Nanotechnology in Modern Practical Electric Vehicles

by Lizilin Liang

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Yutao Chen[a,†], Zhangleyi Fan[b,†], Lizilin Liang*[,c,†] and Kaiyuan Wu[d,†]
[a]Guangdong Country Garden School, Foshan, Guangdong, 511325, China
[b]Cogdel Cranleigh School, Changsha, Hunan, 410100, China
[c]Ningbo Foreign Language School, Ningbo, Zhejiang, 315100, China
[d]Nanjing Foreign Language School British Columbia Academy, Nanjing, Jiangsu, 210000, China
[*] Corresponding author: 100588@yzpc.edu.cn
[†]*These authors contributed equally.*

ABSTRACT

This article aims to discuss the batteries using nanotechnology and the applications of nanotechnology in electric vehicle (EV) material. The reason why the topic is important is that EVs have a huge market nowadays. In order to make a process and reach a higher level in the performance of the batteries and materials of the car body, nanotechnology is an essential element in it. Four aspects are studied in this report: how batteries work, the improvements of the 4680 batteries, the application of nanotechnology in future batteries, and other applications of nanotechnology on cars. Through the research, it is found that the 4680 battery uses more nanotechnology and is a big improvement over the previous two generations; by shaping silicon nanoparticles into several shapes exampled by shapes of wire and eggs, it is made possible for the material to overcome its problem of fracturing and thereby to be able to be used as the material for future EVs; the application of nanotechnology on cars can greatly improve the safety and comfort of EVs.

Keywords: Nanotechnology, electric vehicle, battery, nanomaterial

1. INTRODUCTION

With the development of economic globalization, the increase of self-driving tours, and the growth of long-distance transportation, fossil energy vehicle pollution has attracted more attention from the international community. Many countries have announced their timetable to stop new fuel vehicles from entering the market. As an important foundation to guide and support new development, new energy materials are developing continuously and rapidly. As far as automobiles are concerned, electric power is undoubtedly the future, compared with traditional fossil energy vehicles with traditional materials, which have dominated the car industry since the car industry was born centuries ago. Among all new energy vehicles, electric vehicles (EVs) are currently more popular than hydrogen fuel cars with a tremendous market. Not only has electric power been strongly recommended by the new car producers, such as Tesla (USA), BYD (China), Nio (China), Xpeng (China), Li Auto (China), etc., but also it has been chosen by most of the traditional big-name car companies in their new energy vehicles, such as Ford (USA), Mercedes-Benz (Germany), Volkswagen (Germany), SAIC (China), etc.

Lithium-ion batteries are said to be the dominant technology currently in EVs compared with other types of EVs, such as Sodium-ion batteries or Silicon-ion batteries. Because of the high power-to-weight ratio of lithium-ion batteries, the drivers can experience higher energy efficiency, a longer driving distance and a shorter charging time, which are very important for EVs. It is very important to improve the power of electric cars based on the original lithium-ion batteries. With the rapid development of EVs worldwide, nanotechnology plays an important role in the field of batteries and makes a magical effort. Nanotechnology helps EVs be widely used by increasing battery performance, such as weight reduction, better energy efficiency, and longer battery lifespan. In addition, nanotechnology can be used in many other applications in car industries, such as rubber, metal matrix composite, composite materials, paint, xhaust catalyst materials, etc., because it is possible to cater to the structures of materials at extremely small scales to achieve specific properties by using nanotechnology. The materials produced with nanotechnology can be stronger, lighter, more reactive or can be used for a longer time.

