AN INVESTIGATION ON THE COMPARISON OF THE PERFORMANCE OF LITHIUM-ION BATTERIES AND NICKEL METAL HYDRIDE BATTERIES USED IN ELECTRIC VEHICLES

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Salem A. G. SALEH

ABSTRACT

M. Sc. Thesis

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With the advancement of technology and progress in the past years, the work of engineering scientists has allowed them to access amazing techniques in the field of energy saving using high-capacity batteries and work longer. This has increased the interest of scientists using the advanced techniques used, and has led to the production of most high-capacity batteries and a greater and safer energy source in less time. Over the past decade, the battery industry has diversified for use as an energy source, particularly in rural and remote villages, and the increasing use of batteries has had the effect of preventing the increase in carbon dioxide in automobiles and different cars. However, the materials used to manufacture the battery are harmful and dangerous resources. In this study, the comparison of the general properties of different battery systems (Lithium-Ion batteries and Nickel-Metal Hydride batteries) and also the environmental effects of used battery production to reduce carbon dioxide emissions for harmful systems. Renewable energy generation and new types of energy are commonly used by batteries to help overcome fluctuations in energy supply and demand. In addition, vehicle manufacturers are producing hybrid and electric cars with an increasing number of battery use. We chose two types of batteries based on their density, low weight and environmental friendliness. It has been concluded that lithium-ion batteries are the most suitable battery compared to other batteries for moving the car and for the use of electronic devices.

Keywords : Lithium-ion battery, Nickel Metal Hydride (NiMH) battery, Electric Vehicles (EV).

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ÖZET

Yüksek Lisans Tezi

ELEKTRİKLİ TAŞITLARDA KULLANILAN LİTYUM İYON BATARYALAR İLE NİKEL METAL HİDRİT BATARYALARIN PERFORMANSLARININ KARŞILAŞTIRILMASI ÜZERİNE BİR ARAŞTIRMA

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Geçtiğimiz yıllarda gelişen teknoloji ve ilerlemeyle birlikte, mühendislik bilim adamlarının çalışmaları, enerji tasarrufu alanındaki şaşırtıcı tekniklere, yüksek kapasiteli piller kullanarak erişmelerini ve daha uzun süre çalışmasını sağlamıştır. Bu, kullanılan gelişmiş teknikleri kullanan bilim adamlarının ilgisini artırmış ve yüksek kapasiteli pillerin çoğunun üretimini ve daha az zamanda daha fazla ve daha güvenli enerji kaynağı olmasını sağlamıştır. Geçtiğimiz on yıl içinde, pil endüstrisi, özellikle kırsal ve uzak köylerde bir enerji kaynağı olarak kullanılmak üzere çeşitlenmiş ve pillerin kullanımının artması, küresel ısınma faktörünün otomobillerdeki ve farklı arabalardaki karbondioksit artışını engelleme etkisini doğurmuştur. Ancak pili üretmek için kullanılan malzemeler zararlı ve tehlikeli birer kaynaktır. Bu çalışmada, farklı pil sistemlerinin (Lityum İyon piller ve Nikel Metal Hidrür piller) genel özelliklerinin karşılaştırılmasını ve ayrıca zararlı sistemler için karbondioksit emisyonlarını azaltmak için, kullanılan pil üretiminin çevresel etkileri incelenmiştir. Yenilenebilir enerji üretimi ve yeni tip enerji, genellikle enerji arz ve talebindeki dalgalanmaların üstesinden gelmeye yardımcı olmak için piller tarafından yaygın olarak kullanılmaktadır. Buna ek olarak, araç üreticileri, pil kullanımı artan sayıda, hibrit ve elektrikli otomobil üretiyor. Elektrik kapasitelerinin yoğunluğu, düşük ağırlıkları ve çevre dostu olmalarına göre iki tür batarya seçtik. Otomobilin hareket ettirilmesinde ve elektronik cihazların kullanımı için diğer bataryalara göre en uygun bataryanın, lityum iyon bataryalar olduğu sonucuna ulaşılmıştır.

Anahtar Kelimeler **:** Lityum-iyon batarya, nikel metal hidrit batarya, elektrikli araçlar.

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SYMBOLS

18650	:	Li-ion cylindrical cell format measuring 18mm x 65mm
β-	:	Is alow conductivity p - typ semiconductor when nickel
NiOOH	:	Valence is < 2.25
μ	:	Micro
A	:	Ampere (electrical)
A123	:	Lithium Iron Phosphate
AC	:	Avoided and a laptop connected
Ah	:	Ampere-hour; battery provides energy over specified time
Ag	:	Silver
anode	:	Absorbing negative electrode
C	:	Celsius, Centigrade (°C x 9/5 + 32 = °F)
Cd	:	Cadmium
CGR	:	(CGR) cathodes in commercial lithium-ion batteries during overcharging/discharging was examined using operando neutron powder-diffraction.
CO_2	:	Carbon dioxide
CoO		Xidizing agent is CoO
(DOD)	:	Depth of Discharge watt hours – Wh
Eq	:	Batteries electricity density and precise electricity
e^-	:	Electrons
etc		et cetera
F	:	Fahrenheit (°F - 32) x 5/9 = °C)
FePO4	:	Ferro phosphate
H		Hour
K	:	Potassium
KOH	:	Commonly called caustic potash.

Li+	:	lithium-ion
LiC6	:	The reducing agent is LiC6
LCO	:	Consumer lithium cobalt oxide, battery
LiCoO2	:	Lithium ion cobalt oxide (also LCO, secondary battery)
LiCoO2+binders	:	creating a Cathode
LiFePO4, LFP	:	Lithium iron phosphate oxide (also LFP, secondary battery)
Li-ion	:	Lithium-ion battery (short form)
LiMn2O4	:	Lithium ion manganese oxide (also LMO, secondary battery, spinel structure)
LiOH	:	Lithium Hydroxide
LTO	:	Li-titanate
LiNiCoAlO2,	:	Lithium-ion battery with nickel, cobalt, aluminum cathode
M Ω	:	One megaohm is equal to 1,000,000 ohms, which is the resistance between two points of a conductor with one ampere of current at one volt.
m		Milli
mAh	:	Milliampere-hours
MH	:	A nickel-metal hydride battery, abbreviated NiMH or Ni– MH, is a type of rechargeable battery
Mm	:	Mischmetal
MNi3	:	Carbon-mixed
Na	:	Sodium
NaOH	:	Sodium Hydroxide
NCA		Nickel, Cobalt, Aluminum
Ni	:	Nickel
NiCads	:	Lead acid
NiCd	:	Nickel-cadmium (secondary battery)
NiMH	:	Nickel Metal Hydride battery
NiOOH	:	Nickel hydroxide, Nickel oxy-hydroxide
NiH2	:	An evolution from the Nickel Hydrogen

NB	:	for a 2 000 mAh
I	:	The modern drawn from battery (A)
J	:	Joule (unit of energy), 1J = 1A at 1V for 1s = 1 watt x second.
kWh	:	Kilowatt-hour (electrical energy)
K	:	A constant around 13
Pb	:	Lead, The two letter identifier for lead in the Periodic Table of Elements.
PTFE	:	Polytetrafluoroethylene
QP	:	The ability when discharged at a rate of 1 amp
SoC	:	State-of-charge
T	:	The amount of time (in hours) that a battery can sustain
TPP	:	triphenyl phosphate
V	:	Voltage
Wh/l	:	Watt-Hour per Liter
Wet	:	A wet-cell battery is the original type of rechargeable battery
Wh/kg	:	Watt-hour per kilogram (measurement of specific energy)
Zn	:	Zinc

ABBREVIATIONS

AGM	:	Absorbed Glass Mat
BMS	:	Battery Management Systems
BC	:	Before Christ
BPS	:	Battery Power System
CID	:	Current Interrupt Device
D-l	:	Daikin Ind.
DoD	:	Depth of Discharge
ESS	:	Energy Storage System
EVs	:	Electric Vehicles
EV	:	Electric Vehicle
GSM	:	Global System for Mobile Communications (cell phones)
HEV	:	Hybrid Electric Vehicle
ICE	:	Internal Combustion Engine

KOH	:	Potassium Hydroxide
KHIs	:	Kawasaki Heavy Industries
LCO	:	Lithium Cobalt Oxide
LIPON	:	Lithium phosporous-oxy-nitride
LRV	:	Light Rail Vehicle
NiMH	:	Nickel-Metal Hydride
NiOOH	:	Nickel Hydroxide
NMC	:	Nickel-Manganese-Cobalt
OCV	:	Open Circuit Voltage
OEM	:	Original Equipment Manufacturer
PTFE	:	Poly Tetra Fluor Ethylene
R	:	Resistor (Electrical)
R&D	:	Research and Development
RES	:	Renewable Energy Systems
SoC, SOC	:	State of Charge
SSBs	:	solid state electrolyte battery
SPE	:	Solid Polymeric Electrolytes
SSLA	:	Small Sealed Lead Acid
USABC	:	United States Advanced Battery Concorcium
VRLA	:	Valve-Regulated Lead Acid Batteries

PART 1

INTRODUCTION

Energy storage systems, batteries are important through their ability to store energy during peak hours and give energy during peak hours to ensure consistent energy quality and reasonable use of energy [1]. Moreover, lithium batteries also have application areas, for example tools, robotic devices, battery-controlled bicycles, all in modern electric cars.

Given this circumstance, the use of lithium particle batteries is gradually expanding instead of low-energy nickel-metal hydride batteries [2]. By joining innovation, science and information based on participation in industrial mechanical systems, shortcomings are recognized early and the maintenance limit is expanded. In this way, the use of natural resources can be reduced; maintenance time can be speeded up and system downtime can be prevented [3].

Since the systems remember monitoring the New Age vehicle systems, the hardware security status will be transferred to the customer and management community instantly [3].

The electrolyte gives the charge exchange between the cathode-anode. Electrolytes are commonly used in lithium batteries, because they are composed of salts that have been broken down in liquid electrolyte solvents. Compared to commercially used $LiPF_6$, the arranged electrolyte arrangements with $LiBF_4$ salt give improved battery performance at high temperature due to the preservation of its strength during the discharge and charge cycles. Low temperature as high temperature [2].

The focus has been on ozone layers and battery expenditures so far, but reliable boundaries between environmental and economic impacts are expected to lead to an assessment of the environmental efficiency of batteries.

All the advantages that electricity provides, the battery generally charges us, and in a ertain way that makes it easy to carry it. But the user faces a problem which is that the battery often happens to it damage very quickly and it is the only problem, and this problem makes the process very bad for the environment as people usually when the battery occurs damage, they throw it which causes very great damage to the environment in addition to costs.

It is possible to use the batteries that have the feature of recharging, which leads to retaining and not throwing them, thus reducing environmental damage. But there are many batteries that have a recharging feature, including the lithium ion, which is the best type, for use by a laptop, a mobile phone, some types of modern cars and a music player.

This type of battery began to be used in the last century, it became a great use, this battery was discovered by the American scientist Gilbert Lewis, an American chemist, for the first time he discovered the chemistry contained in the battery between the years (1875-1946) in 1912 [4]. Batteries according to the normal meaning of the word have to do with the fact that you can take them with you they are much in public consciousness because of their use in mobile phones and electric cars.

The car or phone would be tied to the wire plugged into the electrical wall socket from which they would get the electricity to make them work. Batteries allow mobile phone users and car drivers to move away from the electrical socket.

Certain chemicals are specialized to provide the energy which makes electricity. But this energy is used up as the device in which the battery is inserted – the car or phone – uses the electricity provided. The battery is ‘discharged’ - runs out’.

At this stage you need an external source of energy which the specialized chemicals can absorb to replace the energy they lost when the device used it up, the battery is 'charged', or more accurately in this case, 're-charged'. The external source of energy can vary, For the National Grid (which, though not portable, operates like a battery) it includes 'non-renewable' e.g. by burning coal, which can't be replaced once they are used up, and 'renewable', e.g. sunlight, wind and flowing water, which are not used up and which we hope will be with our planet for thousands of years more. For 'normal' cars the energy source is burning petrol, which is non-renewable. For batteries for electric cars and mobile phones the source is the National Grid, which, as we have just seen, can be produced from either renewable or non-renewable sources. Batteries of this sort are called 'rechargeable' or 'secondary' batteries .

There are some batteries which are solely dependent on the specialized chemicals they contain. Once their energy is used up they cannot satisfactorily or dependable be recharged. If they are recharged – e.g. by being gently heated – the charge doesn't last for long. Once the electricity in these batteries has been used up you throw them away. They are called 'single use' or 'primary' batteries.

They do not have the interest that they produce cell phones or electric cars but they can be indispensable. They can, for example, provide portable versions of household appliances that plug into an electrical wall socket. In many cases it will be much preferred option; For example, hearing aids can be connected, but they generally must be portable. Research was underway to develop the science of electric vehicle batteries, to enable them to be a powerful alternative to fossil fuel engines.

In the past ten years, this has progressed very quickly, and we are about to get batteries that require much less time to recharge, in the least amount of time available as the battery can be recycled, plus a battery-powered car will help in the fight, and global warming is called heat plus What is known as acoustic pollution [5].

The other side of the source of electricity is one of the main reasons for making electric cars their personal profile. People are confused about the depletion of resources on our planet. What happens when you run out of coal and gasoline? Global warming "is higher on the agenda of concern. Non-renewable materials tend to produce chemicals that are perceived as harmful to the planet and may ultimately contribute to its destruction as we know it - carbon dioxide is usually the largest contributor."

Batteries that use fossil fuels, such as in a gasoline-powered car, they are major contributors to carbon dioxide and other emissions. Electric cars, produce zero emissions. Therefore, the production and use of electric cars rather than gasoline cars are seen as important ways to help save the planet.

Why, then, are electric cars not being treated enthusiastically? Part of the answer is that only a small percentage of the population sees global warming as a problem, and another part of the problem is that people (perhaps encouraged and largely swelled by the fossil fuel industry) see electric vehicles as having problems. For example:

- The short distance they can travel with a single charge of their battery.
- Time taken to recharge the battery - It takes only minutes to fill up with gasoline, but hours to recharge the battery of an electric car.
- The initial cost of electric cars.
- The safety of some batteries, which can explode or catch fire in certain circumstances, for example misuse or overheating (similar safety concerns exist regarding gasoline-powered cars, but they can be forgotten in the argument against electric cars).
- Short life, mass, volume temperature, care of an electric vehicle battery; and additions to new batteries [6]

The purpose of this thesis is to investigation on the comparison of the performance of lithium ion batteries and nickel metal hydride batteries used in electric vehicles.

This prepared study has been tried to be created under six headings in itself. The first chapter of these "Introduction" is given here in a short summary. Second clue, literature review, Third third data types; The comparative study of Lithium-ion batteries and Nickel Metal Hydride Batteries, the fourth first Lithium-ion batteries and

Nickel metal hydride batteries, the fifth and final conclude with an intent-to-make summary, results and discussion.

PART 2

LITERATURE REVIEW

In the past decade, various experimental tests have shown an advertisement for lithium ion batteries and nickel metal hydride batteries. The drive to focus on his work was two-fold. The main impulse was the search for a comparison between lithium particle batteries and nickel metal hydride batteries, which focused a lot on density, life, strength, capacity, charge and discharge, as well as chemicals. A subsequent drive was to search for accurate evidence about the existence and nature of the common factors, which drove the global advance of lithium batteries.

Her performance was studied on it. As the result of the 44th experiment of this study; how many in studies examining the effect of electrolyte solutions on the $LiMn_2O_4$ cathode discharge capacitance, it was observed that the capacitance was the highest in the 1: 1 solution with the closest EC: DMC ratio. As the difference between the EC and DMC ratios expanded, the cathode expanded and a decrease in the discharge capacity was observed. In addition, LiBF4 salt concentration increasing the battery capacity had a positive effect and increasing the capacity.

But the Li + salt concentration exceeds the capacity after a certain value. He was not noticed to have an effect. At the end of the CV test, redox peaks were clearly formed and first there was no significant change from cycle to fifth cycle. This mode is the cathode that the structure is stable throughout the cycle and the Li + input and output are intact turns out to be taking place. Electrolyte resistance in batteries is an important parameter in determining a battery's capacity. Happen or occur. Analyzes using impedance spectroscopy to achieve optimal battery capacity the electrolyte resistance of the electrolyte batteries was lower than others.

Suggestions it will increase the conductivity of LiBF4 compared to LiPF6 salt, which is mostly used commercially. Research can be done on additives. Apart from adding different chemicals to increase the low electrical conductivity, the effect of B2O3 additive can be examined. At the end of the studies, the electrolyte has high battery performance and the different cathode performance of the prepared batteries can be verified with the materials.

When the LiBF4 salt concentration increases, it is hydrolyzed by ionization in the electrolyte environment. Thus, it will increase the conductivity of the electrolyte [7]. In the field of application of the study another model for estimating battery life if tested with high accuracy. If this model is converted to embed software and loaded into the battery controller, the battery health status can be followed dynamically as in the block diagram lab.

Regression representation is a simple machine learning that can be used to estimate battery life. Although the algorithms are only applied to batteries, it is still possible to obtain very accurate results when assembling and presenting the other type of battery as input. Different battery failures increase the overall success of the life expectancy model. The conclusion to be drawn here is to reduce the total amount of error that would occur in determining life expectancy if they were grouped together to monitor the health of the same species and similar structure.

As other model researchers recommend in the field, he can make a very accurate estimate of life at constant temperature and 4 constant current values. However, time draws a variable current towards the battery in operations; it can be operated at both low and high temperatures. Since the tub instantaneous load and the ambient temperature have a major influence on the battery life, the outflow liquid will be used in the future.

An estimate of the battery life that can be used in artificial neural networks. But for this purpose, more samples will be made, in this context, in addition to batteries, the life of various mechanical or chemical systems can be estimated using artificial neural networks [8]. For the probability distributions of batteries, the peak bars represent the largest amounts of uncertainty.

The result demonstrates an extraordinary amount of probability in the classes of ionizing radiation, nutrient enrichment of freshwater, and human carcinogenic toxicity of Li-ion batteries. On the other hand, NiMH batteries provide a high level of uncertainty for indicators of human carcinogenic toxicity and the effect of ionizing radiation.

The current Uncertainty rate for other effect classes is small, proving that the stock data sets used for life cycle assessment (LCA) analysis of both batteries are robust. The applied field of study with the Regression Announcement Model, is another model for estimating battery life, according to which this structure is useful for description. In recent years, people's sensitivity to the environment, fossils and nuclear resources has increased in the hands of some countries, and the growing interest in renewable energy sources will be exhausted due to their occurrence.

From electrical, electromechanical and microelectronics to chemistry, it can be revamped as a result of increasing technological possibilities in many subjects. The use of energy resources becomes more likely [9]. To succeed with electric cars, developing a new type of battery is critical. The battery will play the role of "the heart of an electric vehicle" and it is imperative to create a power system with high performance, reliability and safety [10].

The special properties of the Li-ion batteries made them the best choice in a various customers, the properties like a specific high energy, high efficiency and long life time, on the their hand they have a many disadvantages like a seafty,cost wide operational temperature and materials, the critical li-ion battery parameters like a (Figure. 2.1) [11].

- Specific energy
- Power
- Safety

➢ Life time

Overall, both the anode and the cathode decomposition processes imply consumption of active masses and of electrolytes, accompanied by gas evolution, see Figure 2.1. This results in a loss of the battery capacity (initial irreversible capacity) and in safety hazards. Both capacity loss and gas evolution are of course undesired phenomena which must be carefully controlled (especially during the production process) to assure proper battery performance [11].

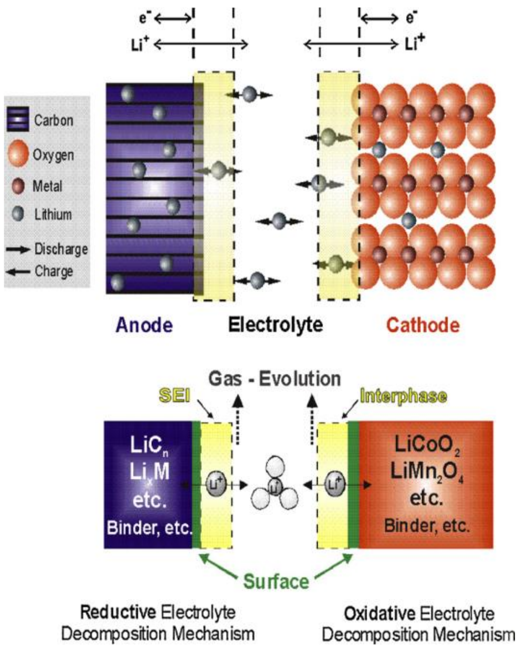


Figure 2.1. Operational principle of solid electrolyte ınterface (SEI) formation in A C/LiCoO2 Lithium Ion battery [11].

In general, solid electrodes are classified into two groups (polymer and inorganic). The solid electrode is characterized by a high ionic conductivity around 1.2 x 10 ^ (-2) cm -1, the main challenges of solid state electrolyte battery SSBs is the solid-state conductivity is lower than the ionic conductivity of the liquid electrolyte, the calamity between the electrode and the liquid electrolyte is very poor [12].

The contact point between the solid electrolyte prevents ion transport. The change in volumes during the ionic spin results in battery failures. The main chemical problems in solid electrolyte filling SSBs are summarized by side reactions between the electrolyte and the electrode and these problems lead to a decrease in the stability of the lining and thus increase the ionic resistance (Figure 2.2) [12].

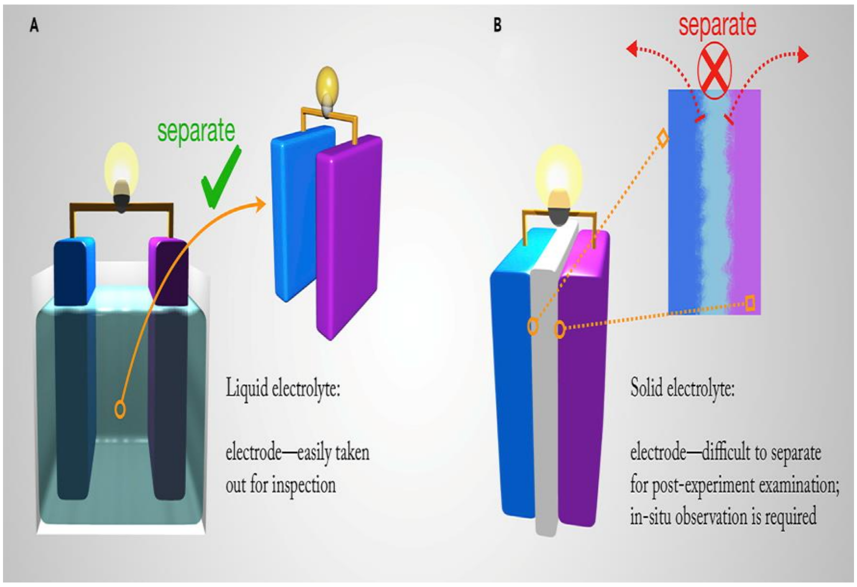


Figure 2.2. Interface contact in the solid state battery [12].

Studies experimentally the fire expulsion in the Li-ion battery and the average in 20 kW realise heated radiation. Many various variables have been measured like a ignition time, mass loss, the average of the heat release and plume temperature. That noticeable the ignition occurs when the batteries temperature reach to 1200 °C and release a harmful compound like a carbon dioxide, the result of the study refers to the high efficient combustion and the harmful compounds Proportional to numbers of the batteries in the one steak (Figure 2.3) [13].

