The Attractive Ternary Lithium Battery in Industry

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Abstract. The fast improved technology brings more problems for energy storage and power conversion for electric devices. But the new ternary lithium battery technology will solve the problems with enough improvement. The main topic of this article is to talk about the basic principle and suggestions for improvements. The results are the disadvantage of the low efficiency in low temperature and it is easy to cause explosion because of the high-speed impact. On the other hand, ternary lithium batteries can store more energy in unit mass and the average output power is higher than the other kind of batteries. If the system for the impact-safety is completed, the batteries will be the most suitable vessels for car industry. The meaning of this article is to improve the battery technology to make the modern life more fit for every citizen in every country and keep the safety for every electric car driver.

Keywords: Ternary lithium battery, new generation energy, chemical energy.

1. Introduction

Nowadays, the new ternary lithium battery has become one of the most popular energy batteries in the car industry. More and more car brands are using the ternary lithium battery as the core battery of their electric cars. The cars that use the ternary lithium batteries become more and more in the street in every country. A very large amount of young chooses electric cars instead of traditional fuel vehicles. Seems like electric cars will take the place of fuel vehicles [1, 2].

In July 2022, the CATL says that they have designed a new type of lithium iron phosphate battery named ‘Shenxin’, the CEO of CATL says this kind of battery will defeat the ‘Daopian’ ternary lithium battery by the strong low-temperature charging speed. More and more car brands have started racing on the update of the technology of the batteries. The main body of the experiments and the research is still the ternary lithium batteries, the ternary lithium batteries have the biggest space to develop than the other types of batteries and ternary lithium batteries are becoming the first evidence for humans to step into the new era of the touchable future of the ‘new energy era’ in people’s imagination. And many scientists are studying every field of ternary lithium batteries, they connect the batteries to a smart system so that the value of every part of the batteries and some smart cloud system can transport the value to the car driver to let them know the whole situation of the batteries in their cars. This is a double-edged sword for the customer and the transportation, containing amazing portability and the high-quality safety become the most troublesome problem for the car industries.

This article talks about the material, structure and mechanism of the ternary lithium battery and compares it to the lithium iron phosphate battery to parse a few advantages and disadvantages between them, and make suggestions to the ternary lithium battery in coming future to improve.

2. The batteries

2.1. The real examples of the car industries working on the batteries

Chinese companies currently studying ternary lithium batteries with significant results include BYD, CATL, and CALB. And CATL has the greatest progress on the batteries, such as the ‘CTP’ and ‘CTC’ technology. The CATL’s batteries have special nano-coating to keep the stability and superconductive electrolyte to reduce the time to full-charge. Now the ternary lithium batteries of CATL are normally used in the new electric cars of almost all Chinese car brands.

2.2. The basic principle of the ternary lithium battery in chemical calculations

The full name of the special "ternary lithium battery" used by CATL and the other enterprises is "ternary polymer lithium battery". The ternary polymer lithium battery is a developed type of lithium battery with the special positive electrode made of lithium nickel cobalt manganese oxide (Li (NiCoMn) O2) ternary positive electrode material [3]. The precursor product of ternary composite positive electrode material is made of the nickel salt and cobalt salt, and manganese salt as raw materials, and proportions of nickel cobalt manganese inside can be adjusted according to actual needs. Batteries with the special made ternary materials as positive electrodes have higher safety compared to lithium cobalt oxide batteries.

Its anode uses a carbon electrode that can absorb lithium ions. When discharged, lithium becomes lithium ions, detaches from the battery anode, and reaches the cathode of lithium batteries. The lithium ions inside the material move between the anode and cathode, and the electrode itself remains unchanged, which is the most iconic fundamental difference between the lithium batteries and the other kinds of lithium metal batteries. Graphite crystal is used as the anode inside the ternary lithium batteries, and the cathode is always considered that is made of LiO2. During charging, the lithium atoms inside the cathode are ionized into lithium ions in smaller size and free electrons, and the tiny lithium ions move to the anode of the batteries inside and the Li atoms are formed by the assembly of ions and electrons. When the reaction of discharge-kind happens, the Li atoms around the positive part form ions and free electrons and secondly, they form Li atoms again around the negative part. So, inside the ternary Li-based batteries, Li ions are the most common form of Li [4]. The main equation of the production of the cathode of the ternary lithium batteries.