This article will discuss the current batteries using nanotechnology and the applications of nanotechnology in producing batteries in the aspects of three types: 18650 batteries, 21700 batteries and 4680 batteries. Four aspects were studied in this report: How batteries work, the improvements of the 4680 batteries, the application of nanotechnology in future batteries, and other applications of nanotechnology on cars. Batteries are the reservoir of energy that store and release energy by charging or discharging the metallic ion embedded and de-embedded back between two electrons. Tesla battery 18650 and battery 21700 are the best among lithium-ion batteries up to date. The dimension of 18650 is 18 mm × 65 mm, while battery 21700 had improved in volume, which is 21 mm × 70 mm, which has greater volume. In addition, the battery 18650 only has a capacity of 3500 mAh, inferior to the battery 21700 (5600 mAh). Another improvement is the increase in the energy density; specifically, the battery 21700 has 500 Wh/kg, which is higher than that of battery 18650.

2. 4680 BATTERIES

2.1 Performance improvement

Compared to the 21700 batteries, the dimension of 4680 batteries is much larger, which is 46 mm in diameter × 80 mm in height. The total energy has increased five times the power supply has increased six times. The distance that a car can travel has increased by 16%.

2.2 Battery tab

The battery tab is the conductor that draws the current out of the cell and is the contact point between the cathode and the anode of the battery. Larger tabbed cells, on the other hand, have struggled to shed heat at high charging rates. Tesla's new 4680 cell eliminates the internal tab instead of integrating the tab's function into the jelly roll itself, resulting in a clean, uniform look to the cell's end. One end of the electrode is connected directly to the housing or specially designed cover plate through a conductive material applied, and the current is conducted directly between the electrode collector and the cover plate ensemble. Tesla has replaced the previous point contact with a surface contact so that heat does not gather at one point, and the conduction area increases, significantly reducing heat build-up.

For example, Traditional cylindrical batteries, positive and negative copper foil, aluminum foil diaphragm stacked winding, in order to lead out the electrode, will be in the copper foil and aluminum foil ends are welded a guide wire called battery tab. The conventional 1860 battery winding length is 800mm, with better conductivity than copper foil. As an example, the electrode tab from the copper foil to lead out the length is 800 mm, equivalent to the current to pass through the 800 mm long wire. By calculation, the resistance is about 20 mΩ. The winding length of the 2170 battery is about 1000 mm with a resistance of about 23 mΩ. 4680 tables battery turns the whole collector into a tab. The conductive path is no longer dependent on the tab. The current from the transverse transmission along the tab to the collector plate becomes the longitudinal transmission of the collector, the whole conductive length from the 18600 or 21700 copper foil length of 800 ~ 1000 mm to 80 mm (the battery is more conductive). 1000 mm to 80 mm (cell height). The resistance is reduced to 2 mΩ, and the internal resistance consumption is reduced from 2 W to 0.2 W, which is directly reduced a lot [1]. This method can lower the resistance and thus reduce heat generation. This design can reduce the resistance by 5-20 times, which can reduce heat generation as well as reduce unnecessary heat waste, and also help to improve the range. Therefore, increasing the current to form a faster-charging speed while ensuring safety is possible.

2.3 Electrodes materials

2.3.1 Cathode materials

Fe, Co and Ni can be used as battery cathode main materials. However, Co is expensive and harmful to the environment and people, causing many serious health problems when the concentration exceeds the limit, but it is very stable. Ni is low cost and has good energy density. Therefore, Tesla's new cathode materials will completely remove Co and increase the use of Ni (and also some Fe). The cathode of the Tesla 4680 battery uses NCM811 material, which contains 81.6% Ni. This can reduce the cost while ensuring energy density.

Tesla also uses the dry-coat electrode process. The traditional battery production process needs to put the material powder into the solution, then dry and press it into a film. On the other hand, the dry-coat electrode process completely skips the step of adding solution and can omit the complicated coating and drying processes, significantly simplifying the production process and directly rolling and grinding the powder into a thin film, which is called a dry electrode. At the same time, by increasing the thickness of positive electrode material (from 55 to 60um), the active electrode material ratio is improved, making it possible to increase the energy density by 5% while still ensuring the power density. Moreover, the dry electrode technology can also speed up the electrode production speed to 7 times the previous one, effectively reducing the resistance, reducing the heat generation and improving the cycle life. It is a disruptive change in the production process of positive and negative electrode materials for electric cells [2].