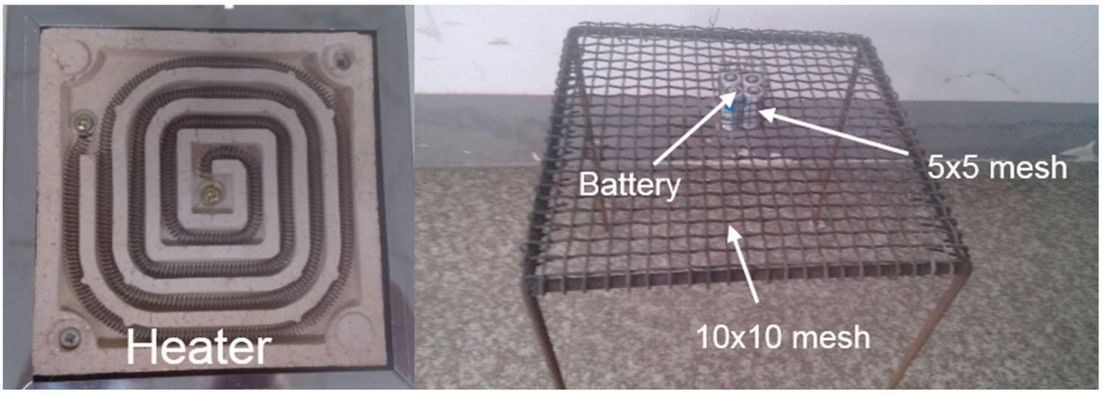


Figure 2.3. Close view of the heater and the specimen holder, fire explusion in the Li-Ion battery [13].

It studies the mechanics of solid-state lithium sulfur batteries (Li6PS5Cl) failure through high voltage and has tested the stability of battles with high voltage. The electrolyte interface between lithium nickel manganese Cobalt Oxide (NMC) and Li6PS5Cl was coated with a thin layer of LiN1,3Mn1,3Co1 around 15 nm. Then he studied coating coefficients and improved coating thicknesses and studied the effect of NMC on the layer of slabs (SLBs). It has been concluded that the very large capacities of SLBs are about 107 mAh and their maintenance in combat efficiency is about 91% [14].

Barut et al. According to what he did in 2019, she made a master's thesis on Production And Electrochemical Characterization Of Solid State Lithium Ion Batteries. In this study, Li1.4Al0.4Ti1.6(PO4)3 (LATP) solid electrolyte glass ceramics were synthesized by the sol-gel method which may be an alternative to the traditional melting-casting method. The characterization and battery performance of the obtained LATP material were evaluated using commercial NMC cathodes. As a result of 1C galvanostatic charge-discharge tests applied to Li: LATP: (NMC + KNT + LATP) whole cells, the capacity value obtained at the end of 50 cycles was obtained, respectively, a specific capacity value of 104 mAh g-1. At the end of 50 cycles, approximately 87% of the total battery performance was also preserved [15].

In a study by Moralı and Erol, electrochemical impedance analysis at the same cell potential, constant temperature, and frequency range was performed for commercial 18650 lithium-ion and 6HR61 nickel-metal hydride batteries which are commonly used among secondary batteries. The significant physical parameters for batteries were determined by the impedance responses and the developed equivalent circuit model of these two rechargeable batteries. The obtained parameters were compared in terms of the performance and capacity characteristics that significantly determine the preference of batteries in energy storage systems. As a result, the lithium-ion battery has a number of superior properties over the nickel-metal hydride battery. In addition, the model developed with the electrochemical impedance spectroscopy technique has been shown to be effective and has a great potential for meeting the energy needs and design of future batteries [7].

PART 3

ELECTRIC VEHICLES

Electric Vehicles started to be used in the early 1900s. The innovations that electric vehicles will bring are briefly summarized below [16]:

- An electric vehicle includes an electric motor, power converter and energy source developed using modern electric drive technology.
- Electric vehicles, beyond a new vehicle concept, are a radical change that will lead to the provision of transportation services with zero emissions and higher efficiency (Greenhouse gases and pollutants are produced by power plants).
- Electric vehicles will enable to create smart systems compatible with modern transportation networks.
- Business conditions and working cycles will be redefined.
- The need for infrastructure, training and standardization will arise in the end user, every maintenance-production level and related sectors.

The number of vehicles in the world is increasing day by day. Due to the increasing vehicle loading, the rapid increase in the amount of pollutant emissions and carbon dioxide gas in the atmosphere, the creation of the greenhouse effect and climate change have brought the use of alternative fuels. In Europe and other countries, the increase in the intensity of transportation last year and the parallel increase in the emission amounts released fulfill the purpose of the use of alternative fuels. In addition, the transition from fossil fuels to alternative fuels does not develop at the expected pace due to the constraints brought by infrastructure and infrastructures. These are production potentials, production style, distribution, marketing and engine harmony. Alternative tools to address all these problems are on the agenda. For this reason, interest in electric vehicles started to increase again.

In 2020, the production of diesel motor vehicles was restricted in Europe, and efforts to remove them from the market were initiated. Similarly, it is planned to restrict the production of gasoline-powered motor vehicles and to remove them from the market in 2030. Therefore, in 2030, electric vehicles will become more common in our country, Europe and the World. The factors that will lead to the increase in the future use of electric vehicles are summarized below [16]:

- Reducing transportation costs,
- Reducing the use of fossil based fuels,
- Reducing air pollutants especially in cities,
- Elimination of greenhouse gas generation on a global scale.

At the last session of the United Nations (UN) climate change meeting on December 12, 2015 in Paris, it was announced that 195 countries agreed on a final document. The agreement reached at the UN Climate Change Summit was to ensure that the world temperature increase does not exceed 2 degrees Celsius until 2030 and if possible, limit it to 1.5 degrees Celsius. The Paris Agreement, which consists of 29 articles, was accepted with an adaptation (implementation) document of 140 articles. The main theme of this agreement, which should be examined in detail and each article according to the conditions of the country; It determines the Intended Nationally Determined Contribution documents submitted by the countries included in the agreement, abbreviated as INDC. These documents are considered the commitments of the countries that ratified the agreement. Procedurally, the agreement will become a final commitment only after it has been accepted by the national authorities. In the implementation document of the agreement, it was emphasized that these conditions will be audited and the audit method was also determined. Turkey's UN Designated National Contribution Certificate of Intent Derived offered to include the following paragraphs [17]:

"In the 2012 National Greenhouse Gas Emission Inventory Report, the total greenhouse gas emissions for 2012 were determined as approximately 440 million tons of carbon dioxide equivalent. Energy-related emissions had the largest share in carbon dioxide equivalent emissions in 2012 with 70.02 percent, followed by industrial process emissions with 14.3 percent, waste with 8.2 percent and agricultural activities with 7.3 percent, respectively. In addition, the per capita emission amount in 2012 was calculated as 5.9 tons / person, which is much lower than the OECD and EU averages. "

The policy applied for electric vehicles for today will allow the contribution specified in the INDC Document. point to be reached as the result in terms of Turkey INDC Document expressed in Figure 3.1. In this graph, the blue line shows the total greenhouse gas emission (1 billion 175 million tons) as carbon dioxide (CO2) equivalent in 2030 if the operations are continued without taking any measures, and the green line shows the total greenhouse gas emission as the CO2 equivalent that will occur if the measures are taken (929 million ton). Widespread use of electric vehicles in Turkey Turkey's total GHG emissions will contribute to fulfill the commitment [17].

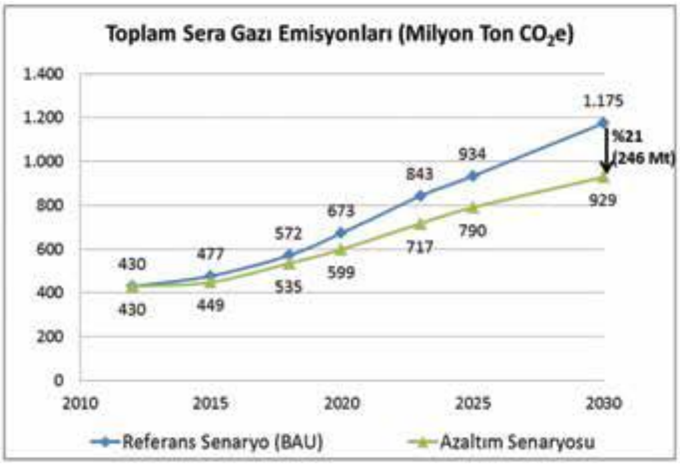


Figure 3.1. Turkey's total greenhouse gas emissions certificate commitment in INDC [17].

3.1. ADVANTAGES AND DISADVANTAGES OF ELECTRIC VEHICLES

3.1.1. Advantages of Electric Vehicles

In electric vehicles, the wheel is driven by the electric motor. The torque and efficiency of the electric motor is much higher than conventional systems. In order to provide a high amount of thrust in the electric vehicle, more than one electric motor can be used when necessary. The power supplied to the electric motor is provided by the electrical energy obtained from energy storage systems. A small amount of emission is generated in the generation of electricity required to charge the batteries in the vehicle [18].

Electric vehicles work quietly. Thanks to regenerative braking, it has a longer brake life, and kinetic energy is recycled and the electric motor is used as a generator, transforming kinetic energy into electrical energy and feeding and charging the batteries. Maintenance costs, including fuel costs, are much lower than conventional vehicles. Since there are not many moving elements, there is no need for adjustment or oil change. The fuel cost of electric vehicles is much lower than conventional vehicles. Since the fuel cost of electric vehicles is low, it is expected that these vehicles will come to the fore with the increase in oil prices.

3.1.2. Disadvantages of Electric Vehicles

The high cost of producing electric vehicles limits the development of the electric vehicle market. The most important factor preventing the wide spread of these vehicles in the market is the very high purchase cost. However, the replacement of batteries and critical parts within 3-5 years, which constitute a significant part of the cost of electric vehicles, increases the cost of use. However, with electric vehicle technology, battery technology is developing and it is thought that demands will begin to increase for this reason. Another way to reduce the cost is the government and industry supported incentives being implemented in Europe and America and increasing these incentives. This will reduce the cost of use as well as the cost of the vehicle. It is clear that as electric vehicle technology develops, demand will increase and costs will decrease. This will accelerate the acceptance of electric vehicles by consumers [18].

Batteries that drive vehicles are very heavy and the range of the vehicle is limited. Electric vehicles can travel much less after charging (Conventional passenger vehicle travels approximately 500-600 kilometers with a tank of fuel). Although it takes a few minutes to fill the tank of a conventional vehicle, it takes about 5-8 hours to fully charge an all-EA. Some high speed chargers can charge the vehicle in 3-4 hours.

However, these chargers shorten the life of the batteries. There are no service stations required for the maintenance and repair of electric vehicles, it will occur over time.

3.2. ELECTRIC VEHICLE POWERTRAIN CONFIGURATIONS AND DRIVE CONCEPTS

3.2.1. Electric Vehicle Powertrain Configurations

An electric vehicle (EV) is a vehicle that is powered, by electricity. EV configurations include battery electric vehicles (BEVs) which are powered by 100% electric energy. Figure 3.2, presents the differences between these basic EV powertrain configurations. A battery electric vehicle (BEV) is a vehicle that is powered entirely on electric energy, typically a large electric motor and a large battery pack. Based on the type of transmission; the use of a clutch, gearbox, differential, and fixed gearing; and the number of battery packs and motors there are many variations on the BEV design [18].

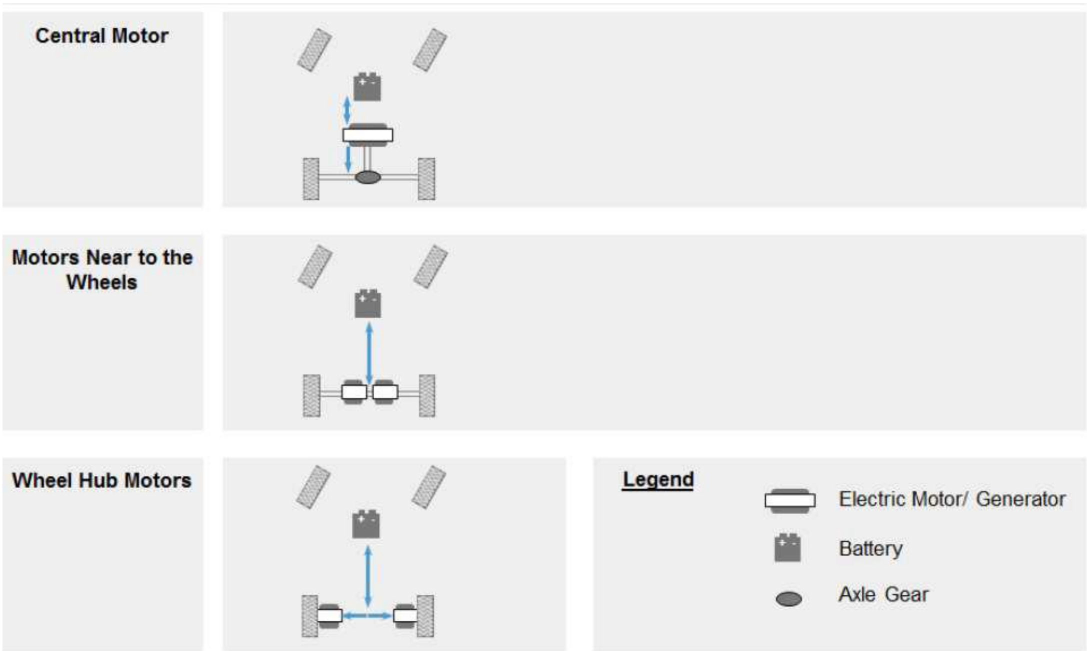


Figure 3.2. Possible BEV powertrain configurations [18].

3.2.2. Electric Vehicle Drive Concepts

An electric vehicle is driven by at least one electric drive motor. It can be configured as a four-wheel drive vehicle or with one drive axle. The two main concepts are described in this section [18].

3.2.2.1. Drive with in-Wheel Motors

No drive shafts are required, no differential transmission required. The wheels are connected directly to the in-wheel motors in terms of design (Figure 3.3).

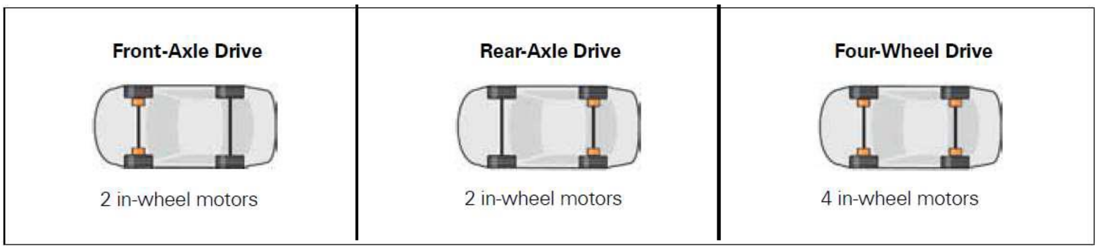


Figure 3.3. Possible BEV drive with in-wheel motors configurations [18].

Advantages;

- Four-wheel drive is technically possible
- Output axles of the in-wheel motors are directly on the wheel
- High efficiency because there are hardly any mechanical losses
- Possibility of regenerative braking

Disadvantages;

- Unsprung masses in the wheel are greater than wheels on a conventional vehicle
- High mass of driven components (inertia and torque of whole vehicle affected)
- New vehicle design required
- Control is complex, both electric motors must run synchronously

- Combination with a hydraulic friction brake is still currently necessary
- Limited space on the Wheel

3.2.2.2. Drive with just one electric drive motor in the central drive train:

Two drive shafts on each driven axle, a differential on each driven axle and Driveshaft required. The electric motor/generator drives a transmission, the drive shafts and the wheels. In a pure electrically powered vehicle, a reduction transmission is used. Fourwheel drive can be added with a drive shaft from the front axle. Another possibility is to use a second electric motor.

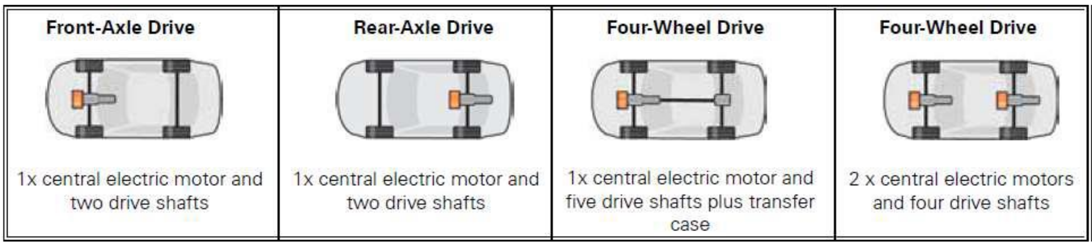


Figure 3.4. Drive with electric motor in central drive train [18].

Advantages;

- Single-axle drive simple to design
- Four-wheel drive is possible
- Integration in existing vehicle concept is possible

Disadvantages;

- Output shaft of central electric motor/generator is not on the drive axles.
- Differential required
- Reduction gear required

3.3. HORIZONTAL/VERTICAL MODULE MOUNTING OF THE BATTERIES IN THE ELECTRIC VEHICLE BODY (FOR EXAMPLE, LITHIUM-ION BATTERY)

The batteries can be mounted on the vehicle body in vertical or horizontal position. Figure 3.4 shows the completed version of the module assemblies of the Lithium ion battery, mounted vertically. As can be seen in Figure 3.5, there are 3 rows of 16 modules in the battery system. Figure 3.6 shows the vertically mounted version of the 6.5 Ah (7.2 V) NiMH battery module, which is used for HEV applications [19].

Figure 3.5. Li-Ion battery assembly (vertical) [19].

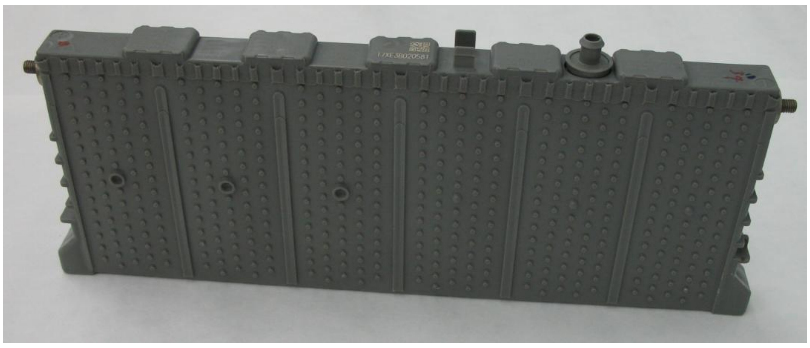


Figure 3.6. NiMH prismatic battery module (vertical) [20].

The assembly structure of the modules and cells that make up the battery may be different from the electrical structure. Another one of the most important examples of this is the type of battery given in Figure 3.7 and mounted horizontally.

Figure 3.7. Li-Ion battery assembly (horizontal) [19].

There are two important purposes of manufacturing Li-ion battery cells in a modular way. The first of these is to provide the different electrical capacity needed in different electric vehicle applications, that is, when a larger energy is needed, this need can be met by using more modules, and the second is that these different electric vehicles can have different physical structures in terms of body architectures. Therefore, while it is more appropriate to use tower type vertical battery given in Figure 3.4 and Figure 3.5 in "vehicle X" project, for "vehicle Y" a horizontal type battery system which can be mounted under the frame and shown in Figure 3.6.

3.4. BATTERY CHARGING SYSTEMS IN ELECTRIC VEHICLES

The charging systems of the battery group used as an energy source in electric vehicles are positionally divided into two as the domestic charging system and the city station charging system. Urban charging stations are used in different parts of the city such as workplaces, car parks, shopping malls, etc., when the battery capacity decreases during the day. On the other hand, the charging points in the domestic charging systems offer the opportunity to charge during the time the vehicle is not in use and when there is cheap energy cost [21].

Charging systems can be located inside the vehicle or inside the station (outside the vehicle). Although some vehicles are compatible with off-vehicle charging systems, electric vehicles generally have in-vehicle charging systems. In-vehicle two-way battery charging systems are directly connected to the AC power grid. Slow charging takes place in these systems and they are generally designed for powers below 3.5 kW. In station charging systems, the charging system is located outside the vehicle and directly reaches the battery voltage. These systems are used to quickly charge the battery. The power capacity of these systems is over 20 kW.

AC / DC and DC / DC power converters are used in in-vehicle charging systems. These converters can be unidirectional, bidirectional, insulated and non-insulated. AC voltage is rectified with an AC / DC converter and battery charging is performed with a DC / DC converter.

Electric vehicles provide the energy they need during use from the batteries they store with the help of charging systems. At this point, as can be seen in Figure 3.8, three different operating modes emerge in the charging systems of electric vehicles in terms of power flow: from grid to vehicle (G2V), vehicle to grid (V2G) and vehicle to home (V2H). The energy flow from the mains to the house (G2H) is the 4th mode of operation, which is the mode of energizing the house independent of the vehicle through the network [21].

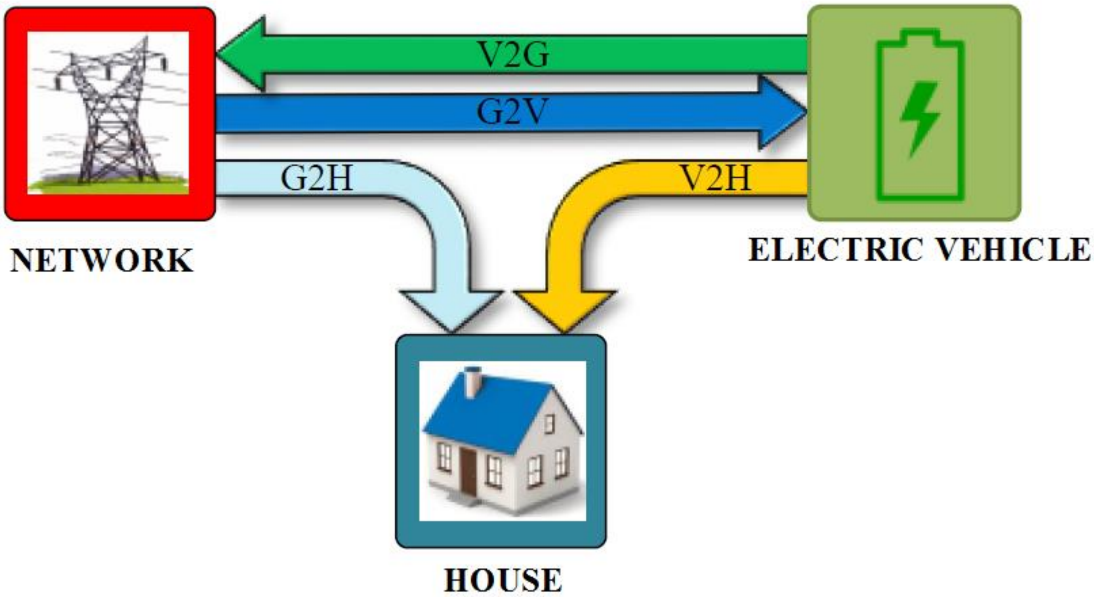
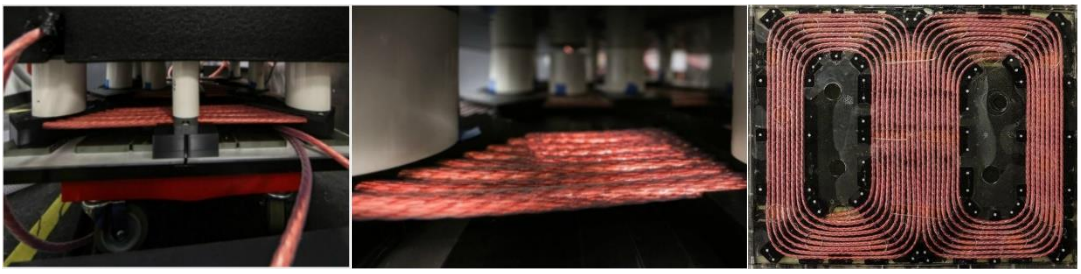


Figure 3.8. Power flow in charging system [21].

In G2V mode, the energy flow is from the network to the vehicle, so in this mode the battery is charged. The AC / DC converter rectifies the mains voltage and gives the energy to the DC bus, and the step-down DC / DC converter charges the battery with this energy.

3.5. INDUCTION CHARGING ALSO KNOWN AS WIRELESS CAR CHARGING

Since batteries have limited lives, electric cars need tube recharged, either by switching batteries and induction charging, also known as wireless car charging. Use this technology as wireless car charging, also known as inductive charging at the U.S. Department of Energy's Oak Ridge National Laboratory (ORNL), they developed an induction charging system with a 6-inch gap between coils that can operate at 120 kW and operates with an efficiency of about 97%. In this system, energy is taken from the network and converted into high frequency alternating current. It is then strengthened into a large air gap and transfer a magnetic field residue. After the energy transfer is transferred, it is converted to direct current and stored in its batteries (Figure 3.9) [22].



a b c

Figure 3.9. a., b., c., Induction charging system details for electric vehicles [22].

