the development and production of lithium-ion batteries, the battery safety issues must be put in the first place. This article summarizes the factors that affect the safety of lithium-ion batteries from the following aspects.

4.1. *Short circuit*

Short circuit is the main factor causing the explosion of lithium-on battery. Short circuit is divided into short circuit and external short circuit. Compared with the external short circuit, the internal short circuit has a greater impact on the safety of lithium-ion battery. When the external short circuit occurs, the temperature of the battery rises, which will largely lead to the occurrence of internal short circuit. In particular, the high temperature will make the inside diaphragm of the battery shrink or completely bad, which results in internal short circuit. When the internal short circuit occurs, the internal temperature of the battery increases sharply, and a series of reactions occur inside the battery. Each reaction promotes mutually and successively. When the temperature rises to a certain extent, the solid electrolyte interface film (SEI film) of carbon anode surface will decompose [8] and then lithium intercalation carbon anode exposed in the electrolyte will react violently with the organic solvent, resulting in further rise in temperature. The reaction of the lithium intercalation carbon anode with the adhesive, the reaction of dissolution, the reaction of decomposition, and the thermal decomposition reaction of cathode release of a lot of heat and gas[9]. Osaka and others have studied the composition of gas produced by overcharge of Li ion battery [10]. The gases, CO₂, CO and a small amount of CH₄ are mainly from cathode. This proves that CO₂ comes from the oxidation of the electrolyte near the anode, not from the carbon negative plate. The anode produces highly flammable gases (mainly H₂ and a small fraction of CH₄, C₂H₄, C₂H₆, etc.). The formation of gas causes the internal pressure of the battery to increase, resulting in the fracture battery, and the outflow of electrolyte and the overflow of flammable gas. The majority of electrolyte is organic solvent. The main component is carbonic acid ester. The flash and boiling point are very low, and it is easily oxidized at about 4.6V. The interaction between combustible gas and electrolyte accelerates the thermal runaway, then it further causes combustion and even explosion, and increases the damage degree of safety accidents.

From the current research reports, there are many reasons leading to short circuit. External shocks, squeezing and acupuncture can all cause occurrence of short circuits. In the manufacturing process of Lithium-ion batteries, their own problems cannot be ignored. For example, the manufacturing process is flawed, copper foil and aluminum foil fragments and metal dust are left between the insulated cathode and anode. These tiny particles happen to be close to the diaphragm between cathode and anode of

battery when the battery overheating. It is easy to cause the breakage of diaphragm and the internal short circuit, then the heat out of control may occur, leading to the occurrence of burning and explosion

4.2. Overcharge

When the lithium-ion batteries are in overcharged, it could lead to thermal runaway, thermal out of control is caused by mainly from two aspects [10]: one hand is the Joule heat of current flowing, the other hand is the reaction heat of cathode and anode side reaction. The cathode voltage increases gradually when the battery is overcharged. When the precipitated amount of cathode lithium is too large, the DE intercalation of lithium ion becomes more difficult, which leads to internal resistance of the battery increasing rapidly, thus resulting in a great deal of Joule heat. This phenomenon is more pronounced when charged at high rate. If the embedding lithium capability of anode is low, overcharge will make lithium precipitate in the anode surface form the lithium dendrite, which puncture the isolation film to short-circuit the battery. The high voltage in the overcharged state causes irreversible changes in the structure of the cathode active material and the decomposition of the electrolyte. Thus a large amount of gas is produced, a large amount of heat is released, and causing the occurrence of thermal runaway, which causes the battery temperature and internal pressure to increase abruptly, causing the battery to expand or even rupture, resulting in the explosion, burning and other hidden dangers.

4.3. Water

In the lithium-ion battery production process of proportioning, grinding, coating, drying, flaking, assembly and other links, the water content must be controlled strictly. Water can react with the electrolyte in the battery to produce hydrofluoric acid and gas. Hydrofluoric acid is a highly corrosive acid that has serious effects on the interior of the battery and brings serious consequences. In the charging process, a series of reactions occur, the gas produced by the reaction will make the battery internal pressure increase, when the battery shell cannot endure the pressure, it will lead to thermal runaway, ignition, explosion. It can be seen, the water on the production environment and the production process of lithium-ion battery must be controlled quite strictly.

4.4. Insufficient of Anode Capacity

When the anode which site on the opposite side of the cathode capacity is insufficient, or no capacity, battery charging, generated by some or all of the lithium cannot be inserted into the lamellar structure of graphite anode, so the lithium dendrite can precipitate on the surface of anode. After several cycles of charging and discharging, the growing lithium dendrite would pierce diaphragm paper, so battery internal becomes short circuit. Thus it can cause thermal runaway, combustion and explosion.

5. Conclusion

This work was financially supported by xxx fund. Factors that affect the safety of lithium-ion battery have become an important issue which constrains the development and needs to be solved urgently. Over the past decade, lithium-ion battery technology developed rapidly. And more and more people pay attention to its security problems. The researchers are committed to the safety problem of lithium-ion battery, starting from the electrode materials, electrolytes and diaphragm, etc. They have improved the research of overcharge protection, short circuit protection, temperature protection and have designed safety monitoring system, which made the safety of lithium-ion battery significantly been improved. With the further increase of scientific research, the safety of lithium-ion batteries will be further protected and the development of lithium-ion batteries will be better.

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