2.3.2 Anode materials

Graphite as anode material in conventional batteries can theoretically reach a maximum battery capacity of 372 Wh per kg, while Si material can theoretically reach more than ten times that of graphite, about 4000 Wh per kg and at a low cost. However, Si will expand to more than four times its size after the lithium ion is embedded, and the battery will be damaged after several expansions back and forth [3]. To deal with this problem, Tesla stabilizes the surface with an elastic ion-conducting polymer coating. This method stabilizes the Si surface structure to address the swelling of the silicon material. This will increase the battery mileage by 20%. The use of Si anode can significantly increase the energy density. In addition, the silicon anode is safer than the graphite anode, and now the anode graphite will produce lithium dendrites.

One of the most serious issues affecting the safety and stability of lithium-ion batteries is lithium dendrite growth. The formation of lithium dendrites will cause the electrode and electrolyte interface to become unstable during the cycle of lithium-ion batteries, destroying the generated solid electrolyte interphase (SEI) film; the formation of lithium dendrites will continuously consume electrolyte and lead to irreversible deposition of lithium metal, resulting in the formation of dead lithium and low Coulomb efficiency; the formation of lithium dendrites will even pierce the diaphragm and lead to internal shorting of the lithium-ion battery, resulting in thermal runaway and combustion and explosion. As a result, the silicon anode not only has a higher energy density but is also safer[4, 5].

3. APPLICATION OF NANOTECHNOLOGY IN NEXT-GENERATION BATTERIES

3.1 Background

Even though nanotechnology has not been widely used in battery production, materials made of nanosized particles are expected to be applied to car batteries shortly. As significant examples, graphene and nanosized silicon particles are considered suitable materials for making anodes in car batteries. By applying these new materials to batteries, it is expected that the batteries would be equipped with higher energy efficiency and power-to-weight ratio, expanding the range an EV could cover.

3.2 Graphene batteries as future car batteries, pros and cons

Graphene batteries can be considered good choices for future batteries because graphene is has high conductivity and can easily pass electrons to those metal wires in circuits. Moreover, batteries with anodes or cathodes made of graphene are expected be high in power density, for not only the anode but also the cathode show surface reactions that’s fast, combined with porous morphology as well as great electrical conductivity. Moreover, due to the similarity of the cathode and the anode in chemistry as well as microstructure, each electrode perform to maximum while "power imbalance", the problem often found in LICs, is not introduced. In addition, for batteries with both cathode and anode made from graphene, the energy densities are high, resulting from the great potential difference between anodes and cathodes [6]. This kind of all-graphene battery can have energy density of 130 Wh kg-1 while having power density measured 2150 W kg-1. However, despite having great performance as cathodes and anodes in a battery, graphene has a problem as a cathode. Since it costs six carbon ions in order to hold on to one lithium ion, the grip is so weak that the amount of lithium the electrode could hold. As a result, the amount of power a battery could store is limited. Moreover, the price has reached $200,000 a ton, making it expensive to be used in the production of batteries [7].

3.3 Silicon batteries as future car batteries, pros and cons

Silicon nanoparticles are also considered probable materials for making anodes for the batteries of future electric cars. In fact, since a single silicon atom is capable of binding to four silicon atoms, an anode with silicon base can potentially store 10 times the energy as a graphene battery. However, even though the capacity of a silicon battery seems satisfying, the problem prevents it from becoming the leading trend in battery materials. While silicon anodes can be made easily, they have a short lifespan. According to Science.com, lithium ions bind to silicon atoms during the charging process of a silicon battery with great speed, causing the anode to become three times its original size.