If we detail the wireless charging for the vehicle, the energy is transferred to the air gap on a second magnetic coil attached to the vehicle before the magnetic coil in the charger. Wireless car chargers route electricity through a four-inch air gap and require a wireless adapter to be installed on the underside of your vehicle. The points to be considered in wireless charging for an electric vehicle are briefly [22]:

- The distance between the two coils should be kept as minimum as possible.
- Coils must be positioned properly. Failure to position the coils properly will reduce the efficiency.
- Primer windings should not be left open as they will create current in the conductor closest to them. Open windings predispose to possible electrical hazards.

Inefficiency in the mentioned charging current It is the power loss that occurs during the conversion of AC current to DC. It should also be noted that inefficiency is not related to induction or connecting wire. Considering the user requests, it is possible that the induction vehicle charging is desired. These systems enable charging without using cables or plugs. However, the vehicle must be in a suitable position to do this. No cable or socket connection is required for this.

Since batteries have a limited life, electric cars need to recharge the tubes by replacing the batteries and by induction charging, also known as wireless car charging (Figure 3.10).

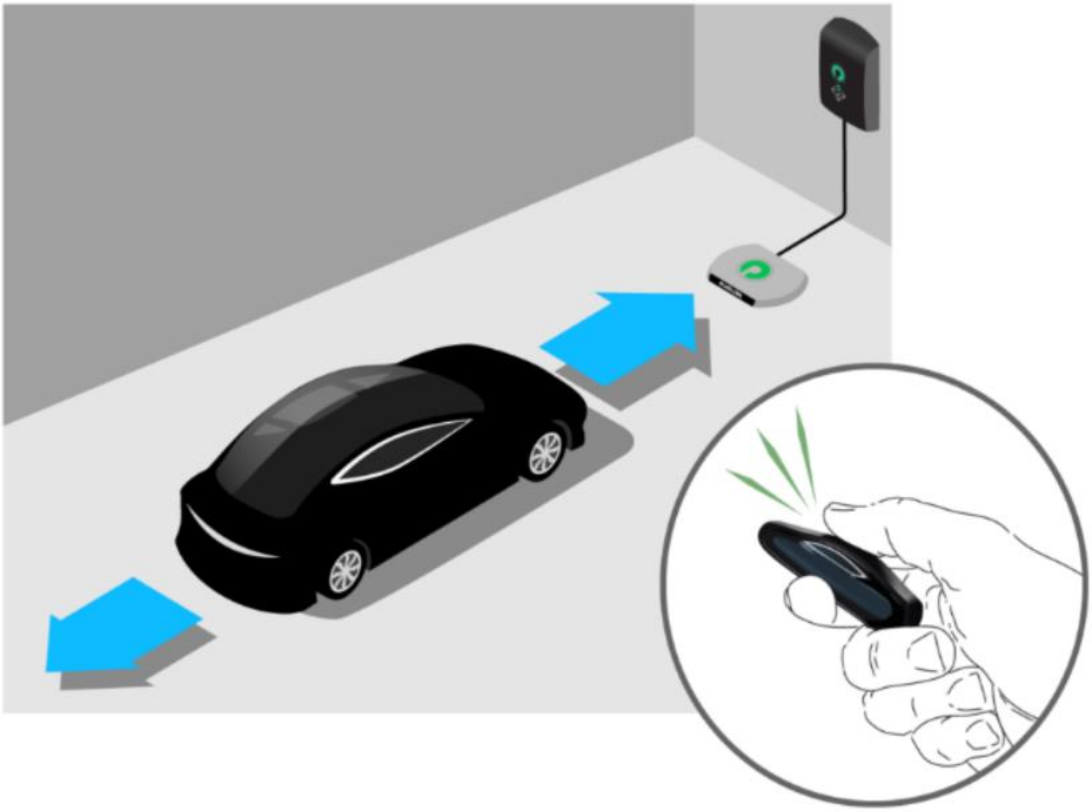


Figure 3.10. Wireless, induction charging and discharging for electric vehicles [22].

One of the advantages of this system is that electric vehicle users can charge their vehicles even while driving. For this, primary and secondary coils should be kept under the road surface. This road may be a separate charging lane and vehicles may be charged by license plate recognition when entering this lane (Figure 3.11) [22].

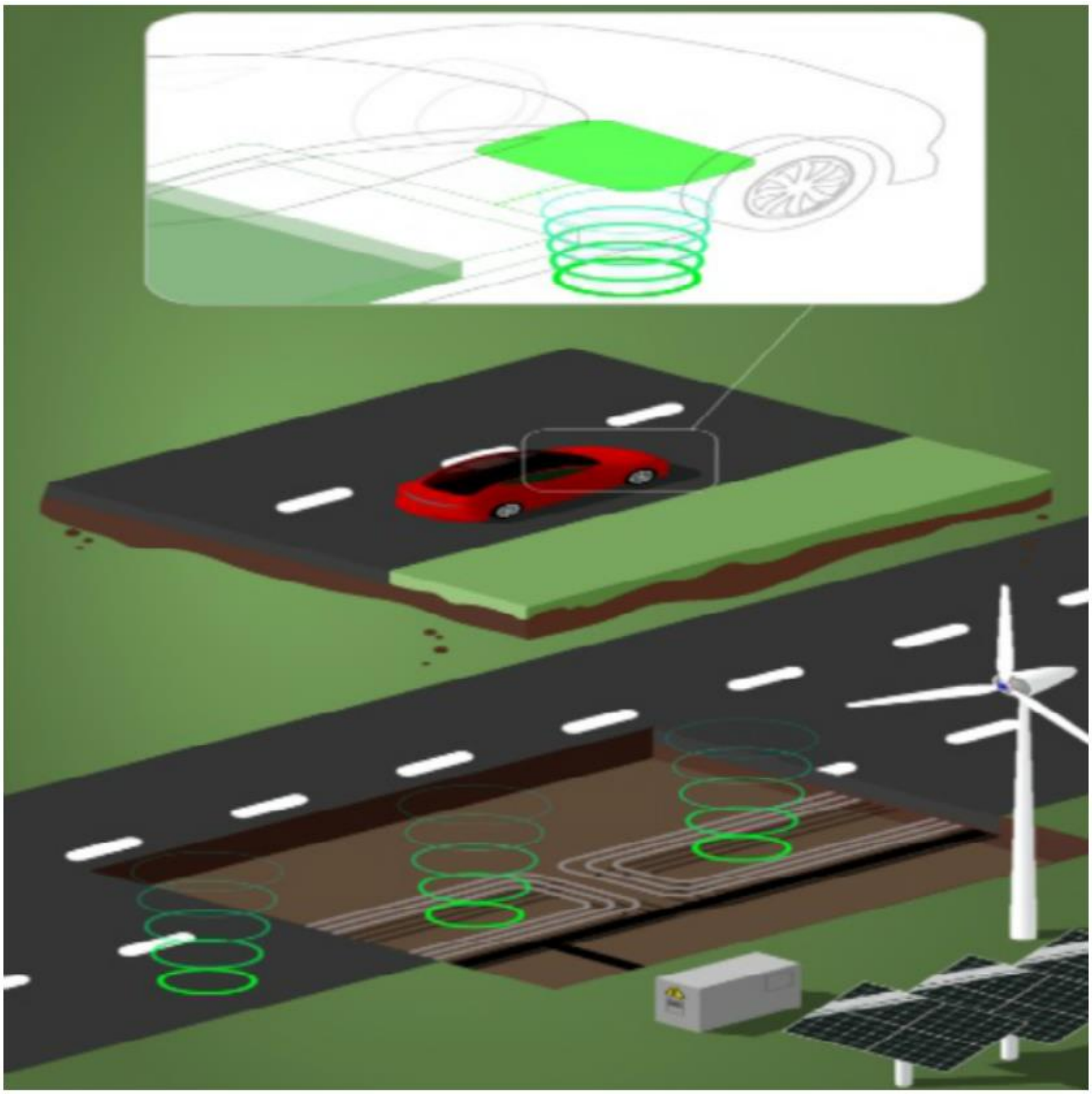


Figure 3.11. Charging strip under the road surface with primary and secondary coils that can be charged even while driving [22].

PART 4

BATTERY TYPES, LITHIUM-ION BATTERIES AND NICKEL METAL HYDRIDE BATTERIES

The battery generally contains two items known as "electrodes". The first electrode, the "positive electrode" (often called the "cathode"), is that this electrode contains chemicals that specialize in energy production. The other, the "negative electrode" (otherwise known as the "anode") has other chemicals that specialize in taking up the energy produced by the positive electrode.

If you stand the electrodes next to each other nothing happens. They need another chemical, called an ‘electrolyte’, to link them. These can be in the form of a liquid, a solid or a gel the energy initially passes through the positive electrode and toward the shaped negative electrode, and this process is by passing through the electrolyte until it reaches the shaped negative electrode and it is always present in electricity or in its form to the phone or car that can be used after that to make it work.

Electrodes and electrolytes come in many sizes, from gigantic with the National Grid to very small in a hearing aid. While using the battery, there may be a flow from the positive-shaped electrode to the negative-shaped electrode or so-called "ions". And the way it works is that the negative electrode, or what are called "electrons", returns these electrons to the positive electrode.

Ions are described as moving directly from electrode to electrode, while electrons are described as moving indirectly.

Once the battery has run out and there is no more charge from the positive electrode, the battery needs recharging – the equivalent of plugging it back into the electric socket in the wall. When this happens the discharge process just described goes into reverse.

Thus, the movement of the ions flowing from the shaped cathode towards the positive electrode becomes the shape.

As for the electrons, they also flow from the positive electrode towards the shaped negative electrode. A battery can discharge and recharge many times until it wears out. Each time it is discharged and charged is called a ‘charge-discharge cycle’.

With concerns developing about the unfavorable effects of global warming and air pollution from greenhouse gas emissions from traditional cars, environmentally friendly electric powered cars have become of interest to researchers, ecologists and other businesses in recent decades [23]. Batteries are generally categorized into a group of types, different categories, starting with size, states where they are used, chemical composition, and form factor, but these types are all among them.

Primary batteries are types of battery that does not have the ability to recharge when the battery is depleted. Its main component is electrochemical cells, which is why it is impossible to reverse the electrochemical reaction. In standalone applications it is widely and commonly used because it is impractical to charge or is impossible to do so, for example military equipment and devices that do battery work.

This type of primary battery is always strong and this power is certain and very high, but its design is for low energy uses so that it stays on for a long time as long as possible. Like remote control toys and wrist watches.

Alkaline batteries from primary batteries are considered one of the most common types of basic batteries for many reasons, because they are environmentally friendly in addition to having a high specific energy. In terms of cost, they are effective and when they are fully discharged, there is no type of leakage.

In the event that it is stored for any period, even if for several years, it remains intact and has a record of that, and when carrying it to the plane it does not damage or cause anything harmful to the plane or passengers. One of its disadvantages is the low current load, which makes its capacity limited and is used only in devices that need low current requirements only limited, such as portable entertainment devices and remote controls.

Secondary batteries, the rechargeable batteries, the secondary cells can be recharged after using the power on the battery. Secondary batteries, small in size and capacity, they are used to operate mobile phones and other devices, but they must be portable devices. A major step ahead in lowering the bad impacts of Transport. The development and success of this batteries depends on presenting the appropriate shape (size and weight) for shipment. Since batteries have limited lives, electric cars need tube recharged, either by switching batteries and induction charging, also known as wireless car charging.

As for electric vehicles, heavy batteries are used for the operation of all high-discharging applications, for example leveling loads in generating electricity. It can be classified based on chemistry, because the chemistry of a battery determines the specific power, storage life and price, to name a few [23]. There are many types of rechargeable batteries, the latest developed and two types of batteries currently used in vehicles: Lithium ion battery and Nickel Metal hydride battery.

4.1. LITHIUM ION BATTERIES

Lithium ion batteries use liquid, gel and solid electrolytes. All other circuit elements are the same, only the electrolyte is different. When we say lithium ion battery, we are talking about the battery with liquid electrolyte. Advantages of this type of battery; Since the electrolyte is liquid, the contact surface between cathode and anode electrodes is high, its technical features such as specific energy and specific power are strong, disadvantages; Battery may explode due to excessive heat, short circuit with dendrid formation, safety precautions must be taken Batteries using solid electrolyte are called solid state lithium ion batteries. Their advantages are that they are safe, non-explosive, their disadvantages are that the contact surface is small due to the point contact surface, their technical features such as specific energy and specific power are still weak, they have not yet been put on the market, they are at the R&D stage. The subject of this thesis is li-ion batteries Lithium ion batteries using normal liquid electrolyte) and detailed information will be given on this subject. Here, will be mentioned.

In the seventies of the last century there was a proposal regarding lithium-ion batteries and this proposal was for the first time, because this battery is running the lives of millions of people every day. From computers and mobile phones and mobile phones to electric and hybrid cars. Then they became more popular because of its many advantages, including their energy density, light weight in addition to their ability to recharge Figure 4.1 [24]. Lithium type batteries have many uses like cars, as they have many advantages that make their use attractive, but they are not without faults, their components are the positive and negative electrode and electrolyte [25].

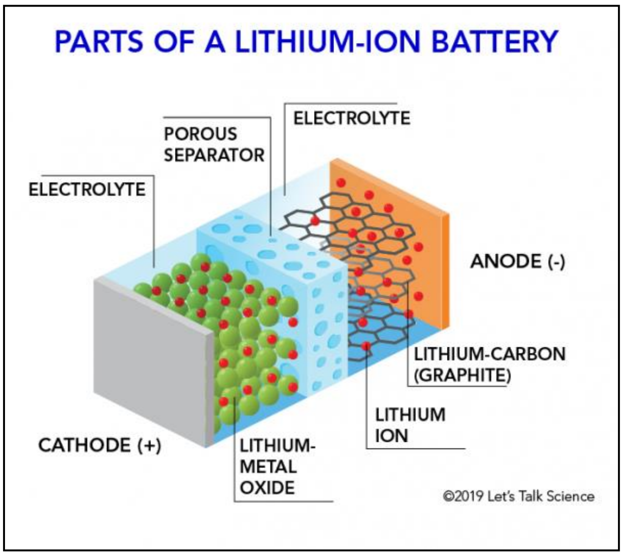


Figure 4.1. Parts of a lithium-ion battery [24].

As for minerals, it is the process of using lithium oxides in the so-called cathode, and it is also used in the so-called anode. Lithium carbon compounds are used because it allows approximation. As for intercalation, this means that the molecules are capable and allow entry to something. In such a case, the electrodes can easily carry out the transfer of lithium ions into and out of their structures (Figure 4.2).

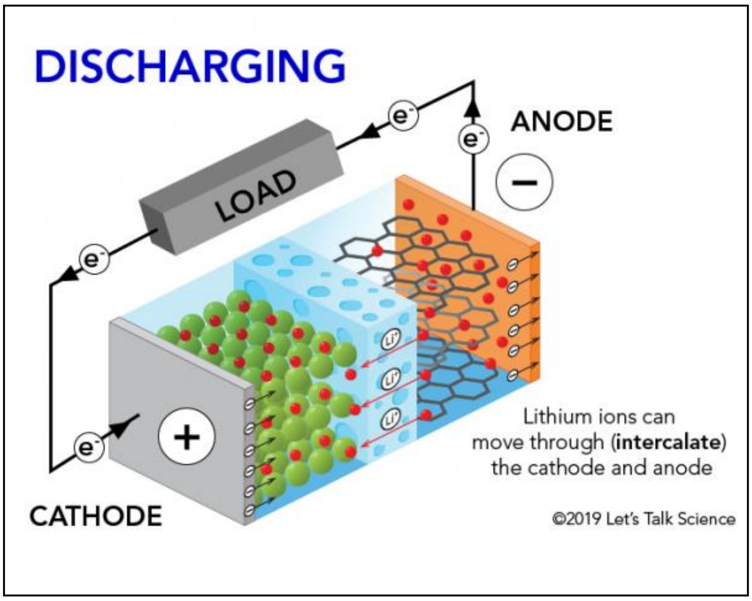


Figure 4.2. Discharging [24].

From inside the Li-ion battery, oxidation (oxidation) reactions occur. Reduction occurs in the cathode. Li-cobalt ($LiCoO_2$). In half of the reaction:

$$CoO_2 + Li^+ + e^- \rightarrow LiCoO_2 \quad (4.1)$$

Oxidation occurs in the anode. There, LiC-6 graphite forms graphite (C_6) with so-called lithium ions. It is a half reaction:

$$LiC_6 \rightarrow Li + C_6 + e^- \quad (4.2)$$

This is a Complete reaction (left to right = equal to discharge, right to left = called charge):

$$CoO_2 + LiC_6 \rightleftarrows LiCoO_2 + C_6 \quad (4.3)$$

Recharging of the Li-ion battery can be done. By installing the battery in the mobile phone, the ions move from the anode towards the negative electrode through the electrolyte.

4.1.1. Rechargeable Battery

- Lithium ions flow from the positive electrode to the negative electrode, when the battery is charging, but for the electrons they move backward from the negative electrode to the positive.
- A reversible lithium battery charging process is the process of charging a lithium battery with respect to the movement of electrons. In lithium batteries, electrons continue to flow. This is what provides energy in order to keep the device does not stop and continue to work [24].

For the purpose of using lithium-ion batteries that are rechargeable, such as the grant of electricity, portable electrical devices and various mobile phones cannot be counted at this time, and it appears that the demand is increasing significantly, which made their generally concern about sources of power in the near future. whether it is This includes portable electrical devices, Electric motors, to improve the lithium-ion rechargeable battery, to the entity that did the growth gain for its research [26].

Lithium-ion batteries express that they are well suited to the type of cars, whether they are hybrids or electricity, because of the precise energy in them and because of their high strength compared to other mobile phones that have rechargeable capacity, however, the marketing of the batteries has not been done significantly in cars to this day, and that Because of cost and safety, in addition to poor performance at all temperatures that are low. These challenges are related to run away and electrical faults, Thermal management inside the battery, and its performance at different temperatures. Because its performance is studied. This relativity contains a number of thermal effects found in overcharging, in addition to the charging charges that appear in electrically powered cars [27].

Technology has been developed for the Li-Ion battery to revolutionize hybrid cars. Because the batteries provide the lithium iron phosphate produced by A123, which is nearly twice the energy that is determined by the energy of steel and nickel hydride batteries used in modern hybrid cars. Batteries also have a huge capacity, which can sometimes reach 3.3 kW / kg. This makes it applicable to high-performance hybrids, which makes it a favorite of the average consume [28].

They Scientists have conducted several studies to make the battery more powerful and lighter, as well as increase the density of electricity, because the use of lead with a higher weight is not considered practical. Therefore, lithium became a good alternative to replace lead because it is the lightest metal in the world.

In addition, its reactivity, and therefore pure lithium is unknown in nature but the manufacture of solid lithium comes from salts extracted from mining and its activities. Therefore, it has been used in all cell phones in the world in addition to many other device. It crosses one of the best and most powerful batteries accessed today and this has made them widely known and used. Lithium cobalt and lithium iron phosphate batteries are available in huge numbers. It has become a major development for iron phosphate batteries, through DR John .

The first time this battery (Li-ion) was made in 2006 by A123 by doing the preparation of Nano Lithium batteries anesthetized. Today the A123 is achieving a tremendous and correct progress in the field of battery science and therefore has manufactured a variety of different batteries, which serve bicycles that have the advantage of working through the electrical energy of the computer servers.

4.1.2. Big Challenge of Li-Ion Batteries

The process of generating electricity in general at the present time is mostly done with the help of renewable energy consumption from fuel, so the process of its implementation is considered one of the huge and important tasks at the same time globally Because they generate all or nearly all of the electrical energy at a cost effective low and comfortably in daily use.

Where a desirable percentage of non-renewable fuel sources is used in cars and thus it is assumed that they are changed by some of the renewable sources quickly and this is done by doing the process of producing electric energy through non-renewable energy sources and then storing them in batteries It is the only way to do that.

There is a type of battery that can store high electrical energy. Modern technology can put pressure on cars. To do this, we need very efficient power batteries that can provide enough energy to power the mega engine for 10 to 12 hours at minimum levels. Therefore, it is assumed that recharging takes place within approximately 10 to 15 minutes.

4.1.3. Discharging and Charging of Li-Ion Batteries

- Lithium ions in the so-called electrode move to a terrible electrode, via the electrolyte, while the battery is being charged. The electrons float as they travel.
- After the ions stop, the battery is fully charged.
- As for the discharge, it occurs when ions slide from the cathode to the anode. Electrons resist and reject by the external circuit, in order to save a laptop (Figure 4.3 and 4.4).

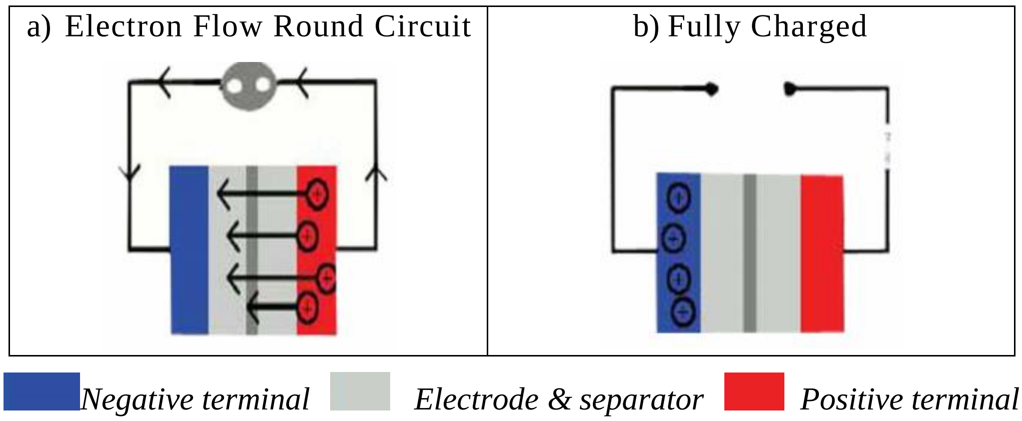


Figure 4.3. a., b. Discharge and charge inside Lithium-Ion batteries [28].

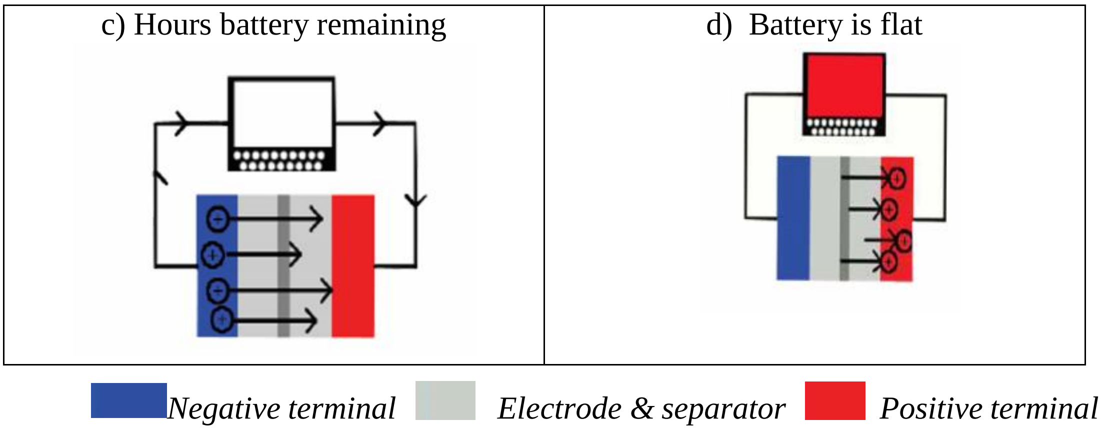


Figure 4.4. C., D. Method of charging and discharging inside Li-Ion batteries [18].