$$M(OH)2+0.5\ Li2CO3+0.25O2 = LiMO2+0.5CO2+H2O. \quad (1)$$

This battery contains lithium-ions is a kind of complicated system, which includes a positive electrode, negative electrode, separator, electrolyte, current collector and binder, conductive agent, etc., involving reactions including electrochemical reactions of positive and negative electrodes, lithium-ion conduction and electron conduction, and heat diffusion. The production process of lithium batteries is long, and there are more than 50 processes involved in the production process. According to the individual special form in shape, the Li-based batteries are always considered that contain three common types: the cylindrical type, prismatic type and the pouch type, surely that they have certainly differences between them, but as a whole, the fabricating process of the Li-based batteries contains three key steps: the previa step at beginning(producing for pole pieces), the main step in middle(About the cell synthesis), and the final back step for termination(formation for packaging for batteries). Because of the well-known high-level strict product standards for the basic safety for Li-based batteries, there exist really utmost high-level standards for the accuracy, ability to stay the common form in different environments as well as the full smart level for the automation of Li-based battery equipment before the complete battery is produced in factories.[5] One of the biggest targets for factories during the front-to-end producing steps is to consummate every product of the (qualified or not) electrode-piece parts. About the primary processes of the steps before assembling step are: mixing, covering the special paint coats, rolling the materials, slicing, film production, and die-cutting, and the equipment involved in the process of the batteries production mainly includes: mixers, coating machines, roller press, slicing machines, film-making machines, die-cutting machines, and so on. One of the most important targets of the main process in the middle duration is to consummate the next producing steps of every single battery cell as the main role to constitute the Li-based batteries, and there still exists some discrepancies in the route in technologic field and the independent production line equipment in factories of the main process in middle of many other disparate types of Li-based batteries. The essence of the middle process is the assembly process, specifically the (positive and negative) electrode pieces made in the previous process, and the diaphragm and electrolyte are assembled in an orderly manner. Due to the different energy storage structures of square (rolled), cylindrical (rolled) and soft package (layered) batteries, there exists many obvious various

discrepancies for the routes in technologic field and the basic tools and machines used in production lines of different types of lithium batteries in the middle process. Specifically, the main processes of the middle process of square and cylindrical batteries are: winding, liquid injection, packaging, and the equipment involved mainly includes: winding machine, liquid injection machine, packaging equipment (shell machine, grooving machine, sealing machine, welding machine), etc.; The main processes of the middle process of pouch batteries are: lamination, liquid injection, packaging, and the equipment involved mainly includes: a lamination machine, liquid injection machine, packaging equipment, and so on. One of the most important targets during the back-end step is to consummate the outer package for paint coats. Up to the main-step duration in middle, there're happening the formation of the functional structure of the Li-based batteries, and that's very important for the next step to activate that, after the step of tests for ability of batteries, sorting the qualified products and assembling together to form the perfectly complete ternary Li-based batteries, to form finished Li-based batteries with safe use and stable performance. The mainly important steps to handle of post-process are: formation step, volumetric separation step, testing step to test the ability of battery cells, sorting step to pass the inferior-quality products, and so on, and the tools and machines needed to take part in the duration mainly includes: charging motors to test the basic current and voltage and others and discharging motors as well, and so on [5].

The highest-limited voltage during charging in termination step of every single Li-based battery is about 4.2volt, at the same time that's surely forbidden for batteries to be overcharged, or else, the Li-based battery will be junked trash because of the loss of so many lithium ions in positive electrodes inside the whole battery. When charging lithium-ion batteries, the special fixed charger in controlling current and voltage is considered to be used, and the fixed current should be charged to 4.2V at both ends of the lithium-ion battery before switching to constant voltage charging mode, but the ternary lithium should be charged to near 3.7V, comparing to the other types of batteries. The measurements can see the Table 1.