Meanwhile, lithium ions "rush out during the discharge cycle, " causing an anode to shrink to its original size. The swelling and shrinking cycle of silicon batteries can cause so great harm to the anode of these batteries that the electrodes break and eventually fracture into small grains. In other words, due to the frequent changes in the size of silicon electrodes during charging and discharging cycles, the electrodes could be easily shattered, leading to a short lifespan of silicon batteries [8].

3.4 Egglike nanoparticles used in batteries

Therefore, even though graphene and silicon nanoparticles are both strong in certain aspects, their problems of high price, capacity and lifespan are great obstacles to them becoming ideal materials for electric cars. Chemists must find a replacement for the two. Cui and his team believed that making the materials into nanosized ones could change the game. The reason is that nanoparticles are structured with higher percentage of atoms at surface compared to the number in interior, leading to atoms at surface being able to move easily when responding to stress and strains. Therefore, Cui and his teams made several silicon nanowires, resulting in these nanowires retaining more than 70% of their energy storage capacity in theory, even after charging and discharging, cycled 10 times. Using this experiment as a building block, Cui and his team devised a new solution: to create egglike nanoparticles. While the "yolk" of the particle is tiny silicon nanoparticles, a highly conductive carbon shell surrounds the yolk like an eggshell. Lithium ions are able to easily pass that shell structure while offering the silicon atoms inside room to swell and shrink. The new material is proven a success, as it is reported that the yolk-shell structured anode has retained around 74% of its capacity.

Moreover, as an improvement based on the current material, it is found that by assembling of the yolk-shell nanoparticles in bunches into micrometer-scale collections similar to micro-sized pomegranates, the anode's lithium storage capacity is promoted. At the same time, useless side reactions concerning the electrolyte are reduced. Thus, the material reached 97% of the original capacity and was retained after 1000 cycles of charge and discharge[8].

4. OTHER APPLICATIONS OF NANOTECHNOLOGY FOR EVS

4.1 Rubber

The new nanoparticles are used as rubber chemicals widely the range of operable nanoparticles. In the production of tire rubber, additives are mostly powder such as carbon black, white carbon black and other reinforcing filler promoters, and anti-aging agents. Powder material nanometer is the main development trend at the present stage. Some macromolecules are embedded in the clay layer channels. The clay layer can be uniformly dispersed in the rubber matrix at the nanoscale. The mechanical properties test shows that the nanoscale carbon black composite has good mechanical properties. Besides this, by adding carbon black to tires, greater fuel efficiency and longer tire life can be achieved because they have a rougher surface than regular tires. For example, in the experiments of Tang et al., they added 12 Phr (parts per hundreds of rubbers) of nano-carbonylated nitrile rubber to increase the Izod impact strength by 96%.

The largest amount of rubber used in automobiles is tires. Modern tires achieve their high range, durability and grip through nanoscale soot particles and silica. About a third of the energy used in transport is used to overcome friction, making energy efficiency low. With the emergence of graphene and nano-diamond hybrid sliding systems, the super lubricity on the macroscopic scale reaches a friction coefficient close to 0.004, which greatly reduces the energy loss caused by friction. This makes for more fuel economy. No matter in strength, wear resistance or anti-aging performance, the new nano tire is better than the traditional tire; with the improvement of tensile ability, tire crack resistance will be improved from 100000 times to 500000 times which makes the tire hardly to break when meeting some rugged terrain [9].

4.2 Plastic

Nano plastics can change the characteristics of traditional plastics and present excellent physical properties: high strength, high heat resistance and smaller specific gravity. Since the size of nanoparticles is smaller than the wavelength of visible light, nano plastics can show good transparency, and high gloss and such nano plastics will be widely used in automobiles. The use of nanocomposites and mixed solutions can reduce the 900kg of steel and other types of metals commonly used in automobiles by up to 300kg.Nanocomposite plastics weigh an average of 25% less than high-fill plastics and 80% less than steel. The Tesla Roadster features a high power-to-weight fuel tank and a lightweight carbon fiber/epoxy composite water tank [10].