4.1.4. Lithium Ion Battery LiFePO4, LiCoO2

Poor pole, gentle pole and chemical electrolytes between them Active is LiFePO4 or LiCoO2. The cathode is made of graphite, so the electrolyte may be different when all types of battery are used. The operation of the entire lithium batteries are additional ions less ions equally.

While it is being shipped, in the beginning it is necessary to pull the lithium-based electrode which moves towards the negative electrode and from reaching it through the use of electrolytes and remains there which is one of the energy products that operate the battery.

During this, the energy becomes stored in the battery. But when emptied, it returns to what it was .However, the electrons are floating in the top, unlike the ions. The electrons tend to be an insulating barrier so they do not descend through the electrolyte, as long as the electrons are concerned. This ion movement is a coherent tactic, they stop together and work together.

The ions stop transporting through what is called the electrolyte, until the battery is completely discharged, so that the electrons cannot go out to the external circuit, so there is a loss of energy. Likewise, we change something the battery was running on, and that the electron stops flowing as well as the battery and ions also stop discharging. Unlike the various batteries. In electronic controllers, lithium-ion batteries were manufactured that modify the charge and then discharge it. It thwarts the overheating and overcharging that can cause damage, such as the accidental explosion that sometimes occurs in Li-ion batteries.

4.1.5. Lithium-Ion Phosphate Batteries are a Safety Factor

Battery safety is a reminder of what is the integrated importance of making lithium batteries. In very large or bulky batteries, the protection problems become big and serious problems are not the same as small batteries, for example electric car batteries have a higher risk such as explosion or fire. As in cell phone batteries and computers. When using a phosphate cathode, for example, a lithium iron phosphate battery, the battery is safe.

And because phosphate has its properties that it can withstand high temperatures, so the battery becomes stable when overcharged and when an electrical short occurs. Li-ion batteries charge more than 4.6 volts ^ (-1), solvent or lithium oxidation precipitates at these potentials, when using flammable liquid electrolyte cathodes and lithium steel oxide cathodes lead to dangerous events. But lithium iron phosphate may be safe, Due to the low voltage due to the complete oxidation of this substance, A ferric phosphate product (lithium iron phosphate oxidation) is considered safe, according to the reaction:

$$LiFePO4 + 6C \rightarrow LiC6 + FePO4 \quad (4.4)$$

For special battery protection, internal mobile electronics have been used to protect short circuit and provide overcharging, and various protection mechanisms are regularly used in conjunction with Li-ion electrical systems. It starts with internal mobile safety dividers and ends at valves, shipping algorithms, contractors and controllers that precisely control them. But the need for safe chemistry automatically is that the batteries must be placed in sensitive areas as the batteries comply with the strict prerequisite.

Misuse may appear in the prerequisites permanently because the battery is in a certain condition, safety equipment may not be able to stop it. The phosphate does not need to be exposed to the thermal runway and in case of misuse it will not burn. Thus, lithium-ion batteries that are made of phosphate as a cathode are considered to have a higher safety degree than other lithium-ion batteries. As for LiFePo4 batteries, they have a long life cycle and good storage life in addition to they do not require any maintenance.

In addition, they are environmentally friendly compared to LiMn2O4, LiCoO2 and Li (NiCo) O2 batteries. They operate at temperatures ranging from -20 °C to 70 °C. percentage. It does not contain any heavy metals and in any way affect the memory, such as cadmium, nickel and nickel metal batteries. Safety tools can reduce explosion hazards and stoves along with proper electrical diagram. Other Required Safety Features for All Types of Lithium Ion Batteries:

- In order not to overheat and break down the lithium ions, the circuit is closed.
- In order to avoid the internal strain tear tab.
- For relief of catharsis (do no breathe) stress.
- In order to avoid thermal interrupt overcharging.

These devices are when connected to a mobile phone but they occupy space and are useful at the same time. These devices are necessary due to the production of oxygen by the cathode after long use, since the heat is produced by the anode, the application of extended electrode designs and the installation of protection units. The explosion eliminates the risk of fire, and thus makes the cost high in order to increase the protection for lithium-ion batteries if we compare them with batteries It is a type of nickel hydride, although at the same time it increases cell protection.

4.1.6. Lithium-Ion Iron Phosphate Batteries

It contains properties that make it possible to produce a wide range of batteries of various sizes and to define their primary applications and fields:

- Large electric cars of all kinds, whether they are hybrid or electric only.
- Light electric buggies: golf carts, forklifts, wheelchairs for cleaning electric cars, and others.
- Electrical tools: electric powered saws, garden motor, no electric powered training.
- Remote play control: boats, cars and airplanes.
- Mobile devices and small medical devices.
- Mobile phones, laptops, iPods and camcorders.
- These batteries are used because they are lightweight in high-end electric motors.

Including the flagship Tesla Roadster, these batteries take approximately 3.5 hours to cost the 6,831 Li-ion cells, which weigh half a ton (1,100 pounds). When the battery is fully charged, it will travel 350 kilometers (220 miles) on the left side under the yellow electric lead, after which the batteries are charged and in a suitable condition under the batteries in the huge compartments without delay over the lower back wheel (Figure 4.5). Advantages of Lithium Iron Phosphate Batteries:

Figure 4.5. The interior of the Tesla car shows the battery and charging cord [29].

- High Performance With Co-Discharge From 2 °C To 5 °C, Excessive Discharge, And Excessive Current Capacity Of 10 °C.
- Strong performance in high temperatures between 65 and 95 °C.
- Suggesting great lifestyle cycles exceeding 500.
- You will receive a charge soon in less time than other types of batteries.
- The cost is relatively low and therefore it is used for a variety of applications.

➢ This battery is environmentally friendly and no longer produces any waste.

4.1.7. Lithium-Ion Cobalt Batteries and Lithium-Ion Cobalt Oxide Manufacturing

Lithium cobalt color batteries. Li-ion batteries are the leader in technology, the majority of these batteries contain cobalt. Cobalt Li-Ion batteries are also recognized as high powered Li-Ion battery, Due to the fact that it is very power dense. The system consists of an active electrode of cobalt oxide as the cathode in addition to that it consists of a negative electrode of graphite carbon as the positive electrode (Figure 4.6).

1- Safetyvant
2- Positive electrode
3- Insulator
4- Negative can
5- Positive lead

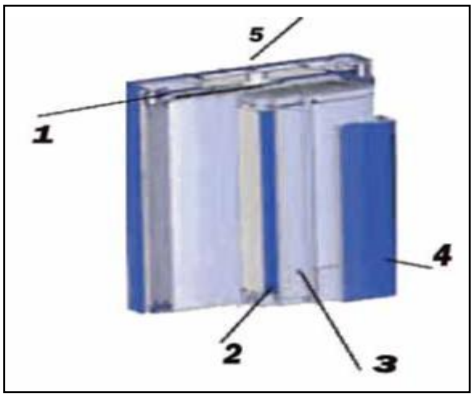


Figure 4.6. Structure of Lithium-Ion batteries [28].

Lithium-ion cell consists of three layers, which is an effective electrode plate consisting of lithium cobalt oxide cathode, and a negative electrode plate is made of graphite carbon anode and a separating layer. An electrical solution, lithium salt, is also present in an organic solvent inside the battery (Figure 4.7).

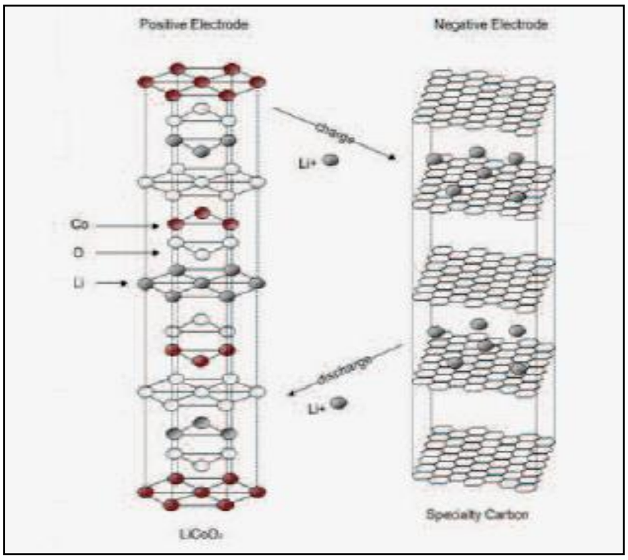


Figure 4.7. The working principle of Li-Ion batteries is in diagram form [28].

The chemical reaction that takes place during charging and through internal battery discharging is explained by the rule below.

$$LiCoO2 \ + \ C_6 \xrightarrow[<--discharge]{\text{charge}-->} Li_{1+a} \, CoO2 \ + \ C_6 L_X \qquad (4.5)$$

The main principle at the back of the chemical response is the principle in which lithium is ionized, which acts as a massive electrode during charging, and hence it strikes from layer to layer in the cathode.

4.1.7.1. Lithium-Ion Cobalt Oxide Manufacturing

They are manufactured by an automatic method, at first the cathode is used in the form of a soft paste and then placed in a laminating method on the sides of the aluminum sheet, as for the anode, the same method is done for the dough and then a separator is placed in the form of a polymer film between these sheets, and at the end it is placed in a cylindrical cover (Figure 4.8).

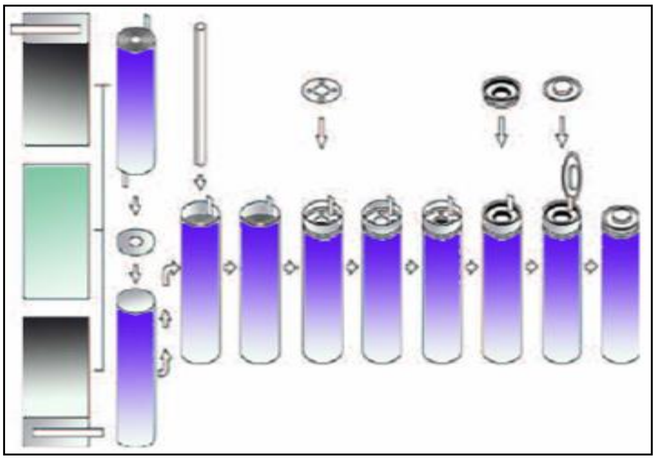


Figure 4.8. Lithium Cobalt Oxide battery cells [28].

After that, charge the phone and when the mobile phone is turned off. The charging and discharging process is managed after an electrical circuit is connected to it. These circuits prevent the previous discharge of the specified voltage to prevent the discharge from too deep.

4.1.8. The Energy Density of Lithium-Ion Batteries

Lithium cobalt oxide is the cathode tissue that is commonly used in Li-ion type batteries. Thus, it has many uses in electronic devices and gadgets, such as lithium cobalt oxide batteries. Because it has a very high density, as for the use of electricity it is considered low, so it is used in other electronic applications, and it is completely different from the iron phosphate of Li-ion batteries.

Which has a medium energy density, so it is used in electrical and other devices. It's easy on the Internet. A picture of the phone in Figure 4.9 shows a 26650 cell which is a lithium iron phosphate battery also built in a cylindrical shape, and a picture of the mobile phone 26650 appears in a summary (Figure 4.10). The summary of the specifications for both batteries has been proven (Table 4.1). A summary of the energy calculations is shown in Table 4.2.

Figure 4.9. Panasonic CGR18650E Lithium Cobalt Oxide battery [28].

Figure 4.10. 26650 A123 Lithium Iron Phosphate battery [28].

Table 4.1. All battery specifications [28].

Cathode Chemistry	Manufacture / Model	Price [$]	Volume [m3]	Mass [g]	Voltage [V]	Current [A]	Capacity [Ah]
Lithium Cobalt Oxide ()	Panasonic/ CGR18650E	11	1.77	47	3.7	4.9	2.55
Lithium Iron Phosphate ()	A123/ 26650	15	3.42	70	3.3	70.0	2.30

Table 4.2. Data for calculating the electricity output of the battery [28].

Cathode Chemistry	Energy [Wh]	Energy Density	Specific Energy
Lithium Cobalt Oxide ()	9.44	533	203
Lithium Iron Phosphate	7.59	222	108

The process of calculating the electrical output of any battery is carried out through the following calculation .Energy, its density and the resulting power calculation.

As in Table 4.3, the lithium-ion lithium iron phosphate battery has an energy density of more than six and a half times that of the lithium cobalt oxide type, although it has a tremendous strength of 8.46 times compared to a lithium-type battery. Cobalt oxide, as in Table 3.4 but there is very little difference in price between the two different types of Li-ion batteries.

Table 4.3. Data to help in calculating the power of any type of battery [28].

Cathode Chemistry	Power [W]	Power Density	Power Energy
Lithium Cobalt Oxide ()	18	1023	390
Lithium Iron Phosphate()	231	6756	3300

Equation 4.7 is used to calculate the watt-hour fee for any battery.

As we can see from Table 4.4, the lithium-ion battery of the lithium cobalt oxide type has twice the energy density available, and this type of lithium iron phosphate type battery is very similar to the specific energy that the lithium iron phosphate type batteries possess. They are completely different with power.

Table 4.4. The cost is a watt/hour for any battery [28].

Cathode Chemistry	Price per Wh
Lithium Cobalt Oxide ()	1.17
Lithium Iron Phosphate ()	1.98

Although hybrid and electric vehicles require high energy density and high energy density, this is that lithium cobalt oxide batteries provide high energy density even though the energy density is not high. There is a difference in this in lithium iron phosphate batteries [28].

4.1.9. Methods for Determining Battery Capacity

Capacity measured in kilowatt hours is a measure of the force (volts + amps + time) required to charge a fully depleted battery. As is the capacity in any battery it is a measure of the full amount of energy that you store it in, in addition to the electricity available in a fully charged battery and its temperature, i.e. the last discharge and charge cycles and the type of battery. Amps per hour also measures the current with which the battery is normally discharged at a certain rate but is always constant by measuring a certain amount of time. In general, the amount of current per hour, for example, a discharge is 20 hours. It is denoted as C / 20. This means that the battery output is 60 Ah C / 20 60 Ah for 20 hours of discharge.

4.1.10. PEUKERT’S Law

It is the relationship that exists between the current on the one hand and the discharge time and the capacity of the ordinary lead-acid battery on the third side (through several specific groups of current day values) which is approximated by the Biocert law:

$$t = \frac{Qp}{I^T} \tag{4.6}$$

Where:

QP is the ability when discharged at a rate of 1 amp

I is the modern drawn from battery (A)

T is the amount of time (in hours) that a battery can sustain. The difference in K is a constant around 13.

The overall performance of the premium battery in the high current is enormous. The actual capacity of an ordinary excessive modern day battery is greatly reduced due to the Peukert number while this amount on lithium ion batteries is closer to 1 compared to that of lead acid battery, which capacity is likely to be less current dependent and which in the face shows better current performance Excessive.

This graph indicates the discharge this graph indicates the Peukert curve of the lithium-ion battery with the effect on the peukert number of the lead lead calculated as a 1.016 battery. Peukert number for distinctive source: Brands of lithium ion batteries may additionally (Figure 4.10 and Figure 4.11).

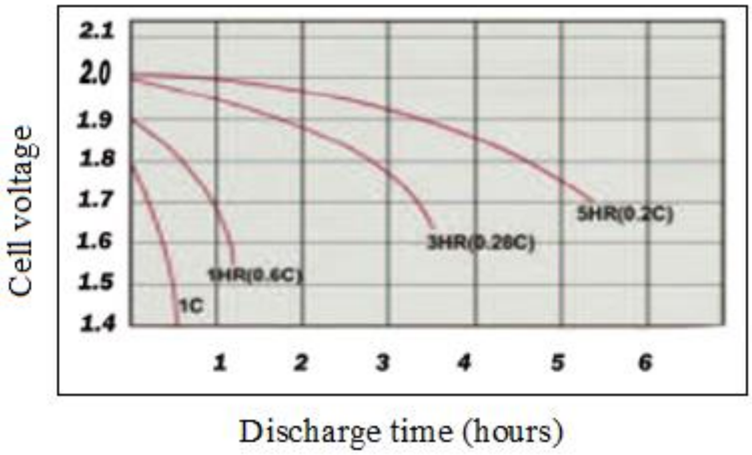


Figure 4.11. Discharge rate characteristics [25].

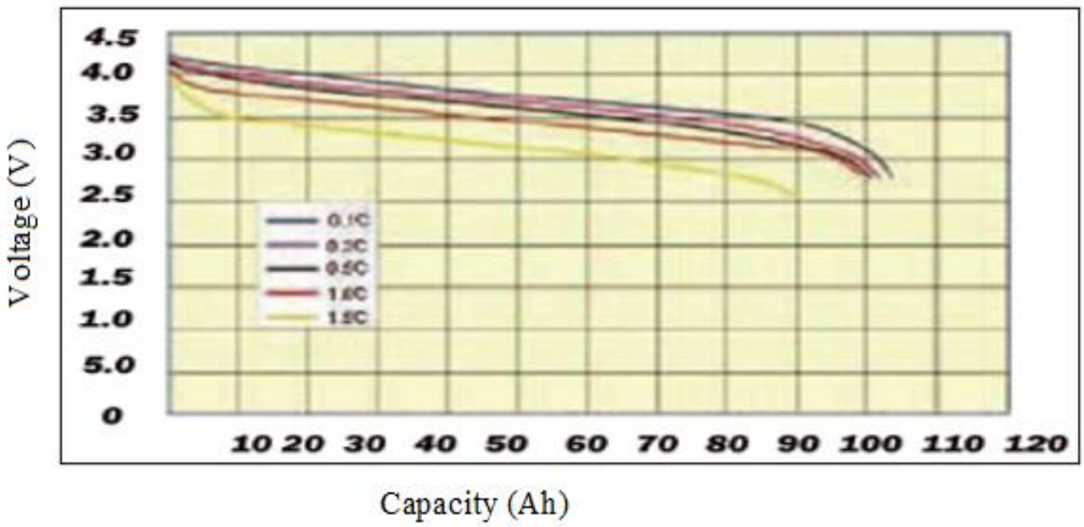


Figure 4.12. Discharge curve under different current of power batteries [25].

The diagram below shows the regular discharge curves of cells when discharged at 0.2 °C. By using some chemicals, each battery had a nominal voltage curve (Figure 4.13).

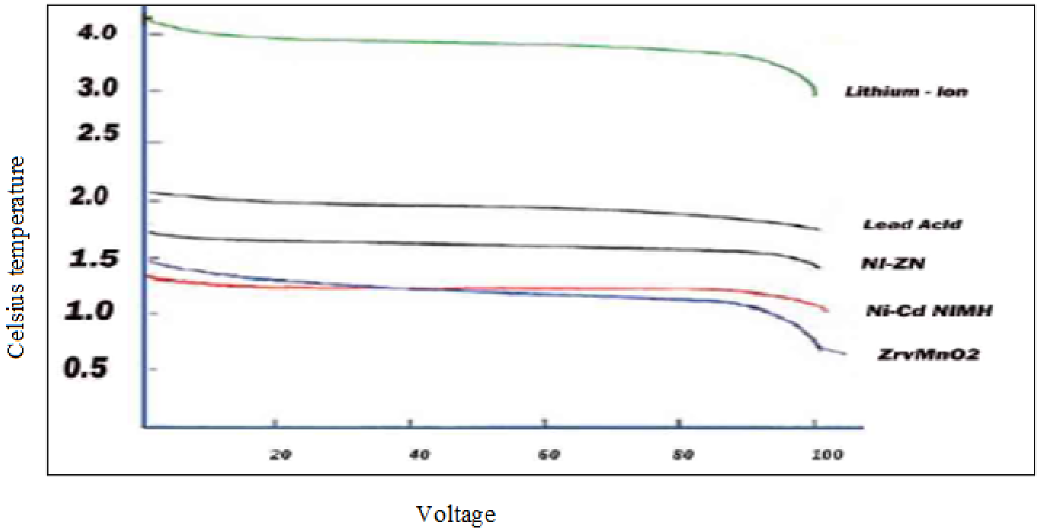


Figure 4.13. Percent of capacity discharged [25].

For a performance as high as an electrically powered vehicle, the discharge curve steadily decreases at some point in the discharge cycle with Peukert's large battery.

The Li-ion battery is a replacement for the standard lead-acid battery for superior and high performance, because sometimes the flat discharge curve wants to provide a constant voltage saving process during the discharge cycle, but in spite of that the iron phosphate of lithium has a good effect on Biocert with a highly developed density.

The diagram below shows the DC discharge curves of the lithium-iron phosphates with characteristic densities. In the event of increased current and density, LiFePO4 may sometimes be affected in terms of capacitance and may lose some of it due to the control dynamics propagating in the electrochemical process (Figure 4.14).

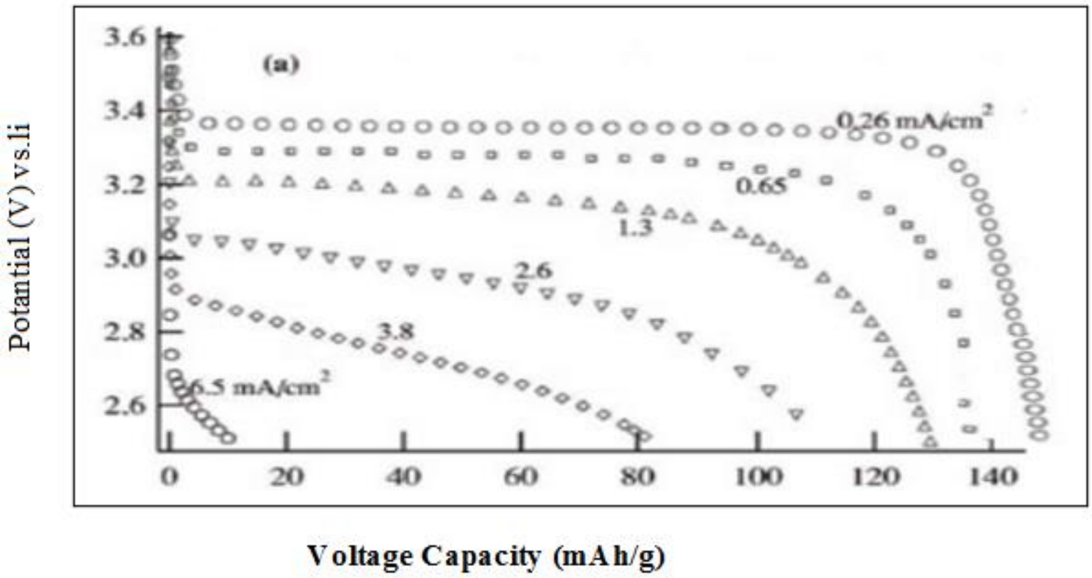


Figure 4.14. The current discharge curves of iron and phosphate with a distinct density with increasing current density [30].

The graph indicates the current discharge curves of iron and phosphate with a distinct density, with increasing current density [30]. A preliminary assessment of the chart above, we find that the curve structure is very similar to the potential electricity of the j0 plot of the gas mobile phone battery, because the voltage undergoes a drop and hence stably drops to an ohm loss. A drop in voltage across a single-phase region of lithium iron phosphate. After that, the plot turns into an apartment of the two parts district. We also have to formulate a slope gradient that grows with increasing current density due to the constrained transfer process. This unique contemporary density dominates and limits the capacity of the lithium battery.

Even this dependence is reduced, a steroids approach has been added that includes network steroids and the non-synthetic steroids method. The non-reticulate doping method helps to form LFP crystals by using dopants for communication while the retinal doping method improves the digital connectivity of the network through selective doping and simultaneously positively moderates the lithium site in the LFP crystals., a combination of these two strategies has been further developed which are referred to In the name of how to take steroids.

4.1.11. Special Characteristic of LFP Batteries

Other than this effect above, there are some characteristics of the LFP cathode fabric that cause the effect of the energy Li-ion capacity and cells, in addition, have the advantages of flat circuit open circuit through long-term reliance on load, internal resistance and bicycle records (Figure 4.15).