Table 1. Diagram for the lifetime and density of a few types of popular batteries [6]

Type of battery	normal voltage / V	Energy density per unit mass / Wh kg-1	Memory effect	Cycle life /time
lead-acid battery	2	50-70	no	500-800
NiMH battery	1.2	80-90	no	1000
lithium manganate battery	3.8	130	no	800+
lithium iron phosphate battery	3.2	160-180	no	1500-2000
ternary lithium battery	3.7	200	no	2000+

When 1000mAh becomes the fixed charging current of the batteries, we should immediately cut the connection between the batteries and charger. The normal number of current as charging in unit of mA in charging step can become from smallest 0.1* normal battery capacity to biggest 1.5* normal battery capacity, for example, one 1350mAh Li-based battery, the standard current in charging need to be controlled between from 135mA to 2025mA [6]. About 0.5 * battery capacity is selected as the number of the standard current in charging, and 2~3 hours are the recommended time to take in charging. Because of their special structure inside Li-based batteries, the Li ions cannot freely move to any positive-charged part during the discharging step, and that's integrant to keep a fixed sum of ions around the negative part inside the batteries to ensure that Li ions can be perfectly embedded in appointed channelsat the time of new charge appears. Or else, that's 100% happened to shorten the total life time of the Li-based batteries, so that's essential to make sure that the basic Li ions inside can be kept in the Pb layer after the discharging step, limiting the number of the lowest number of discharging voltages of the final finishing step of discharge is super essential, that is, being over-discharged for the Li-based batteries is fatal for daily use. The number of the voltage during the ending-discharge step of a single-cell inside the Li-based battery is usually considered about 3.0V, at the same time, 2.5V is the lowest standard for batteries to discharge. The time for Li-based batteries

to discharge relies on the average battery capacity in normal situation and the number of current in discharging duration in daily use. The time for batteries to fully discharge (hours) = battery capacity/discharge current, and the lithium-ion battery discharge current (mA) should not exceed 3 times the battery capacity, as an example, when Li-based batteries are in 1000mAh condition, 3A is the lowest standard number of current to be controlled strictly in use, or else, that's a 100% case to cause the battery damage to affect the daily use. Ternary lithium batteries have many uses in daily life, such as serving as a single cell in the battery pack of new energy electric vehicles, or as an energy storage medium used in medical devices and photographic equipment. For example, the famous car brand 'Tesla', cars use ternary lithium batteries. And almost all Chinese electric cars like 'NIO' and 'BYD' use the ternary lithium battery as the energy supply system [6].

2.3. Comparison to the other type of battery and the suggestion about the ternary lithium battery

Lithium iron phosphate battery has many advantages in lifetime, like security and the high-temperature resistance. Because the lithium iron phosphate battery is made of a material that won't on fire in cases of short circuit. The theoretical life of ternary Li-based batteries is about 2000 times, but basically to 1000 cycles, the capacity of the battery's decays to nearly 60% [7]. Indeed, in Tesla, one of the most successful car factory brands in the whole world, their technology is just able to keep about 0.7* the normal work power of the batteries after using about 3,000 times, at that time lithium iron phosphate batteries have about 80 of 100 of the original capacity with the same number of cycles. On the other side the ternary Li-based batteries have advantages in unit weight, efficiency of charging in different situation and resistance in low temperature environment. Because ternary Li-based batteries have higher energy efficiency than other kinds of batteries. The charging process of Li-based batteries forms methods for limit to current and limit to voltage, that's a fixed current charging step is done in first previa step during charging the batteries, at that time that the number of current in ampere and the power efficiency in percentage of the batteries is measured that is much higher than the normal standard of the batteries. The fixed current charge reaches a number of a certain voltage is the previa step to continue the next steps, after that it has able to go to the next stage of charging in a number of a constant voltage, at that time the current is so small and the efficiency is so low to cause the measurement for the efficiency during the charging of the two, the fixed current ratio is the measured number of the calculated ratio of the fixed current charging power to the average capacity of the Li-based battery totally. The experimental data show the exist of some discrepancies between those two ratios when charging under conditions for 10C, but above 10C condition it will make the distance larger, as the condition for 20C, the constant current ratio of the ternary Li-based battery is about 52.75%, and the constant current ratio of lithium iron phosphate battery is about 10.08%, the former is 5 times that of the latter. For the car industry, the ternary Li-based battery can be the best choice for the customers, because of the easy eagle of the customers to spend less time on charging. At the same time, the higher energy density means that the whole size of the ternary Li-based battery is a decreasing trend comparing to the other kinds of batteries, and the car can get more spare space to install other devices like an automatic cruise system that only the car of higher configuration has.