Car paint peeling and aging is the main factor causing the deterioration of automobile aesthetics which is also tricky and difficult to control the aging variable. Many factors affect aging in the lacquer that bakes. However, one of the most critical is the sun's ultraviolet rays ultraviolet ray to make material molecular chain rupture which improves the performance of the material aging polymer plastic is like this as is organic coatings for organic coating because the ultraviolet ray is all factors the most aggressive so if people can avoid the effect of ultraviolet (UV), It can greatly improve the aging resistance of baking paint. TiO2 nanoparticles are the most effective materials for shielding ultraviolet rays [11].

4.3 Composite materials

4.3.1 Carbon Fiber Reinforced Plastic (CFRP)

CFRP material is widely used on cars to the frame, the seat or even the shell. Composites are being considered to make lighter, safer and more fuel-efficient vehicles. Carbon fiber reinforced plastic has a high modulus of over 395 GPa, and the strength could be over 3.5 GPa undefined high modulus and high strength could have good protection of the vehicle and passenger and reduce the risk as much as possible. The vehicle's exterior is made of carbon fiber to protect it from impact.

4.3.2 Metal matrix composite

Metal matrix composite material is widely used in frame production compared with CFRP metallic composite with a cheaper price and mature and stable technology and production line. Nanotechnology is used in the composite metal material of the body frame and contributes to a lightweight body structure with better impact and corrosion resistance. It also strengthens the tensile strength of the car body, which can better ensure the stability of the overall structure of the car body in the face of impact and create a safe space for the passengers. Nano wc, ZrO2, Al and Si3N4 are used as reinforcing agents to reduce hardness and increase bending strength (up to 50%), and improve wear resistance (2-10 times) and friction coefficient (up to 4 times). The designed alloy acts as a binder for diamond tools, increasing tool life by four times without reducing cutting speed [12].

4.4 Application of other components

4.4.1 Radiator

Conventional heat dissipating media such as water, ethylene glycol and minerals are ineffective in removing all the heat generated. The heat transfer rate of the coolant can be significantly increased by adding nanofluids to the coolant. Compared with the traditional heat sink, carbon nanotubes, silicon dioxide, and titanium oxide nanofluids in the carrier liquid greatly improve the heat capacity and heat transfer speed of the coolant, which makes the heat dissipation speed greatly increase.

4.4.2 Mirror

A functional layer nanocomposite material that can be electrically induced to change color is installed on the reflector so that the voltage of the mirror changes if light falls on the mirror. This change will absorb a large amount of incident light, and only a very small amount of light will be reflected so that when driving at night, it is excellent to protect the driver from being able to observe the road conditions behind.

5. CONCLUSION

The 4680 battery has great improvements over the previous two generations of batteries (18650 & 21700 battery). First, the battery tables technology reduces the accumulation of battery heat and makes it possible to increase the current to form a faster-charging speed while ensuring safety. Second, Tesla's new cathode materials will completely remove Co and increase the use of Ni to reduce costs and ensure energy density. Third, using the silicon anode is not only much higher energy density and also safe. Even though batteries made from graphene and silicon nanoparticles are being obstacle by their problems of capacity and lifespan, the electrode made from these materials is still expected to be applied in car batteries in the near future. Moreover, by shaping silicon nanoparticles into several shapes exampled by shapes of wire and eggs, the material can overcome its fracturing problem and be able to be used as the material for future EVs.

Nanotechnology has not been widely used due to the price and raw material, but the improvement cannot be ignored. The nano rubber greatly reduces ineffective friction to improve fuel efficiency, while the ZrO_2 act as reinforcers to strengthen the car body to protect passengers and add nano-coating material for better driving vision. Furthermore, SiO_2-TiO_2 nanofluids can act as heat sinks, providing longer car life and safety. In addition, there are nano-plastics, nano-rubber additives and other applications. The application of nanotechnology can greatly improve the safety and comfort of EVs. Nanoscale EVs are an inevitable trend.

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