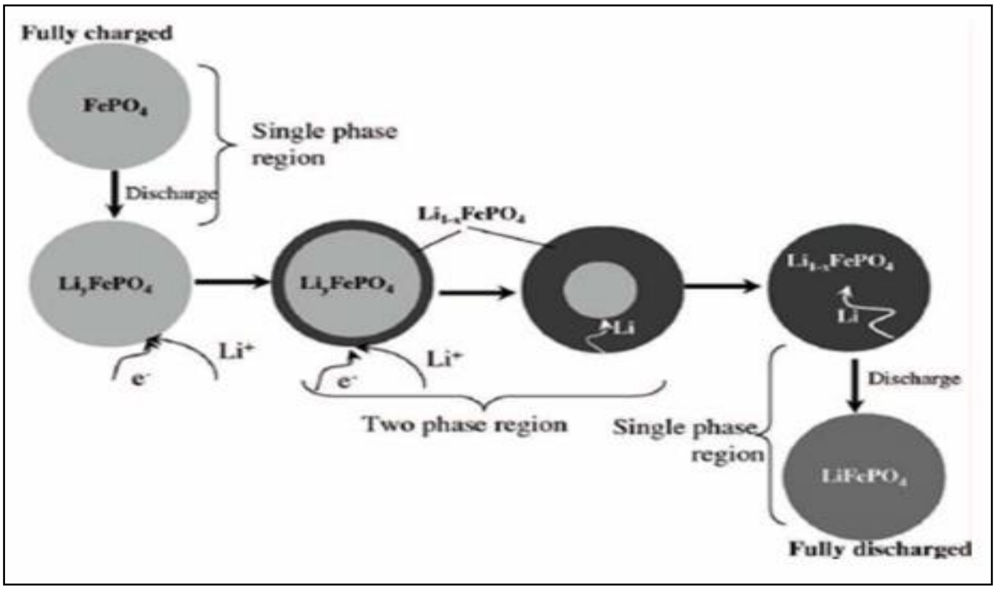


Figure 4.15. Discharging the Lithium battery [31].

During the insertion of lithium into the cathode particle, the location of the particle's floor will become rocky and distinct phase regions (rocky section and clear cross-sectional area) appear inside the homogeneous material at the beginning, There are areas of them that represent a partitioned barrier between every two regions, and then one of the stages turns into its counterparts with the introduction of lithium and in the center particles spread superficially and form a barrier, but the lithium remains a center inside, the lithium moves in two stages.

The barrier becomes gradually disappearing through the policy of diffusion the length of the long relaxation period. There are many regions within the electrode molecules, and these regions have an effect on regions called discrete phase, this also affects the electrical performance of Li-ion cells. Lithium normally moves during the discharge process from the core of the stone to the surface of the particles, so in order for lithium to enter the grid, it must overcome the circumference and distance of the coating, and it can also enter the lithium in the host net.

4.1.12. The Effect of Two-Stage Transmission on Battery's Internal Resistance

During the two-stage transition process, a change in OCV appears across the electrode because the lithium concentration is constant within the cross section. The floor area is loosened at some point in the entire input process. Inbound lithium only causes the section barrier to shift. Hence, the achievable electrode linked to Li's awareness within regions of the outer portion of the particles remains constant. The surface was located during the removal of lithium (Figure 4.16).

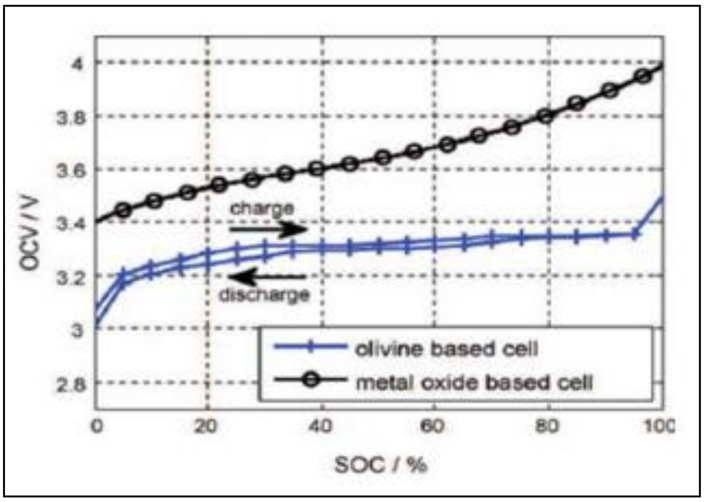


Figure 4.16. OCV cells LiFePO4 and metal oxide [31].

For this purpose, OCV and its curves for cells because the lithium which is based on the graphite anode, the cathode consisting of LiFePO4 in a flat form, and the graphite and the cathode exhibit different behavior in two stages throughout the process of removing and inserting the lithium. When distinguishing, the metal oxide curves will increase by approximately 0.6 V from SOC = 0-100% without affecting the two-stage transition. As is evident, the olive cell phone OCV indicates only moderate adjustments with the various.

4.1.13. Charge History Dependent Power Capability

In the figure and diagrams, they are shown by discharging, charging and conditions. Cells operate at the potential nominal rate. Points a, c and e represent the cost pulse and are denoted as b, d, and f for the discharge pulse condition. Through the analysis, the researcher reached a conclusion that electricity is obtained through lithium iron phosphate (parts C and D), which depend heavily on the method of reaching the cost situation (Figure 4.17 and Figure 4.18).

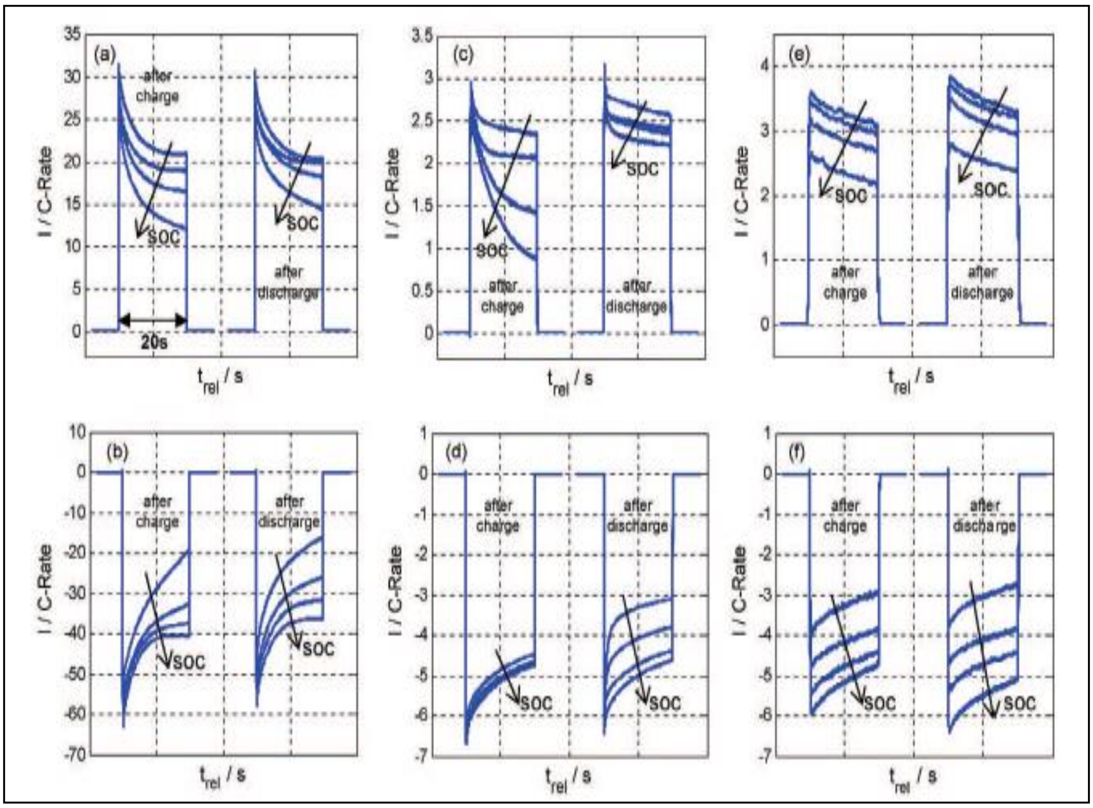


Figure 4.17. Charge history dependent power capability [31].

After discharging the discharging the talk (piece C) is almost unbiased from the realm of the cost while after discharging, the latest discharging differs greatly (piece D). The required power of the metallic oxide cells is completely unbiased according to the charge and the time at which it was made, and it is also related to the state of charge, which leads to a limit of the power capacity with the reserve voltage.

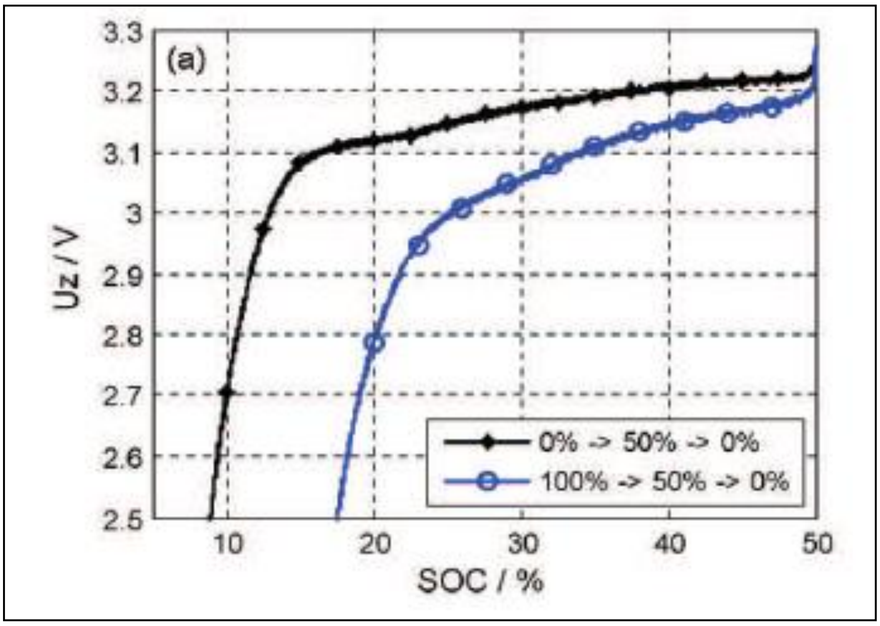


Figure 4.18. Charge history dependent available discharge capacity [32].

4.1.14. Shipping and Its Date Based on Discharging and Its Available Capacity

The graph above shows the moving voltage which is typical for power cells at a point at a discharge of 0.3 °C. It is clear that the abnormal initial cost situation must give rise to an extraordinary internal resistance (Figure 4.19).

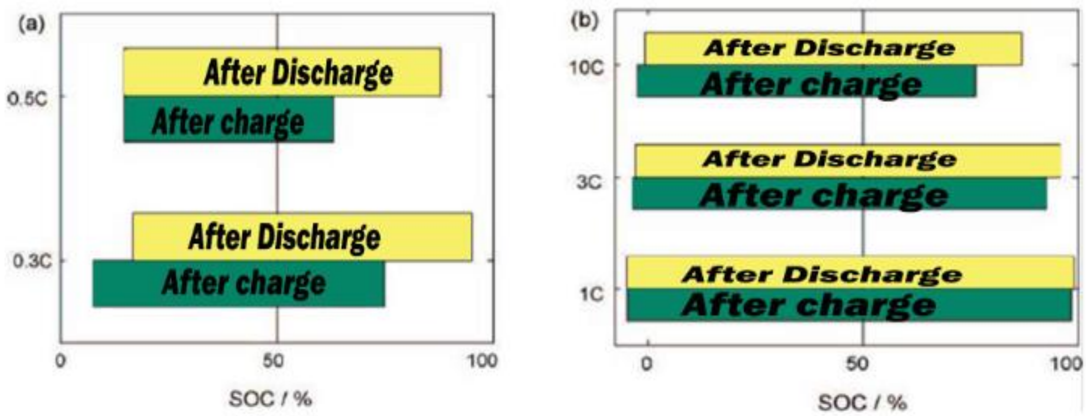


Figure 4.19. The SFP inaccessible charge and discharge capacity [32].

Typical SOC values start at SOC = 50%. The graphs above show 50% of the SFP inaccessible charge and discharge capacity. So the LFP battery should be used as it is in a much better condition than being reliable.

LFP potential is based on modern density under conditions except for contemplation of the doping method. The LFP suggests that there should be cost-condition control in the direction of power capacity. Suppose the capacity of discharge power after charging is much greater than discharging and that the kingdom cost is much less important. These features give it a strong use in the market.

4.1.15. Cost Analysis

The price of one battery pack consists of cloth and production. One building agent battery can be called as: cathode, anode, separators, electrolyte and circuit management. In our case, the cathode material is LFP. It is illegal to evaluate the value that occurs by custom and imitation as there are many new synthesis techniques under development in the laboratory such as sedimentation method, emulsion drying approach, etc. Practically industrial in mass manufacturing (Figure 4.20).

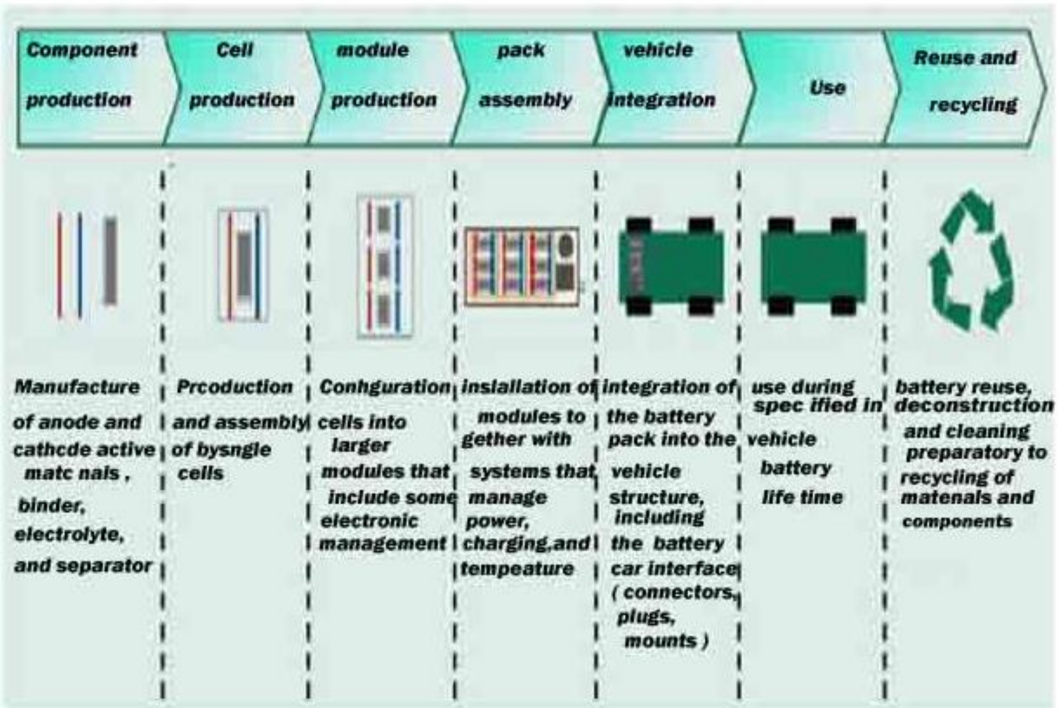


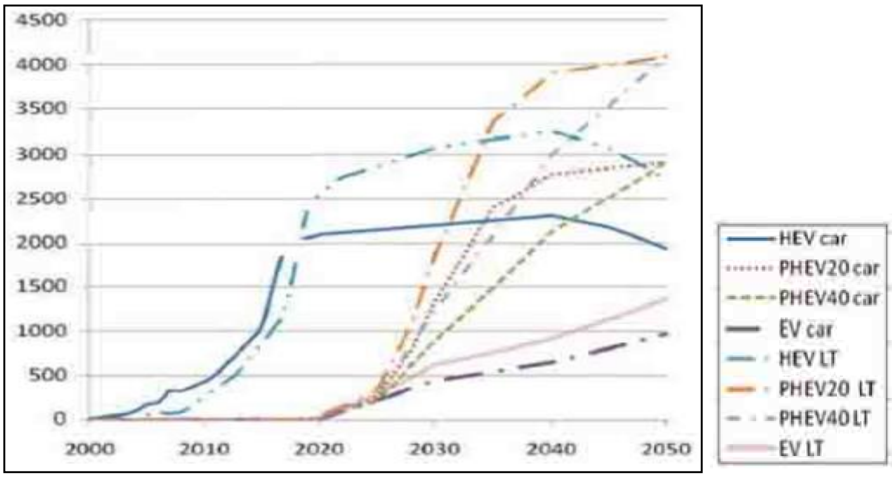
Figure 4.20. Decomposing steps for the cost chain of EV batteries [32].

The price at which the business can buy has been estimated at approximately 50%, meaning that batteries with high and advanced technology make them very attractive for purchase by the consumer and make their price much higher than the price of manufacturing batteries with unique features.

4.1.16. Current Cost

Based on battery making and development in 2009, the cost can be roughly estimated for future LFP battery production. Interestingly, the price of an LFP battery is quite high, according to a standard similar to an NCA battery. Given the fact that although LFP cathode tissue is half the rate of NCA, LFP desires more material in the cathode and offsets this graphical feature.

As technologies increase, LFP should beat the competitor in conclusion due to overuse. Consequently, the rate will decrease to meet customer needs. Since this OEM price is not now a residual fee on the market because manufacturers require approximately 50% of the scrap price and the actual price ranges from $ 1,500 to $ 1900 per kWh (Figure 4.21).



Sales (1000s)

Year

Figure 4.21. Electric vehicle sales % of sales [32].

4.1.17. Lithium-Ion Batteries and Future Cost

Potential material value and issues are reduced by laboratories. Also, the batteries will decrease dramatically if production increases. The chart above shows the growth charges in the HEV market and their confidence balances. Assuming that 14 million cars will consist of multiple trains, whether hybrid or electric, by 2030, payee fees will drop to $ 570 to $ 700, and the battery price will drop to $ 270 to $ 330 per kilowatt-hour, respectively (Figure 4.22).

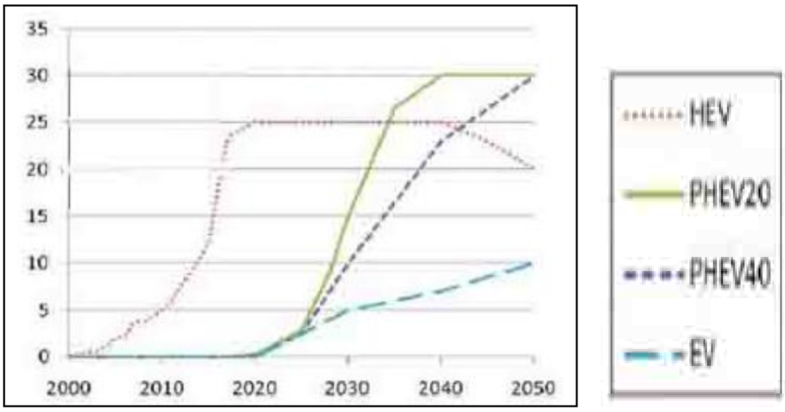


Figure 4.22. Elctric vehicle market shares [32].

4.1.18. Lithium-Ion Batteries and Future Ahead

At the present time, there is a mixture in lithium cobalt batteries, which makes them provide longer life and better performance for heavy applications and also provides very large power and the type of lithium iron phosphate, makes them provide safety as they are considered very safe, but with much less power than lithium cobalt. Although lithium cobalt batteries are equipped with digital safety units along with the protective casing on its body, they are still not fully used in cars and other cars due to the fact of the protection problems as they can seize the oven or burst due to intense heat or overcharging or listed thermal.

Lithium iron phosphate batteries are used a lot in small units in various types, such as laptops, iPods, etc. [28].

4.1.19. Advantages of Lithium-Ion Battery

Li-ion batteries have many advantages if we compare them to conventional rechargeable batteries because they have developed very quickly as Li-ion batteries have high strength, long life and safe. And density because it is considered a good environment for storing energy in applications in smart grids and emerging cars, so the technology is widely used. To better understand the advantages, disadvantages or limitations of using battery technology.

In addition to the advantages of lithium-ion batteries, the most harmful types of batteries that do not harm the environment except for batteries that are composed of mercury, cadmium and mercury, are therefore preferable to recycling rather than throwing them in the waste or burning them (Figure 4.23).

Figure 4.23. Li-ion battery is environmentally friendly [28].

The development of a functional electrolyte is an effective approach to improving the performance of these batteries [33]. There are several important properties in a battery and it is electrical power, which is the output voltage and current. The advantage of the amount of energy left by the battery divided by the amount of energy that is inserted into the battery. The relationship between energy density by weight and volume is an important feature of batteries.

Energy density refers to the amount of energy available in a specified period of time per pound, measured in watt hours per pound. Energy is a product of voltage and current. Volumetric energy density is the same as normal energy density except that every gallon or cubic foot contains a certain amount of energy for a specific period of time. Its symbols can be watt hours per cubic foot or they can be watt hours per gallon. Energy density is important because it shows how far an electric vehicle can get out of its batteries.

Besides, battery capacity is made up of several main factors of batteries. The capacity is limited to hours in amperes. 50Ah battery can reach 1Ah current for 50 hours. This characterizes the battery and shows the amount of discharge from the battery charge [34]. The life and performance of lithium batteries will vary depending on the overall spit and operating temperature of battery Lion.

Therefore, in semi-empty environments, decreases in battery performance and life lead to reduced power and capacity and consequently degradation of battery condition, thus developing low-temperature batteries and ions when they reach subzero degrees and high ionic conductors, which includes checking rods, including MCMB anodes and LiNiCoO2.

Where the results present the tests in the description in the vacuum that were made on the cells through the results when placed at a large temperature from 30 to 70 °C and at different rates, varying from C / 100 to 3 °C, all available from Trulitat-based carbon conductivity is increased The performance is highly rated at low temperature. In this respect, this performance improvement is a clear plan at lower temperatures [35].

Among its many advantages are the cost of repair and cobalt in Canode, which is a major contributing factor [36]. Due to their primary advantages, lithium-ion batteries in all likelihood continue to store portable electrochemical energy. Lithium-ion batteries are the first choice for storing electrochemical energy, improving cost and performance, and can expand their applications and enable new technologies that rely on energy storage.

Lithium-ion batteries such as high-capacity charging and high-capacity electrodes can operate at high enough voltage to improve the strength and density of the lithium battery, making it cheaper and smaller. There are several advantages to using lithium-ion batteries. As a result, this technology is increasingly being used in various applications. Everything in vehicles and many other applications.

4.1.19.1. High Energy Density

High energy density is one of the main advantages of lithium-ion battery technology. Because electronic devices require batteries with a higher energy density to last longer. The high energy density afforded by lithium-ion batteries is a clear advantage. Electric cars also require high energy density battery technology.

4.1.19.2. Low Self-Discharge

A lot of the rechargeable battery's problem is the self-discharge rate. The self-discharge rate of lithium-ion batteries is much lower than other rechargeable batteries (such as Ni-Cad and NiMH batteries). The first 4 hours after charging is usually around 5%, but it drops to about 1-2% per month.

4.1.19.3. Low Maintenance and Low Maintenance Costs

The lithium-ion battery does not requirement maintenance to ensure its execution, and this is one of its most important advantages. Ni-cad cells require periodic vacuuming to ensure that they show no effect on memory. Since this does not have any effect on the Li-ion cells, maintenance measures are not required and the process to confirm the effect on memory is also unnecessary.

The main advantage of lithium-ion batteries is that they can ensure their performance without active maintenance. Lead-acid batteries require maintenance, and some require periodic increases in battery acidity.

4.1.19.4. Battery Cell Voltage

The voltage generated by each Li-ion battery cell is approximately 3.6V. This has several advantages. Since it has a higher voltage than nickel-cadmium, nickel-metal hydride or even standard alkaline batteries (about 1.5 volts per battery) and lead acid (about 2 volts per battery), the voltage of each lithium-ion battery is higher, in many battery applications.

4.1.19.5. Loading Characteristics

The charging characteristics of lithium-ion batteries or batteries are very good. When using the last charge, it provides a reasonably stable 3.6 volts per battery before dropping.

4.1.19.6. No Configuration Required

Some rechargeable batteries need to be prepared for first charge. One of the advantages of lithium-ion batteries is that they have no requirements, so they can be used at any time.