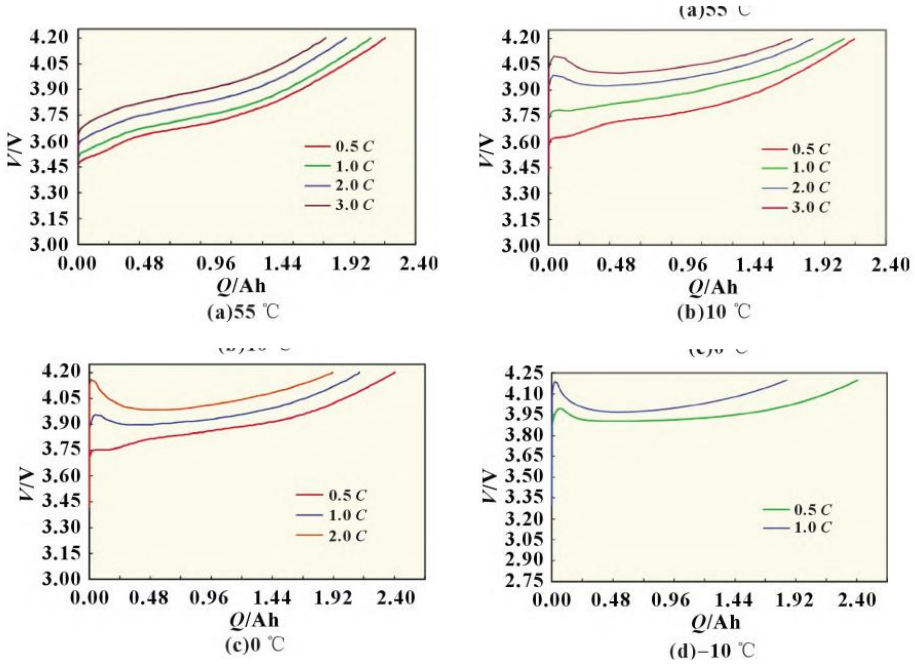

Figure 1. The voltage in charging and the charging capacity in different temperature [9]