4.1.19.7. Several Types are Available

Several lithium-ion batteries are available. This feature of Li-ion batteries may mean that appropriate technology can be used for the specific application required. Certain forms of lithium-ion batteries can provide a high current density, making them ideal for electronic devices. Others can provide higher current levels that are ideal for power tools and electric vehicles. [37].

4.1.19.8. Energy and Its High Density

One of the most important successes of Li-ion battery technology is its high energy density. Because electronic devices for example, cell phones run for a longer period between charges while increasing power constantly, batteries are required permanently and with very high energy density, and there are many applications for electric tools for electric vehicles. The high energy density that lithium-ion batteries provide is a huge advantage because an electric vehicle needs it.

No requirement for priming commonly, the rechargeable cells in the battery have to be prepared to perform the first charge, but the lithium ion cells and batteries do not need this. Also, there is a wide Variety of types available there are many types of Li-ion cells.

Which makes it used in the needs of a specific application using appropriate technology and this is an advantage to it as it is ideal for portable electronic equipment because it is available in many forms some of which provide high current density and there is another form that can provide much higher current levels and is ideal for electric vehicles and electrical tools [38]. But Li-ion battery is not flawless so it must be weighed with benefits before use.

4.1.20. Disadvantages of Lithium-Ion Battery

4.1.20.1. Protection Required

Batteries and lithium-ion cells are not as powerful enough as all other rechargeable technologies. Over charging and discharging protection takes a lot. It also needs a conservative current within safe limits. This is one of the disadvantages of a lithium-ion battery that it must have built-in protection circuits in order to keep it working safely.

To ensure the relative ease of the device in the event that the battery cannot be replaced or in the battery, modern integrated circuit technology is used, because it allows the integrated battery management department to use Li-ion batteries without any experience with it after the battery is fully charged, when charging after that, you can charge the charger to cut Supplies it up.

4.1.20.2. Ageing

The lithium-ion battery has drawbacks, the most important of which is that consumer electronic products suffer from aging. Without relying on or calendar or time only, it depends on the charge discharge cycles that occurred for the battery and is mostly from 500 - 1000 discharge cycles and after this number its capabilities decrease with the development of lithium-ion technology.

The number of discharge cycles required by the battery to decrease its capacity and after a certain period will The battery needs to be replaced, and this becomes a problem in devices where the battery is built-in. Cobalt oxide is an ordinary consumer, it must be partially stored in a cell battery or LCO for use when needed at a rate of 40% to 50% in cold stores which makes the battery life long.

4.1.20.3. Transportation

In accordance with using the lithium-ion battery for a period of time, it became clear that there is a defect that air travelers need to protect, especially the separately made battery. This protection is against short-circuiting with dome caps and on moisture buds. The security situation changes from time to time for several types, and this poses a challenge for airlines, for that matter, some companies specifically make circuits.

4.1.20.4. The Cost

The major disadvantages of a lithium-ion battery are its high cost, as it costs more than 40% of NiCd cells to manufacture. Because additional costs are a big problem, in terms of depreciation in manufacturing. As they are, lithium-ion batteries are considered immature technology because they are to some extent a developing region, and this is one of their disadvantages, but they have the advantage that their technologies are constantly developing because they provide better solutions [31].

4.1.20.5. Damage When Li-ion Battery is Completely Discharged

Draining and charging the batteries is a chemical reaction, but some claim that the lithium ion is an exception, since the energies flow to and from the battery through the movement of ions between the cathode and the anode, in the event that the claim is true the battery will live forever. The ions do not fade with usage, as happens in all battery systems.

The degenerative effects and internal wear or meaning parasitic reactions that occur on the electrolyte and electrodes. The Li-Ion battery charger is a voltage regulator very similar to the lead acid system. With some differences with Li-ion, there is no slight charge and it has a higher voltage in each cell, and it can withstand more pressure and floating charge when fully charged.

But lead acid provides flexibility with regards to cutting, because Li-ion cell manufacturers are meticulous to the correct setting because Li-ion battery stops charging completely and cannot accept overcharging. However, no charger gains extra battery capacity or extends battery life, pulsations and other tricks. Li-ion is a "clean" system because it only takes what it can absorb.

The very active substance is ions. So it reacts in a simple way and generates a lot of heat. So it shows that there are circles in those cells. It is used to check voltage and temperature. In other words, the circuits prevent cells from detonating. Cannot Be Completely Discharged: When the Li-ion battery is completely discharged, this causes damage. When it is charged, it leads to low efficiency. And scientists advise that this type of batteries keep a charge of more than 50%[39].

4.1.20.6. Charging Cobalt-Blended Lithium-Ion Batteries

The charge of lithium-ion is usually with the traditional cathode materials of nickel, cobalt, aluminum and manganese to 4.20 volts / cell. Tolerance is +/- 50mV / cell. Charging a number of nickel-based elements is approximately 4.10 volts / cell; the high capacity of lithium ions is approximately 4.30V / cell and higher. This allows for increased voltage boost. But exceeds the specifications, emphasizing safety and battery problems. Because it does not allow the embedded protection circuits to package the voltage group.

The Figure 4.24, shows the current voltage and signature during the passage of the lithium ion in the stages of overcharging and DC where it reaches full charge when the current becomes almost low between 3 and 5 percent of the Ah rating.

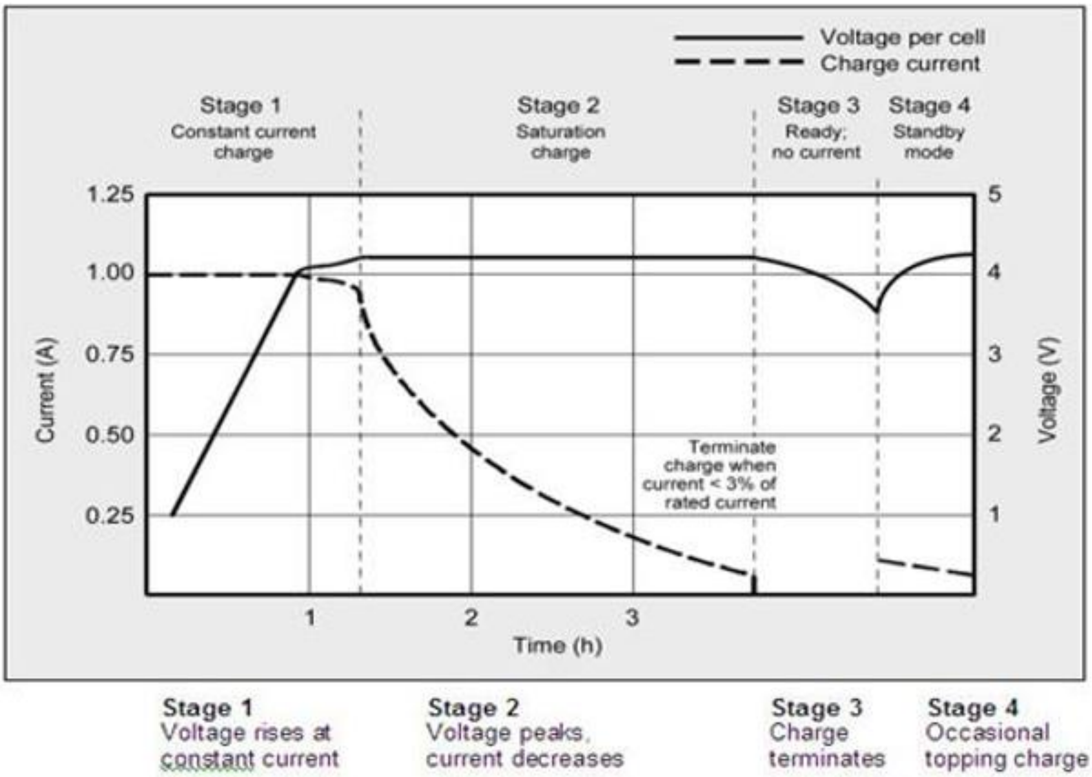


Figure 4.24. Charge stages of lithium-ion. Li-ion is fully charged when the current drops to a set level [40].

The recommended charging rate for any energy cell is between 0.5 °C and 1 °C; during full charge about 2-3 hours. It is also recommended to charge at 0.8 °C to extend battery life. Also, most energy cells take a higher C rate while adding less pressure. Its charging efficiency is approximately 99 percent and the cell remains cool throughout the charging period. Lithium-ion packages sometimes experience a temperature increase of about 5 °C (9 °F) when full charge is reached. This is due to the high internal resistance or due to the protection circuit. In the event that the temperature rises above 10 °C (18 °F) under moderate charging speeds, the charger or battery should be discontinued. Full charge occurs when the current drops to 3% of the rated current.

The battery is fully charged in the event that the current energy levels are low and cannot decrease further. Self-discharge can be high, which is the reason for this. The increase in the charging current leads to work to accelerate the method of full charge better, however the battery reaches its peak quickly, while for charging saturation takes longer than usual. Meaning that the first stage is with high current, and the second stage takes longer, which makes the battery fill up by 70% quickly.

Charging the entire lithium ion is not necessary like lead acid, and it is best not to charge it fully because the high voltage presses the battery. Which increases the battery life due to the elimination of saturation charging although it reduces the operating time, the chargers for consumer products operate at maximum speed and long service life is not important and the chargers cannot be modified. Use consumer chargers because of the low cost of "running and charging".

Where the lithium-ion battery is charged in less than an hour or an hour maximum because the saturation charge in the second stage appears "ready" because the battery in the first stage reaches the threshold voltage. The charging state (SoC) at this point is 85%, which is enough for almost all users. Industrial chargers set a minimum charging voltage to extend battery life. Table 4.5. illustrates the estimated capacities when charged to different voltage thresholds with and without saturation charge.

Table 4.5. Typical charge characteristics of lithium-ion [40].

Charge V/cell	**Capacity at cut-off voltage***	**Charge time**	**Capacity with Full Saturation**
3.80	~40%	120 min	~65%
3.90	~60%	135 min	~75%
4.00	~70%	150 min	~80%
4.10	~80%	165 min	~90%
4.20	~85%	180 min	100%

Adding full saturation at boosts the voltage setting capacity at about 10 percent, but it adds stress due to the higher voltage [40].

The voltage runs out quickly the first time the battery is charged. The behavior of the rubber is very similar to that of weight lifting, as the power will eventually be delivered when the battery is almost fully charged (Figure 4.25). And this charging is distinguished for all rubber bands, and charging is a cell with a high internal resistance that increases the batteries that promise a model order. Increases the charging current, and increases the effect of the capacity in the battery that follows the charging voltage, for example lifting a heavy weight through a rubber band.

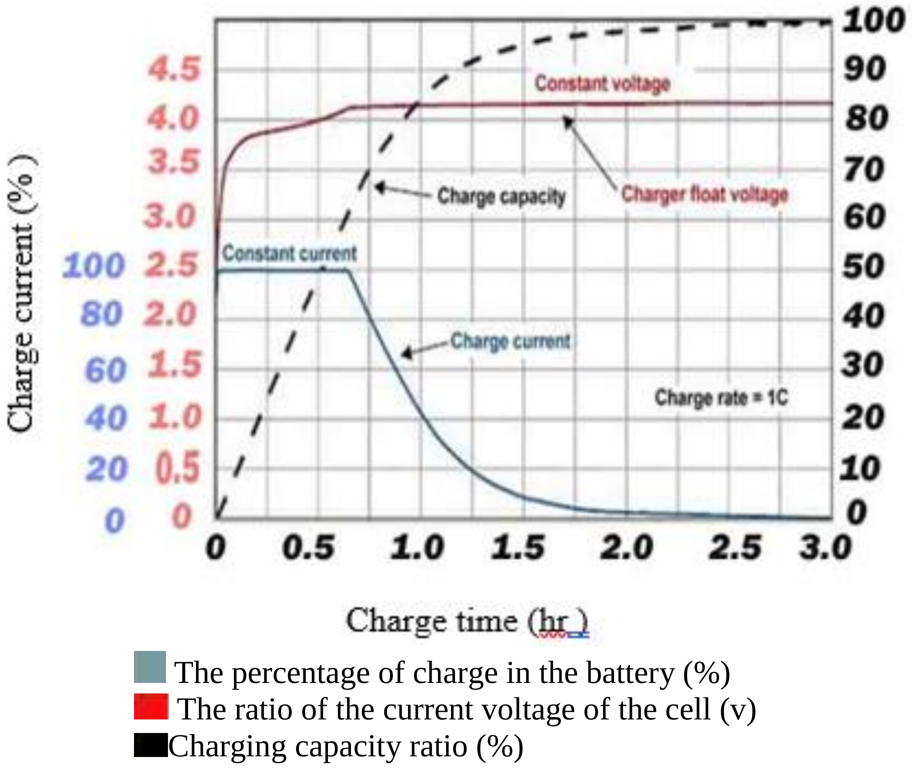


Figure 4.25. Voltage/capacitance is directly matched by time during lithium-ion charging [40].

Estimating the SoC by doing a reading of the charging battery voltage is inaccurate and practical. The process of measuring the open circuit voltage, called OCV, which is greatly affected by temperature, is good indicators after the battery takes a break for a few hours. The Li-ion battery is greatly affected by the active substance as the SoC for computers and mobiles is estimated through Coulomb calculation.

Li-ion cannot absorb excess charge. When it becomes fully charged, it must be disconnected. The drop charge may occasionally compromise safety with metallic lithium plating. To maintain the lithium-ion battery, stress must be reduced, and at peak voltage must be cut off as short as possible. Thus, the battery voltage decreases and over time the open circuit voltage will stabilize between 3.70 volts and 3.90 volts / cell. A fully charged Li-ion battery will remain on high voltage for a relatively longer period of time compared to one that has not been fully charged.

Some short chargers carry a charge called compensation because it compensates for the self-discharge battery and protection circuit for the initiation, so when Li-ion batteries must be left in the charger for operational readiness the charger may start when the open circuit voltage drops to 4.05V / cell and it turns off again when it becomes 4.20 volts / cell.

Therefore, in order to reduce the voltage to the degree of 4.00 volts / cell, the charger is always put in the operational standby mode as it recharges until it becomes only 4.05 volts / cell instead of battery life 4. Well on 20 volts / cell. This makes the pressure that is directly related to the voltage less, which makes the battery life longer, in some portable devices there is a base that has an operating position. The current drawn through the device and called the parasite can distort the charging cycle.

Therefore, battery manufacturers advise against parasitic loads during the charging process because they the action incites a small rotation. This cannot be avoided as this laptop is connected to the main AC power. The battery can be charged up to 4.20 volts / cell, and then it is discharged through the device. The battery pressure level is high because the cycles occur at high voltage thresholds and at elevated temperatures.

It is preferable to stop the mobile device from operating when charging, because this makes the battery reach the specified voltage in addition to the saturation point and the parasitic load confuses the charger by preventing the saturation from falling well by pulling the leakage current and by pressing the battery voltage When the battery is fully charged, sometimes the charging continues due to some circumstances, which increases the stress a lot.

4.1.20.7. Lithium-Ion Battery Charging but Without Mixing the Cobalt with It

The Li-ion battery has a cell voltage of approximately 3.60 volts, but LiFePO (LiFePO) excludes the nominal cell voltage of 3.20 volts and charges to 3.65 volts. Li-titanate (LTO) stress is approximately 2.40 volts and charges to 2.85 volts. Non-cobalt ion chargers with standard 3.60 volt lithium ions do not correspond together. Chargers must be provided in order to select the systems and to provide the correct charging voltage.

The 3.60 volt lithium battery, if a charger designed for lithium phosphate is used, it will not be able to receive a sufficient charge. It is possible that the lithium phosphate battery if the regular charger is used will cause an overcharge. Li-ion overcharging safely performs its work within a specified operating voltage; but one of the disadvantages of overcharging is that the voltage becomes above the specified voltage and thus the battery becomes unstable.

Extended charge up to over 4.30 volts on Li-ion designed for 4.20V / cell and plate and metallic lithium cell on the anode, as the cathode material transforms into an oxidizing agent, making it unstable and producing CO2. The cell pressure will gradually rise if charging is allowed to continue, the CID device responsible for cutting cell safety at 1,000-1,380 kPa (145-200psi). If the pressure increases further, this opens the safety film of some lithium-ion bursts at around 3,450 kPa (500 psi) and the cell may eventually explode in flame.

Connecting the torch to a higher temperature is called venting, and with this process the temperature of a fully charged battery is generally lower in addition to that it breathes faster than a partially charged battery. All lithium batteries today are safe and cost less, which is why authorities will charge the air charge of Li-ion at 30 percent of the state of charge instead of fully charging. Li-cobalt threshold at fully charged is 130-150 °C (266-302 °F); Manganese-Nickel-Cobalt (NMC) is 170-180 °C (338-356 °F) and Li-manganese is about 250 °C (482 °F).

Li-phosphate has similar and better temperature stability than manganese. The lithium-ion battery is not the only battery that is not considered safe in the case of overcharging. Batteries of both types of nickel and lead have melting property, which makes them dangerous and may cause fire if not handled properly. Properly designed charging equipment is important for battery sensor systems as well as for temperature [41]. Li-ion batteries have excellent performance.

In order to reach its best, it must be shipped safely. As the lithium-ion battery works badly in the wrong way, which causes a bad charge to damage it, so it must be accurate. And if charged in a proper way, it makes the battery life and service longer, so charging with the battery management system. It controls discharge, the level of charge and the rates at which it can occur.

4.1.20.8. Basics of Lithium-ion Battery Charge / Discharge

Lithium-ion battery charges are completely different from those of other batteries such as NiMH or Ni-Cads. The charging of lithium-ion batteries is sensitive to current and voltage. Much like charging lead acid batteries. We must not overlook that lithium-ion batteries cannot handle overcharging.

Therefore it is important to accurately discover the charging state, as these batteries have a high voltage in all of their cells, and once fully charged requires you not to allow the battery to float, consumers direct the charge of lithium-ion batteries to a voltage of 4.2 volts / cell, which means that they carry about 50 volts per cell. Because charging after this percentage causes pressure on the cell, which causes its oxidation and thus reduces its service life and capacity in addition to safety problems.

First and Second Stage in Charging Lithium-Ion Batteries

The First Stage

The charge current should be greatly controlled. It is approximately between 0.5 and 1.0 °C. For a 2000 mAh battery, the charge rate should be approximately 2000 mAh versus a C charge rate. For consumer based LCO cells and batteries, a maximum charge rate of 0.8 °C is recommended. The phase voltage increases across the lithium ion cell for DC charge. The charging time might be around an hour for this stage.

The Second Stage

When the battery voltage becomes 4.2 volts the LCO cell. The battery becomes in the second stage of charging, which is charging saturation. The battery in it needs approximately two hours to charge and at this stage the voltage is maintained at 4.2 volts and then the current is gradually reduced until it reaches 10% of the current and the charging time varies depending on the charging efficiency, for example or type Cell, plus the manufacturer.

4.1.20.9. Lithium-Ion Battery Charging Precautions

When choosing a charger for a lithium-ion battery, whether it is a simple charger or a complex charger, the chemical structure of the battery and the amount of energy stored in it must be taken into account before charging, so that the most appropriate charging method for this battery can be chosen. Mechanism for discharging and charging the lithium-ion battery should be provided.

Today, researchers are trying to improve the performance of Lithium-ion batteries to meet the demanding requirements of electric vehicles. However, conventional commercial Lithium-ion batteries have several inherent drawbacks, all of which are related to liquid electrolyte [15].

First, the safety and durability of conventional Lithium-ion batteries are unacceptable. The spontaneous combustion or explosion of batteries in mobile phones or laptops attracted the public's attention. Reliability and tolerance of use in bad conditions become more important for the batteries of electric road vehicles, which often need to be operated in harsh conditions. Mechanical abuse (crushing, leakage, shock), electrical abuse (short circuit, overcharging, over discharge) or thermal abuse (overheating from external / internal sources) due to certain mistakes made from time to time or under conditions of abuse. may cause malfunction [42,43].

These conditions are particularly dangerous for a conventional battery due to the presence of highly flammable liquid electrolyte. These batteries; It tends to enter a dangerous state of “thermal runaway” as it triggers internal heat generated by the battery due to abusive environments, initiates a chain of exothermic reactions and reaches the required threshold temperature causing spontaneous combustion. At the same time, to prevent this leakage, the highly flammable liquid electrolyte must be well sealed in a hard battery case, usually made of stainless steel. This may cause an increase in pressure. As a result, when thermal runaway occurs, an explosion can eventually ocur (Figure 4.26).

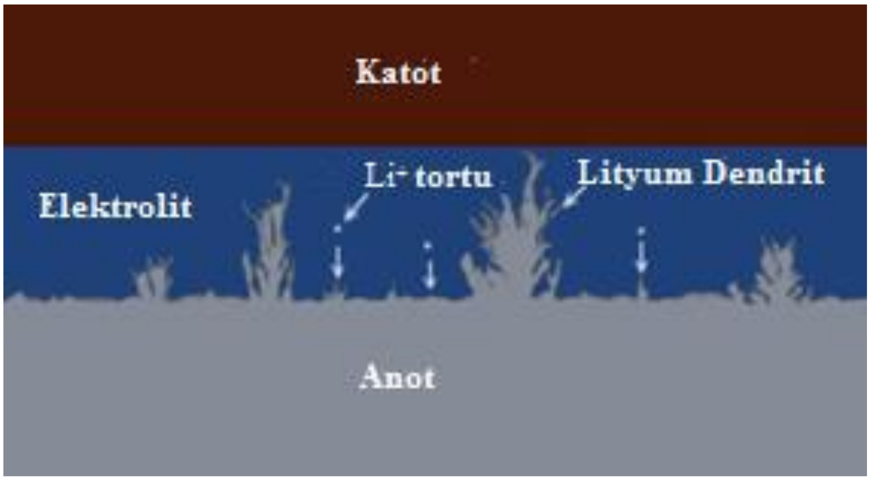


Figure 4.26. Schematic structure of Lithium dendrite growth [15].

Second, the liquid electrolyte limits the application of lithium metal as the anode material. Lithium metal is considered the "final anode material" because it is the most electropositive element against the standard hydrogen electrode. It can also provide approximately 10 times more (3800 mAhg-1) capacity than the carbon-based anode (372 mAhg-1).

However, dendrite growth of lithium metal prevents this change of liquid electrolyte Lithium ion batteries. In commonly used liquid electrolyte systems, the formation of lithium dendrites is caused by the inhomogeneity and interface imbalance between the liquid electrolyte and lithium metal, where the lithium ion deposition and dissolution processes are observed in an irregular pattern. The lithium dendrite nucleate is then produced from the lithium anode and continues to grow in a tree-like structure during the charging phase until the dendrite, polypropylene (PP) and polyethylene (PE) penetrate the separator and come into contact with the positive electrode. In this case, it creates a short circuit in the battery, which can cause the battery to malfunction, generate too much heat, and ignite the liquid electrolyte or explode the battery. Figure 2.2. Is the schematic growth of lithium dendrites [15].

The Charge Current in the Battery

The highest value is 0.8 °C, while the lowest value varies according to the type of battery, which explains why some batteries rely on the charging current on Li-ion batteries for faster and safer charging than others. As in, the charging temperature and the charging temperature of the Li-ion battery must be taken into account, and the cell or battery should not be charged when the temperature is below 0 °C or greater than 45 °C.

As the voltage increases, the charge must be protected from overvoltage’s so as not to get too high voltage across the battery terminals. The increase in voltage leads to a rise in the discharge current, which must be protected so that no explosion or damage occurs in the event of a short circuit.

Protection Called Reverse Polarity

This protection is very important because it protects the battery from explosion or damage. Regarding the lithium-ion battery, it checks the charging direction and stabilizes it so that it is not in the correct direction to avoid damaging the wrong charging direction. This circuit is used when the voltage in the cell or battery rises above 4.30V, and the overcharging has stopped. This over-discharge protection is absolutely necessary to prevent the battery voltage from falling below 2.3 volts, subject to the standards of the companies that produce it.

Prevent Battery Running When Overheating

One of the ways to protect the battery, if its temperature rises above 100 degrees Celsius, it must be stopped because it can cause great damage and cannot be bypassed and repaired, so the manufacturer's charger must be used because of the safety elements that the charger system works and the battery systems that follow the design.