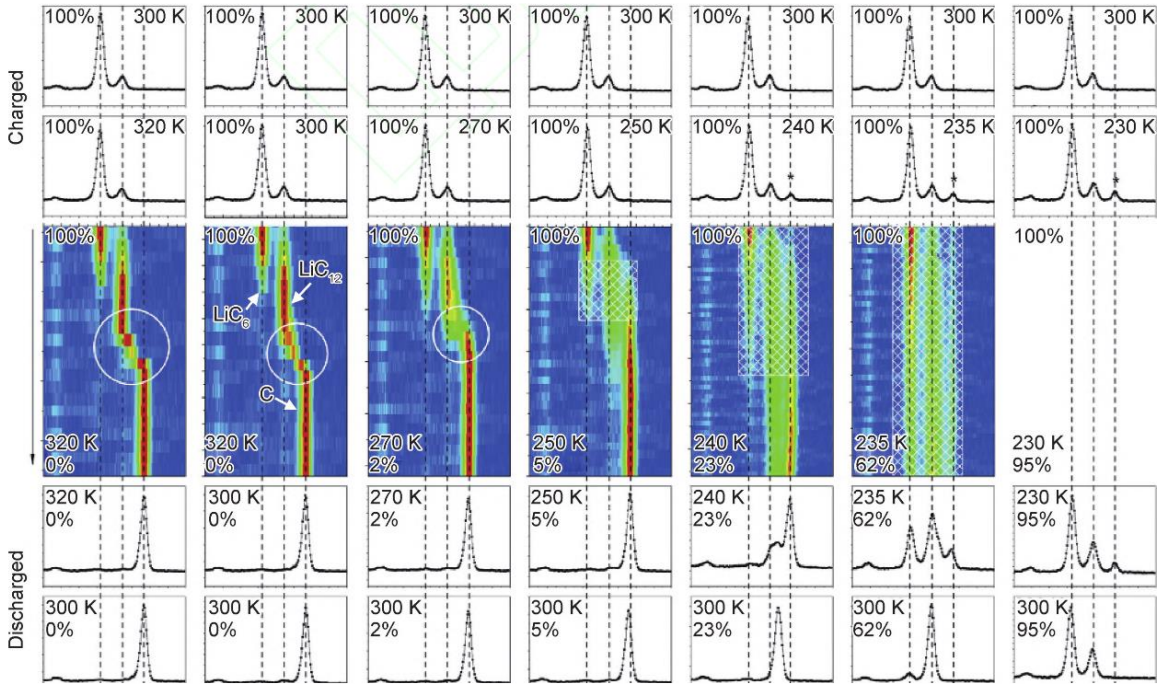

Figure 2. The working efficiency in different temperatures [10]

The enlarged section of the change of neutron diffraction patterns in charged state and discharged state at different temperatures from 230K to 320K [10]. From the current technology nowadays, the average density of energy per unit mass of the ternary lithium batteries is generally about 200Wh/kg, and probably reach about 300Wh/kg in the coming future; For lithium iron phosphate battery that's easy to get 100-110 Wh/kg and a part of them can get 130-150Wh/kg, but 200Wh/kg is calculated that is impossible for it to reach in use [8,9]. At about -20 °C condition, the ternary Li-based battery can release about 70.14% of its original capacity, while the lithium iron phosphate battery can only release about 54.94% of its own original capacity, that's because the discharged position in whole 'system' of the ternary Li-based battery is much higher than it of the lithium iron phosphate battery under the conditions that have lower degree in temperature, at same time the voltage platform starts faster. The measurements can be seen in figure 1-2[10].

The authors believe the ternary Li-based battery needs to be completely connected to every single cell in the pack using some material that releases energy and heat more quickly so the pack doesn't burn up in seconds, or the pack could be connected to a safety system. When the battery pack is short-circuited or the pack is shocked, the safety system releases an inert gas similar to argon that stops the pack from reacting with oxygen, thus stopping the pack from burning up. The safety system releases an inert gas, similar to argon, that stops the battery pack from reacting with oxygen, thus stopping the battery pack from burning.

3. Conclusion

There is still a lot space for ternary lithium batteries to improve to make the uses on electric cars or the others safer to make sure the ternary lithium battery will change the life of humans easily and make the tools more useful and durable. In the field of fighting against extreme environments, the ternary lithium batteries still need to develop the materials and the linking method inside the ternary lithium batteries to prevent the probable risks of the batteries. The research significance of this article is to provide a few methods for the battery industries to improve the technology of the ternary lithium batteries to apply on the devices of some emergency like the communicators for firefighters, the improved batteries will help the firefighters connect to the commanders better to get the correct order. And the improved batteries will be used in the robots for rescue in freezing or extremely hot environments, they can fit better than the real person. But the ternary lithium batteries still have a core limitation, it’s the efficiency of the batteries can be transferred to the impetus to the vehicles is hard to keep a constant number, now the most electric cars use the ternary lithium batteries are normally driven in the cities but hard to see in the highway, because the battery life is attenuated, the real number of kilometers traveled is less than the standard number od kilometers traveled. The newly generated ternary lithium battery will be the key to changing the whole direction of the battery market in the whole world. More and more industries will use the ternary lithium battery like public transportation and high-tech devices.

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