Specifications for Discharging Lithium-Ion Batteries

It is distinctive as this battery can withstand 1000 cycles of discharging and charging in addition to maintaining 80% of its initial capacity. The process of discharging or charging a lithium-ion battery is one of its most distinctive features as it reveals its long-term performance, because the battery packs are integrated with battery management chips, and thus manage the charging and discharging process, and thus it is possible to put the battery in the charger and leave it until it is charged) [44].

Lithium-Ion Battery Charging Instructions

The charging of lithium-ion batteries, as it works to accommodate current and voltage restrictions, which affects the battery life and becomes more durable, in addition to that this battery does not need saturation, and it is possible to carry out intermittent charging, and this can be done as well. The battery stores solar energy, wind energy, etc., and it is possible to fully charge the battery except for satellites or electric vehicles. To stop saturation, the device must be switched off, and the device should not be charged in the case of freezing, and the battery must not be full [41].

4.1.21. Non-Explosive Solid-State Lithium-Ion Batteries Using Solid Electrolyte

Today's current batteries contain these dangerous liquid electrolytes despite safety drawbacks, as their performance is unmatched. Liquid electrolytes should be replaced with non-flammable solid electrolytes to have a higher degree of safety of batteries [15].

When the battery breaks down and thus its energy is disrupted, in this case the car, whether hybrid or electric, becomes useless. Therefore, scientists, including Dr. Chu, a solid electrolyte polymer used mainly in its use in lithium ion batteries, so the liquid electrolyte is replaced in order to do a process of improving safety and improving Also battery performance [40].

A solid state battery is similar to a liquid electrolyte battery except in that it primarily employs a solid electrolyte. The parts of the solid state Li ion battery include the anode, cathode and the solid electrolyte. The anode is attached to copper foil, which helps improve the electrical conductivity of the battery. During the charging cycle, there is movement of the Li ions of the LiCoO2 crystal toward the electrolyte interface. As a result, the Li ions cross over to the carbon layers in the anode through the electrolyte. During the discharging cycle, the reverse process takes place, and the Li ions travel via the electrolyte toward the LiCoO2 particles. Figure 4.27 is a schematic diagram of a lithium based solid state battery. The curved arrows indicate the movement of the Li ions during the charging and the discharging process, respectively. The electrons produced due to the reaction are used to drive a load in the external circuit. The set of cathode and anode materials and their corresponding suitable electrolytes are also given in Figure 4.27, marked with matching colors [45].

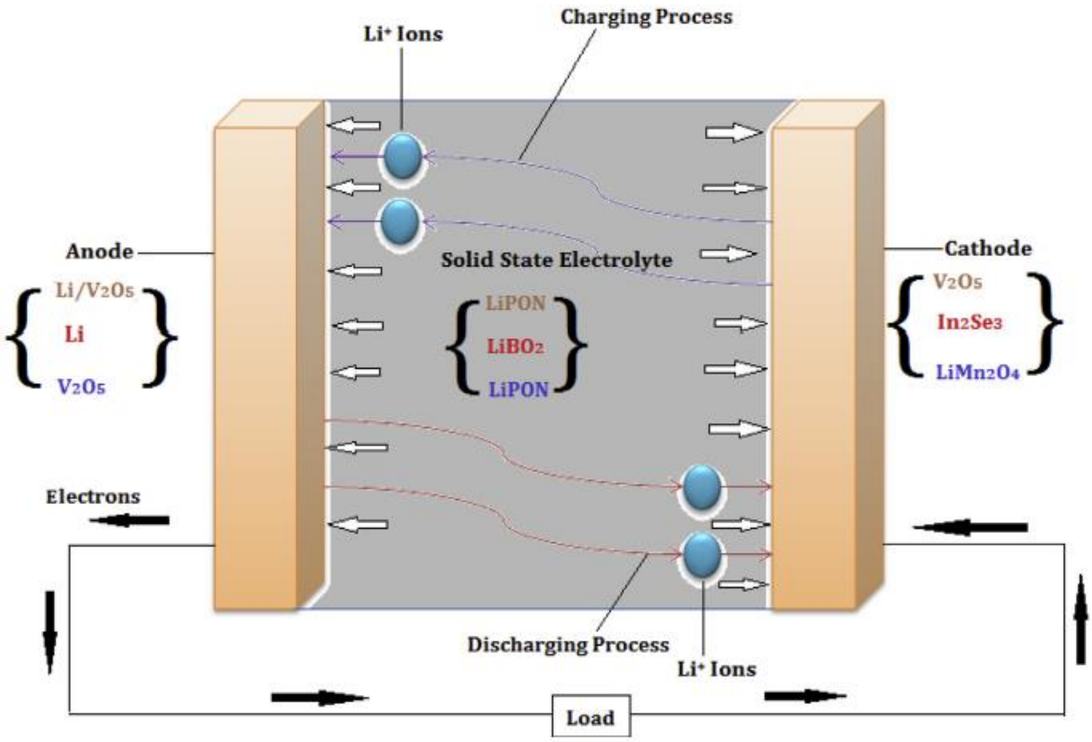


Figure 4.27. A Schematic representation of a representative Lithium based solid state battery, showing the direction of ion movement and some of the possible anode, electrolyte, and cathode combinations [45].

4.1.21.1. Bulk Solid State Electrolytes (Electrolytes at The Macroscale) and Thin Film Solid State Electrolytes (Electrolytes at the Nanoscale)

As the performance of a solid state battery depends on the diffusion of ions within the electrolyte, solid electrolytes are required to have high ionic conductivity and very low electronic conductivity and should exhibit a high degree of chemical stability. Crystalline materials such as lithium halides, lithium nitride, oxy-salts, and sulfides have been found to be good as solid electrolytes. The most favorable features of the solid electrolyte are that there is no corrosive or explosive leakage and the chance of internal short circuit is less, and hence it is safer. Solid electrolytes should have a sufficient number of mobile ions to enable conduction to proceed smoothly. Solid state electrolytes should therefore have enough vacancies in their crystal lattice to permit the ions to move, and the overall activation energy must be low.

Different types of solid state electrolytes have been employed, based on their configurations and electrode/electrolyte materials setups. Therefore, solid state electrolytes are broadly classified into two types, bulk solid state electrolytes and thin film solid state electrolytes. The primary distinction is on the degree of thickness of the electrolyte; thickness of bulk solid state electrolytes are usually in the range of several hundred micrometers, whereas that of thin film solid state electrolytes are in the range of hundreds of nanometers to several microns. Another primary area of difference between the two is the way they are fabricated: bulk solid state electrolytes are usually prepared by techniques such as mechanical milling, sintering and compaction, annealing and heat treatment whereas thin film solid state electrolytes are fabricated by pulsed laser deposition, spark plasma sintering, CVD etc.

Bulk Solid State Electrolytes (Electrolytes at the Macroscale)

Among the most commonly used solid state electrolytes are the solid polymeric electrolytes (SPE). The main aim while developing SPEs is to obtain ionic conductivities as high as those of liquid electrolytes.

Thin Film Solid State Electrolytes (Electrolytes at the Nanoscale)

The most commonly used thin film solid state electrolyte is the LiPON (lithiumephosphorus-oxy-nitride) electrolyte.

The solid-shaped electrolytes inside lithium batteries have not been marketed, because some drawbacks such as high interstitial resistance with electrodes and low ionic conductivity are not marketed. On the other hand, it is believed that the solid-shaped electrolyte has lithium-ion batteries because it has many advantages, including that it is non-flammable and because of its mechanical strength and makes the battery not easily fail, such as its use in electric cars [45].

4.1.21.2. The Most İmportant Advantage and Disadvantage of Solid State Lithium İon Battery

The most important advantage of solid state lithium ion battery is safety. The most favorable features of the solid electrolyte are that there is no corrosive or explosive leakage and the chance of internal short circuit is less, and hence it is safer.

Most of the challenges, disavantage for the solid state Lithium ion battery arise at the electrolyte-electrode interface. As the solid electrolyte is replaced by the liquid electrolyte; Solid particles are placed between the electrodes while making contact. Consequently, the contact is in point-contact between the electrodes, while the liquid electrolyte is in contact with the surface. Therefore, the channels through which the Li-ions are transferred are limited. As a result, large interfacial resistance is produced between the electrodes and the solid electrolyte, which prevents ion transfers and current [15]

4.2. NICKEL METAL HYDRIDE BATTERIES

Nickel Metal Hydride's battery is famous for its technology climate, as it powers everything from hybrid electric cars to cell phones [46]. The NiMH battery is considered as an electrochemical device for basic consumer storage [47]**.** The widespread use of electric cars sometimes affects air. Air quality and energy independence. The efficient battery is an important technical component in making corrosion resistance.

In addition to the great potential for hydrogen storage in solid hydride batteries as it has a high energy density to long life, wide temperature range and multi-operation, and fast charging capacity, thus it has a described maintenance free operation. Knead that it has a wide core of multi-characteristic metal hydride materials that use great structural excitation in several gauges, which are used as negative electrodes in this battery. The battery also works at normal temperature and can be recycled for technology. A fast charging capacity is described and it is generally airtight.

As a process without all kinds of maintenance. For this purpose, a large number of metal hydride materials that have multiple elements in structural disturbances are used. It can also be installed on multiple gauges along the battery with negative electrodes [46]. The NiMH battery has grown and developed significantly compared to the lithium battery in its life and development. Because of its extraordinary life cycle and its specific energy [47]. In order to carry out the process of improving the operation efficiency of vehicles, some energy must be used to operate the vehicle, which is important and necessary to reduce greenhouse gas emissions [48].

Reasonably specific strength and exceptional life cycle make nickel hydrogen batteries attractive and good for use in aerospace applications. However, nickel-hydrogen batteries do not have high efficiency. On the contrary, they are considered to be of high quality. Low volumetric efficiency [46]. The use of electric energy with gasoline to implement the use process in the vehicle's traditional internal combustion engine, to obtain power above average power, which is necessary for the car.

An integrated energy storage system is therefore required, and batteries such as Li-ion and NiMH have been shown to contain efficient storage devices. The exceptional life cycle and its specific energy are good, so that electric energy can be used, to meet the increasing demand for medium energy needed by the car. This requires a parallel energy storage system. Nickel-hydrogen batteries are ideal for use in heavy vehicles that require strength and density. Nickel-hydrogen batteries have poor volumetric efficiency and require tanks of compressed hydrogen gas and platinum catalysts .A technically important reason is that the NiMH battery with an alkaline storage battery is due to the use of potassium hydroxide (KOH) as an electrolyte [46].

Nickel Metal Hydride battery allows high conductivity and high power applications:

- Battery system, longevity and initial cost can be specified.
- Design is focused on minimizing maintenance defects and energy leakage. The operating temperature is in the range of increased longevity and the initial cost is high in relation to the ideal technology.

- To obtain the energy density, NiMH batteries were developed to meet the market demands, such as recyclable batteries, high energy density and long life.

Which needs high currents and a deep discharge of a battery, which contains the electrolyte, which is a liquid solution of potassium hydroxide, as the conductivity rates are high, so the cell reaction needs to be greatly increased. This results in the electrolyte (cell resistance) in a stable plane in the full charge range of the charging or discharging mode, which results in the battery operating in high performance and longer life. Also, the electrolyte concentration is constant because it is essential in cell resistance, and this stability continues throughout.

In a NiMH battery, the active substances are metal oxides that, if charged, become good conductors and metallic compounds. Nickel oxide - a hydroxide electrode that exchanges the boron to discharge and react the charge and then transfer the electron very quickly, which contributes to a high energy capacity. A slight change in the electrode size between the charge and then the discharge increases the mechanical stability, resulting in a longer life cycle. Also, NiMH batteries can be sized from any tens of mAh that run hundreds of hours or more.

Steel is compatible with the electrolyte. Some systems have been successfully implemented to store energy for many different applications from infection transmission to stable backup power through the use of NiMH technology. This diversity always leads to new applications for NiMH batteries where environmental factors and performance are extremely important [46].

NiMH battery is alkaline storage as it uses potassium hydroxide (KOH) as the electrolyte. NiMH battery is electrically similar to cadmium nickel batteries, it has memory effect, it is not charged when the battery is half-discharged. Because, the battery charges forward from this point it keeps in its memory. This decreases the capacity of the battery. Therefore, NiMH batteries are first discharged and then charged.

Rechargeable Alkaline Storage Batteries are a powerful and dominant player in the market for a variety of reasons and are technically important. Ni-MH battery developed by a number of scientists in recent years is considered one of the promising secondary batteries, and even more, this battery because high capacity and high energy density in addition to environmental acceptability.

The electrode is the negative electrode in this type of battery, and hydrogen is stored in place of gas pressed into alloys such as nickel hydrogen batteries. Thus the pressure in the batteries is greatly reduced. A number of soft mineral terrestrial compounds have been found using general AB5 or AB2 formulations to absorb and release large amounts of hydrogen quickly and backward [49].

4.2.1. Definition of Terms in the System is Here: Primary, Secondary, Voltage

An electrochemical cell consists of a chemical reactor in which there is an electrical conductor and the reactants combine with it in a specific, controlled manner to produce a continuous flowing electrical current.

- **In a Primary**

It is not possible to reverse the interactive battery in general or the cell; That is, after the discharge is complete, it is not possible to recharge the battery or cell by doing the provision of current and that is in the opposite direction, or it can be recharged to a very small portion of the initial amount of energy available from the first discharge due to the inability to measure the opposite of reactions Chemical inside the cell. Batteries are generally used once, and are then replaced with new cells or a new battery.

- **A Secondary**

The battery or cell contains a group of chemicals that allow reverse interaction with the discharge when a charge current is provided for the cell, resulting in that after the discharge process it is possible to return the cell to what it was from the original amount of energy and this happens by Doing the charging current in a specific way. The discharge and charging activity may occur for several thousand cycles. It depends on the specific battery technology.

- **The Voltage**

The output of the pressure or electrical voltage produced by the electrochemical cell on the types of chemicals that participate in a number of reactions, while the energy depends on the nature and quantities of chemicals that make up the cell and is calculated in watts per hour per watt. The ability of a cell to carry out an energy saving process (in watts (current x current)) is determined by several factors, including cell structure, chemical composition, temperature, etc.

It can be said that the battery consists of a group of electrochemical cells connected in series to reach the highest voltage. For convenience, at first, a specific cell is called, then the addition to the parallel cells and a connected chain connected to the battery as it is usually known when in use. Batteries can also be indicated by boosted voltage and cell chemistry.

4.2.2. The Contents of the Basic Electrochemical Cells

Anode is the electrode in which oxidation can occur and this is done by feeding the electrons and this feeding begins from inside the cell to the outer circle. The cathode is the electrode where the reduction occurs, and then the electrons return in a backward movement as they begin to exit from the outer circle into the cell. These names differ in the secondary and primary cells.

In the primary cell, the anode is the cathode and cathode. In the secondary cell, in the charge it is negative or when it becomes so, the positive electrode becomes the positive electrode and the negative electrode becomes the negative electrode. This is because the roles are reflected in a secondary cell, the electrodes will be indicated as negative or positive (never changing) either with respect to the current direction of flow, whether branching or charging is determined.

Electrolyte transfers ions from one electrode to another and act as a pathway to complete the electrical circuit inside the cell. The active substance is a liquid, gas or solid, and this substance reacts to form the electrodes, and the electrolyte may be a solid or liquid (Figure 4.28).

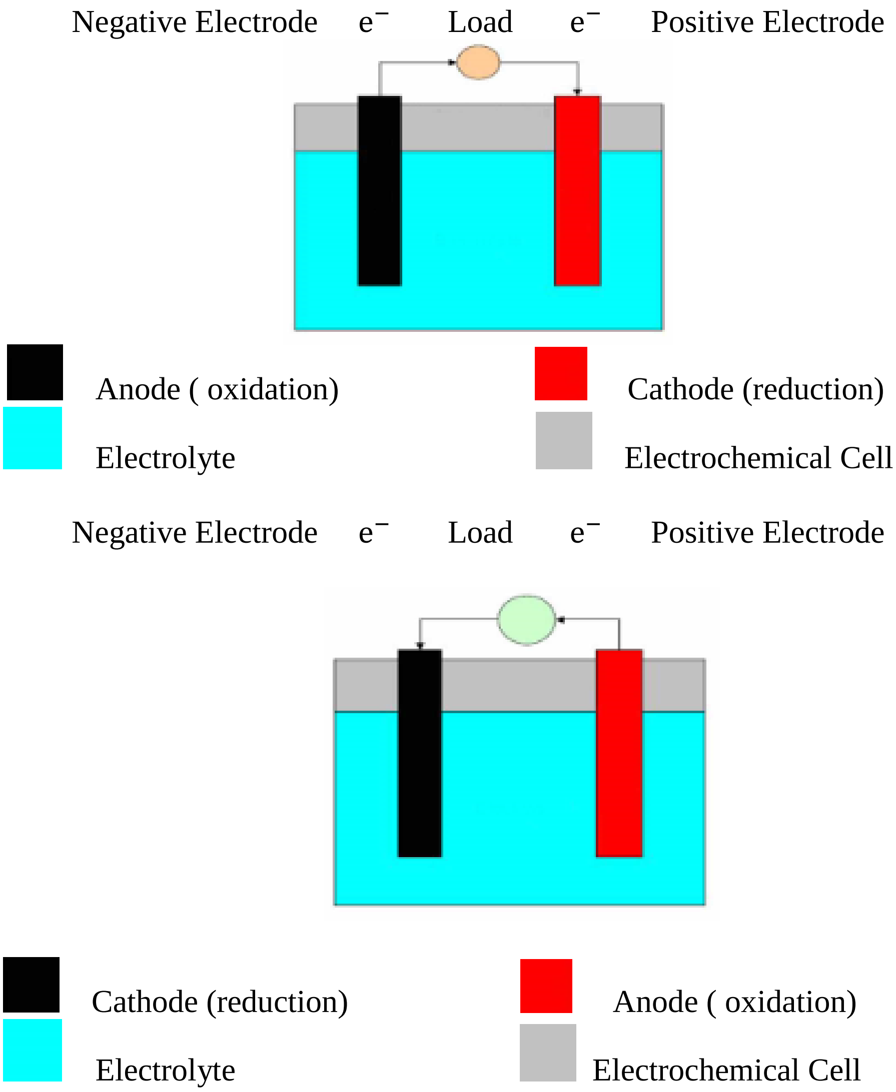


Figure 4.28. Electrochemical cell schematic [46].

From Figure 4.28 it is shown the diagram of an electrochemical cell for discharge and charge. Electrical components must be connected electronically. Most of the compounds used in positive active substances are in particular oxides in conventional batteries with poor conductivity of electricity, and therefore must be supported or integrated into networks or connected vehicles.

With additives to the electrode materials and the structure or mesh of the electrode plate are made of multiple materials, including lead, graphite, copper, nickel and copper. Electrolyte - It must be an ionic conductor. Separator - Provides physical isolation between the electrodes to prevent shortening and separation of electrode interactions from one another. To knead it must have the ability to contact ions through the housing to allow the current to flow. So the package - contains the electricity, all the battery electrodes, the vents, the terminals, etc. [46].

4.2.3. Positive Electrode

The positive electrode of the NiMH type battery is nickel hydroxide. It is an electrical material that has been developing enormously nearly 100 years ago and contains the same combination of NiCd type batteries. Alkaline batteries that are made of nickel are considered attractive, and the nickel electrode is manufactured in large areas and shallowly in order to perform its work in the event of high current and density. The electrolyte does not enter into the interaction of the so-called electrode so that the conductivity remains at a high level along the capacitance that is suitable for use of the battery.

Also, the active nickel cannot dissolve in the electrolyte (KOH) and this leads to better tolerance to abuse and a longer life. The proton participates in the discharge / charge reaction only and this leads to an improvement in the mechanical stability of the electrode during its rotation and small changes in density. The gravitational energy, density and good size of the nickel electrode [23]. The simplified nickel electrode reaction in the cell:

$$\text{Ni}\ (\text{OH})_2 + \text{OH}^- \frac{\text{charge}{-}{-}>}{<{-}{-}discharge}\ \beta\text{-NiOOH} + \text{H}_2\text{O} + \text{e}^- \quad (4.7)$$

β-NiOOH : is alow conductivity p - typ semiconductor when nickel valence is < 2.25.

Oxidation states if nickel >3 have been determied to be present (i. e. k $(NiO_2)_3 \rightarrow Ni^{3.67+}$).

Transformattions of the NiOOH occur in the KOH solution. Actual reaction is complex and more complicated:

- Uneven nickel electrode.
- In the solid state, protons propagate through interaction in this case.
- The effect of additions to the electrode is achieved by transferring the crystal structure of the electrode and the charge.

4.2.4. Negative Electrode

The active substance of a negative electrode in a NiMH type battery is actually hydrogen, similar to a nickel hydrogen battery, but with a slight difference that hydrogen ions (protons) can act as an electrode in addition to being stored in a structure. Depending on its composition, the metal hydride can carry between 1% and 7% hydrogen in weight. As in the storage of hydrogen, because the metal hydride is very effective, it is efficient in terms of volume and is better than liquid hydrogen.

Practical materials today contain NiMH batteries containing approximately 1% to 2% hydrogen by weight. There are many primary metal hydride materials, although they are not considered in battery applications, because the balance of pressure is high, which makes these materials appear at room temperature. This can be changed if vehicles are developed between the minerals that collect the weak and strong hydride formation materials.

This is done by achieving the metal hydride in order to achieve the required balance pressure and in addition to the chemical properties by adjusting the ratio between these two types of materials and their components. Compounds between metal are alloys of two or more elements to metallic elements with narrow ranges of integral numerical integers, compounds are divided into a number of groups classified by Ax By based on their crystalline structure and composition (Table 4.6).

The components A and B consist of a number of multiple compounds in several domains in a parabola. The variety of metallic hydride components provides for designing materials with desired and desired properties for use in battery applications, for example, low equilibrium pressure, mechanical persistence, corrosion resistance and the ability to store hydrogen and reflection, among others).

Table 4.6. Mineral materials and chapters [46].

A,B Calss (Basis)	**Components**	**Storage Capability (MA/G**	**Comments**
$\mathbf{AB_5}$ ($\mathbf{Lani_5}$)	A: Mischmetal. La,Ce,Ti B: Ni,CO,Mn.Al	300	The most used alloy range for NiMH battery applications
$\mathbf{AB_2}$ ($\mathbf{Tini_2}$)	A: V,Ti B :Zr,Ni,(+Cr, Co,Fe,Mn)	400	The multi-component alloy basis used in some NIMH battery systems
AB (Zrni)	A : Zr. Ti B :Ni, Fe, Cr,V		Used in the early development of hydrogen storage
$\mathbf{A_2}$B ($\mathbf{TI_2}$NI)	A: Mg, Ti B: Ni		

Capacity NiMH batteries and their uses are either AB2 or AB5 metal hydride alloy for the cathode. The feedback on the cathode can be written as:

$$M + H_2O + e^- \frac{\text{charge}-->}{<--discharge} MH + OH^- \quad (4.8)$$

Where, M represents the metal hydride material.

The common complete cell reaction can be written as:

$$M + Ni(OH)_2 + H_2O \underset{<--discharge}{\overset{charge-->}{\rightleftharpoons}} MH + (\beta - NiOOH * H_2O) \quad (4.9)$$

The whole cell of the NIMH battery is schematically represented in (Figure 4.29).

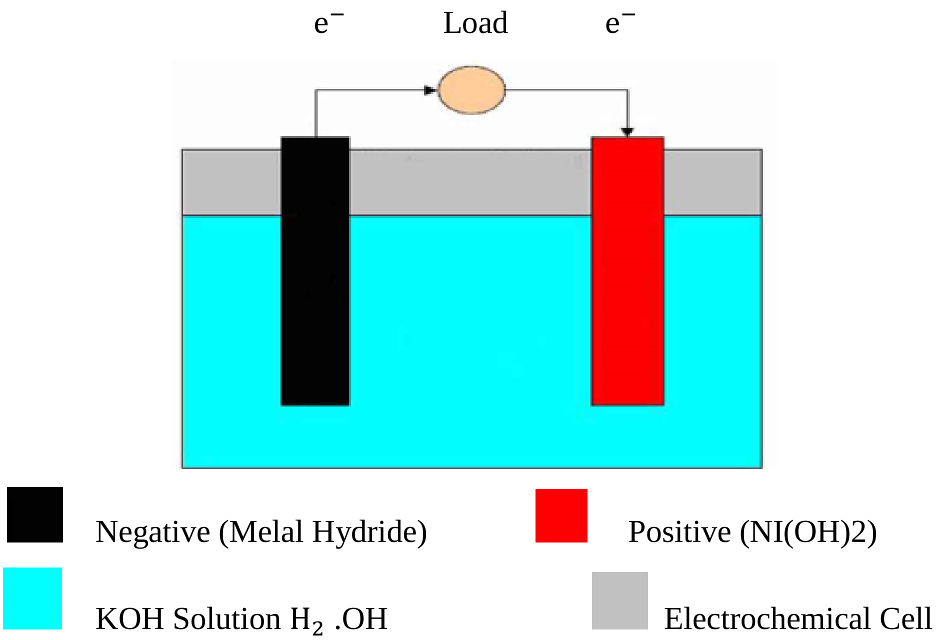


Figure 4.29. The NIMH cell [46].

4.2.5. Charge and Discharge Characteristics

Figure 4.30 shows a typical charge and discharge curve for the NiMH battery. NiMH DISCHARGE FEATURE The NiMH battery consists of a number of reactions in the case of discharge and overcharging that allow the battery to handle in the event of misuse without any harmful effects, and this is called the oxygen cycle of overcharging. When the battery is overloaded as it has a hydrogen cycle.

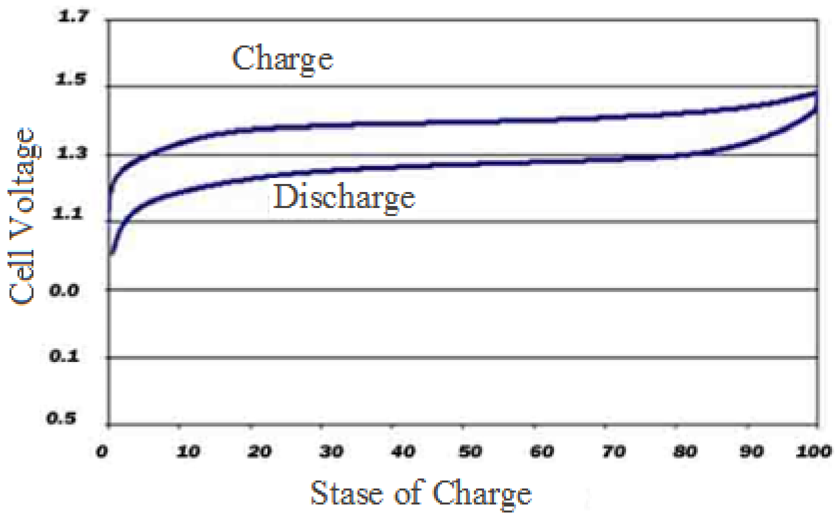


Figure 4.30. NiMH charge discharge characteristic [50].

4.2.6. Oxygen Cycle Functions as Follows on Overcharge

This type of battery has no reaction, it only generates heat and is equivalent to an increase in cell pressure and energy input.

For the positive electrode:

$$4 \times OH^- \rightarrow 2 \times H_2O + O_2 + 4 \times e^- \quad (4.10)$$

For the negative electrode:

$$2 \times H_2O + O_2 + 4 \times e^- \rightarrow 4 \times OH^- \quad (4.11)$$

The hydrogen cycle worked as follows when the discharge was increased:

For the positive electrode:

$$2 \times H_2O + 2 \times e^- \rightarrow H_2 + 2 \times OH^- \quad (4.12)$$

For the negative electrode:

$$H + 2 \times OH^{-} \_2 \times H\,O + 2 \times e^{-}\ 2\ 2 \qquad (4.13)$$

The end result is not a reaction but rather a pressure in the cell by generating heat. In the event of an excessively high charge, the cell is compressed enough to cause the safety hole to open as well as to release additional pressure, thus avoiding the risk of cell rupture. The NiMH battery packs the power to save large amounts. It also depends on requirements such as application and design, with 200 products / kg available for some specific products and more than 1000 W / kg of Cobasys NiMH products available.

NiMH batteries also have a linear resistance to charging and discharging in any given SOC, which makes them embodied in battery types and simple applications as in electric vehicles and other applications. One of its high energy characteristics. NiMH batteries have a cycle life of over 80% of deep discharge and discharge cycles. In applications such as hybrid electric cars that use shallow drain cycles 200,000 to 300,000 cycles have been achieved.

4.2.7. Advantages of NiMH Batteries

4.2.7.1. Energy Density

Patented in 1986 for the NiMH battery. As for the negative cell, which is nickel metallic hydride, in the seventies it became used as an alternative energy source, as if the alloys were chosen accurately and appropriately, they could be dynamically balanced. Recently, NiMH batteries have become used in high-voltage automotive applications. Energy density is the amount of energy stored per unit volume of the battery. Energy density of NiMH batteries is high.

4.2.7.2. Power Density

Power density is the power obtained by the battery per 1 kg battery. Power density is inversely proportional to the Energy density. Some batteries have very good specific energy but low specific power. This means that they can store a lot of energy, but deliver it very slowly. If you want to travel a long distance with an electric vehicle, the vehicle should be used at low speed.

Li-ion and NiMH batteries can actually carry the same amount of energy, but with the slight difference that lithium-ion cells can be charged and discharged more quickly. Li-ion does not have a degree of "memory effect" either, which usually happens when the battery is recharged before it is completely discharged, which makes the battery capacity low, Li-ion batteries are less affected by the memory effect than NiMH batteries.

4.2.7.3. Safety

When the operating temperature range of NiMH cells is expanded to more than 100 °C (-30 °C to + 75 °C) which is well above the temperature range that can be produced by lithium cells, NiMH technology is ideal for use in the automotive industry. NiMH is able to handle high energy levels typical in EV applications, and active chemicals behave safer than lithium cells and NiMH batteries are undesirable for complex battery management systems (BMS) with lithium batteries.

- High energy density (W/kg), about 50% better than Nicads, but only about 60% of Lithium ion. Low internal impedance though not as low as NiCads Typical cycle life is 3000 cycles.
- Can be deep cycled. (80% to 100% DOD) Using NiMH batteries, more than 3000 cycles at 100 % Depth of Discharge (DOD) have been demonstrated. At lower depths of discharge, for example at 4 % DOD, more than 350.000 cycles can be expected.
- Robust - NiMH batteries also tolerate over charge and over discharge conditions and this simplifies the battery management requirements.

- Flat discharge characteristic (but falls off rapidly at the end of the cycle) Wide operating temperature range Rapid charge possible in 1 hour Trickle charging cannot normally be used with NiMH batteries since overcharging can cause deterioration of the battery. Chargers should therefore incorporate a timer to prevent overcharging.
- Because of potential pressure build up due to gassing they usually incorporate a re-sealable vent valve Reconditioning is possible.
- Environmentally friendly (No Cadmium, Mercury or Lead) Much safer than Lithium based cells in case of an accident or abuse due to the use of more benign active chemicals, a particularly important property in high power and automotive applications.

4.2.7.4. Applications and Costs

About half the cost of lithium-ion batteries [51]. With no time-saving potential for lithium cells in the market, due to their low cost and consumption applications, they are provided for use in electronic devices such as electric razors, telephones, cameras, portable medical devices, car batteries and high-power stationary applications such as (telecommunications, UPS, smart phones).

4.2.7.5. Capacity

NiMH saves energy significantly and almost 30% more than NiCad if it is the same size. The comparison is usually done through the standard, as an alternative to NiCad which is characterized by large capacity. Some NiCad cells provide some of them that are characterized by high capacity. A certain level of energy is close to the level of NiMH. But NiCad high capacity batteries cannot provide large and high current for example standard Ni Cad batteries. In addition, it is considered to be the least durable course number, although it has a long service life advantage over NiMH batteries [46].

Research into metal and nickel hydride began in 1967. As the metal hydride led to the development of hydrogen and nickel, then a new hydride was discovered in 1980. The battery is more sophisticated and sensitive than cadmium and nickel. Power transmission batteries are used to achieve the required service life and durability. Thus, NiMH has become one of the most easy to recharge batteries as well as a low cost for mobile devices. Generally, the charging voltage ranges from 1.4 to 1.6V / cell. However, the constant voltage charging method cannot be used for automatic charging.

Because when doing fast charging, to avoid overcharging and damaging their cells, it is recommended to charge NiMH cells with a smart battery charger, so the Ni Cd charger is not different from the automatic NiMH charger [52]. The implementation of the development of high-performance traction batteries is a major issue leading to future market acceptance by both hybrid and electric vehicles. Also, the Ni-MH system is the most promising battery system for electric cars to the Li-ion Cell Battery (Li-ion), so Ni-MH batteries have already spread in the global consumer market.

High durability and design flexibility, makes the Metals better battery and system ideal for filtering in a full range of battery applications ranging from small consumer cells to large traction batteries. Because it has a high capacity for charging and discharging, the Ni-MH system is the ideal battery system for use in hybrid cars. This paper describes Ni-MH batteries and high performance Li-ion cells for electric traction applications [53].

The differences between Li-ion and NiMH batteries are clear, that Li-ion batteries are made from highly reactive lithium and carbon, because much energy can be stored. The nickel hydrogen batteries are used to store energy, in addition to keeping nickel and other metal, for example, titanium cover on the hydrogen ions. So with these many different structures, there are also many practical differences.

4.2.7.6. Cost

Nickel batteries are, for the time being, the least expensive technology. The savings in it has a fundamental role because of the increase in the production of lithium ion cells, so it is assumed that the cost of lithium ion cells will decrease. In the beginning, the cost is higher in the case of demand for the first time and when the increase in manufacturing costs are lower on the factory in relation to these batteries.

4.2.7.7. Durability

These two types of batteries are both durable and have been used for several years in many different applications, the NiMH battery has an advantage. Some lithium-ion batteries do not last for a long time in the event of very high temperatures, especially in some with a very hot climate. Therefore, the manufacturers paid attention to the process of improving the chemistry in order to manufacture other lithium-ion batteries that will last as long as the vehicles have energy [54].

The production of lithium-ion beams for specific and well-known applications causes them to greatly exceed the energy density of a commercial equivalent. Unfortunately, this superior capacity of lithium-ion batteries is considered unsafe if used in the hands of the public in addition to its high price, which makes them out of the reach of the commercial market. NiMH has a very high energy density which is higher than NiCd but with a low life cycle. NiMH toxic metals are not among its contents.

The lithium-ion battery system is the fastest growing. Where lithium-ion is used where the weight is light and the energy density high, but protection must be provided to ensure consumer safety. Applications include mobile phones and laptops.

Li-ion Polymer (Li-Ion Polymer) has many advantages of Li-ion in its simplified packaging and ultra thin engineering. The main applications are mobile phones. It compares the characteristics of two commonly used rechargeable battery systems in terms of life cycle, energy density, cost and exercise requirements. These figures are based on the average rating of commercially available batteries at the time of publication (Table 4.7) [40].

Table 4.7. The characteristics of the two most commonly used rechargeable battery [40].

	NiMH	Li-ion
Gravimetric Energy Density(Wh/kg)	60-120	110-160
Internal Resistance (includes peripheral circuits) in mΩ	200 to 300[1] 6V pack	150 to 250[1] 7.2V pack
Cycle Life (to 80% of initial capacity)	300 to 500[2,3]	500 to 1000[3]
Fast Charge Time	2-4h	2-4h
Overcharge Tolerance	low	very low
Self-discharge / Month (room temperature)	30%[4]	10%[5]
Cell Voltage(nominal)	1.25V[6]	3.6V
Load Current - peak - best result	5C 0.5C or lower	>2C 1C or lower
Operating Temperature (discharge only)	-20 to 60°C	-20 to 60°C
Maintenance Requirement	60 to 90 days	not req.
Typical Battery Cost (US$, reference only)	$60 (7.2V)	$100 (7.2V)
Cost per Cycle(US$)[11]	$0.12	$0.14
Commercial use since	1990	1991

4.2.8. Disadvantages of NiMH Batteries

To raise the level of the nickel-hydrogen (NiH2) cell in the NiMH battery. The NiH2 cell is primarily used in space applications extensively, which has advantages in working on a large life cycle in addition to the required energy. However, it has disadvantages of the NiH2 cell which is the poor volumetric efficiency that requires hydrogen gas tanks, and it is also high cost due to the use of a stimulant such as platinum. Thus, a new good nucleus, such as the NiMH battery was explored using a similar metallic hydrogen storage system such as an electron.

Overwhelmingly, NiMH batteries are available in an application similar to Li-ion batteries, so high energy must be specified just as it is in electrical appliances and even in some hybrid cars. Although NiMH batteries are cheaper than lithium ion batteries, they have less specific power that leads to newer technologies that often use lithium ions. Other disadvantages of NiMH include high self-discharge (about 50% greater than wear and tear) and deteriorating performance if stored at elevated temperatures [55].

4.2.8.1. Weight

NiMH batteries are generally heavier by weight and larger in size than Li-ion batteries, which leads to weight problems for hybrid cars, because inertia in the car is overcome by battery power without where kind of help from the gasoline engine is even In the event that you travel a large number of miles and to the maximum extent of them. Operating the car with a lighter battery that has dense and high energy through the battery packs.

4.2.8.2. Low Cell Voltage

The Colombian efficiency of nickel metal hydride batteries can go up to 85% but it is usually only around 65% and reduce the charging speed although it is desirable for them. Also, the battery may be of high capacity, but it is not necessarily available because it may produce full power up to 50% DOD during application mode. When the cell voltage is increased only 1.2 volts, this means that many cells are needed to replace the high voltage batteries. Competitor lithium cells usually have 3 times the cell voltage (3.2V to 3.7V), and the power density is much higher [51]. The decrease in cell capacity and voltage of primary alkaline cells. Limited supply of the rare earth element lanthanum.

4.2.8.3. Negative Features of Current NIMH Batteries Cycle Count

It has a NiMH rating of only 500 charge / discharge cycles. Shallow vacuum cycles are preferred over deep vacuum cycles. In conjunction with the longevity of the battery is directly related to the depth of discharge. Also, fast charging NiMH produces a greater rated temperature when charged which requires more complex algorithms and calculations to fully recognize the NiCad when the temperature sensor is not available.

(Most NiMH batteries are currently equipped with an internal temperature sensor to aid in full detection charging.) NiMH also does not accept fast charging like NiCad; the charging time may be twice that of the NiCad. Diameter charging must be controlled more carefully than NiCad control.

4.2.8.4. Charging Characteristics

- Run down fully once per month to avoid memory effect.
- Do not leave battery in charger.
- Slow charging method: Constant current followed by trickle charge.
- Rapid charging method uses dT/dt charge termination.
- Use timer cut off to avoid prolonged trickle charge.

4.2.8.5. Memory Effect

NiMH batteries contain many components, including nickel hydroxide and a cathode, as well as an anode component of KOH, which is considered significantly milder than the chemicals used in competing lithium batteries. Like cadmium, nickel and cadmium batteries, they are subject to a "memory effect", to a lesser degree than batteries, but are more expensive than nickel batteries and cadmium batteries, but they are environmentally friendly.

4.2.8.6. Rechargeable Battery Features

- Internal resistance of a battery pack varies with cell rating, type of protection circuit and number of cells. Protection circuit of Li-ion and Li-polymer adds about 100mΩ.
- The life cycle focuses on the battery that requires regular maintenance. Failure to apply cyclic full vacuum cycles may triple the life of the cycle.
- The life cycle depends on the depth of discharge. Shallow drains provide more cycles than deep drains.
- The internal protection circuits usually operate 3% of stored energy per month.
- The commonly used value is 1.2V, and 1.25V is the open cell voltage. There is no difference between cells. It is just a classification method.
- Capable of high current pulses.
- It works on discharging only; the charging temperature range is more confined.
- Maintenance may be in the form of "equivalent" or "higher" charges.

4.2.8.7. Self Discharge

NiMH batteries have a certain level of self-discharge, which occurs when the battery is in rest mode. For a typical self-discharge feature of a battery unit in an electric vehicle available from Capacity (Figure 4.31). It indicates the factors that will contribute to self-discharge and includes the energy used by the oxygen cycle in highly charged situations.

Self-discharge contributed to the lean oxygen cycle which had a minimum of 70% in the charge state. Long-term contributions to self-discharging are caused by chemical ion shuttles that empty the cell continuously in an orbit shape that occurs over longer periods of time. The rate of self-discharge is highly dependent on the temperature of the cell, and higher temperatures are produced with higher self-discharge rates (Figure 4.31).

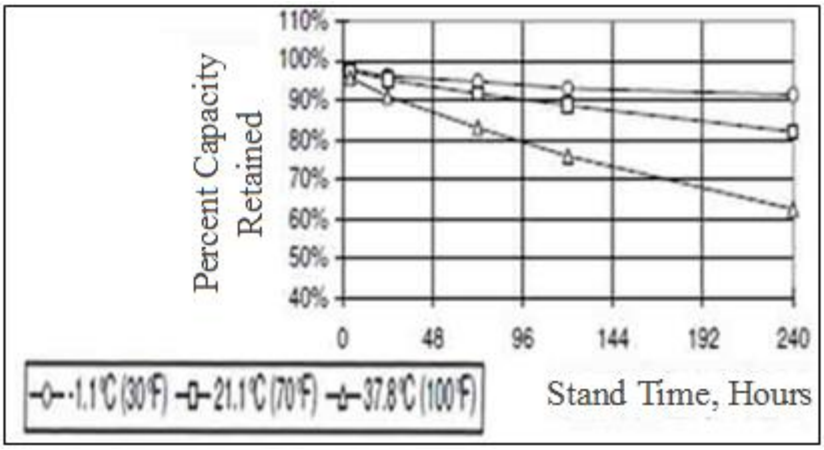


Figure 4.31. Capacity retention at several temperatures for NiMH EV battery [51].

4.2.8.8. Discharge Current and Self-Discharge

NiMH can produce much less current than NiCad. To achieve the best results, manufacturers recommend a load current of 0.2 °C to 0.5 °C. This deficiency may not be critical if the required current load is low. For applications requiring high power or pulsed load, such as GSM digital cell phones, portable transceivers, and power tools, NiCad is the recommended choice.

On the other hand, NiMH and NiCad are affected by reasonably high self-discharge. NiCad loses about 10% of its capacity in the first 24 hours, so self-discharge stabilizes at around 10% per month. The level of self-discharge NiMH is sometimes twice that of NiCad. Choosing hydride materials that improve hydrogen bonds to reduce self-discharge can also reduce battery capacity.

PART 5

COMPARE OF LITHIUM-ION AND NICKEL METAL HYDRIDE BATTERIES IN ELECTRIC VEHICLES

Batteries are installed in electric vehicles in a vertical or horizontal position, in different powertrain and driving configurations. In electric vehicles, batteries only store energy, they are the heaviest, most bulky and the most costly parts. A battery consists of two or more interconnected electrical cells. These cells convert chemical energy into electrical energy. Cells consist of positive and negative electrodes connected by electrolyte. The chemical reaction between electrodes and electrolyte is a chemical reaction that generates DC electricity.

Lithium-ion battery (LIB) has received considerable attention for traction uses due to the higher energy density (70-170 Wh/kg), power capabilities, lowest standard reduction voltage (Eo=-3.04V) and low atomic mass compared to previous battery technologies. Figure 5.1 shows the relationship between various types of secondary batteries in a Ragone plot. The required amount of energy stored in PHEVs and EVs is much higher than for HEVs in order to be able to travel long distances in all electric range. In the 2000s, the LIB are considered as one of the most promising solutions for environment-friendly transportation such as HEVs, PHEVs and EVs.

Lityum iyon pil (LIB), daha yüksek enerji yoğunluğu (70-170 Wh / kg), güç yetenekleri, en düşük standart azaltma voltajı (Eo = -3.04V) ve düşük atomik kütle, öncekine kıyasla çekiş kullanımlarında büyük ilgi gördü. pil teknolojileri. Şekil 5.1, bir Ragone grafiğindeki çeşitli ikincil pil türleri arasındaki ilişkiyi göstermektedir. PHEV'lerde ve EV'lerde depolanan gerekli enerji miktarı, tüm elektrik menzilinde uzun mesafeler kat edebilmek için HEV'lerden çok daha yüksektir. 2000'li yıllarda, LIB, HEV'ler, PHEV'ler ve EV'ler gibi çevre dostu ulaşım için en umut verici çözümlerden biri olarak kabul edilir.

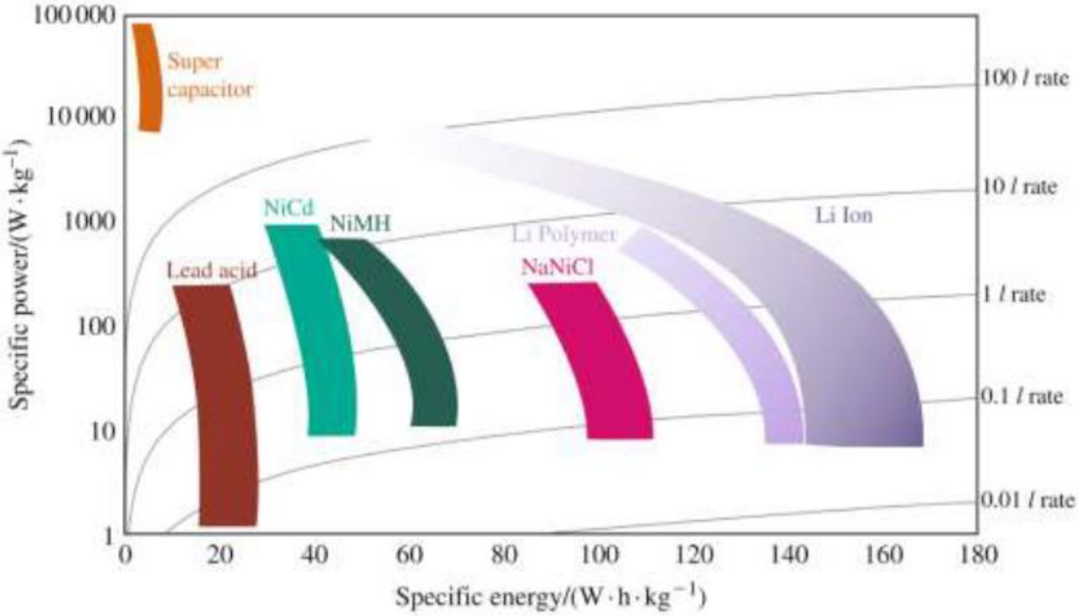


Figure 5.1. Specific energy and specific power of different battery types [56]

The most obvious advantage of lithium-ion batteries over NiMH batteries is the battery cell voltage. The charging characteristics of lithium-ion batteries or batteries are very good. The voltage generated by each Li-ion battery cell is approximately 3.6V. This has several advantages. Since it has a higher voltage than nickel-cadmium, nickel-metal hydride or even standard alkaline batteries (about 1.5 volts per battery) and lead acid (about 2 volts per battery), the voltage of each lithium-ion battery is higher, in many battery applications.

Lithium ion batteries such as high capacity charging and high capacity electrodes can operate at high enough voltage to improve the strength and density of the lithium battery, making it cheaper and smaller. There are several advantages to using lithium-ion batteries. As a result, this technology is increasingly being used in various applications. Everything in vehicles and many other applications.

High energy density is one of the main advantages of lithium-ion battery technology. Because electronic devices require batteries with a higher energy density to last longer. The high energy density afforded by lithium-ion batteries is a clear advantage. Electric cars also require high energy density battery technology.

NiMH batteries need to be prepared for first charge. One of the advantages of lithium-ion batteries is that they have no requirements, so they can be used at any time.

For a performance as high as an electrically powered vehicle, the discharge curve steadily decreases at some point in the discharge cycle with Peukert's large battery. The Li-ion battery is a replacement for NiMH battery for superior and high performance, because sometimes the flat discharge curve wants to provide a constant voltage saving process during the discharge cycle, but in spite of that the iron phosphate of lithium has a good effect on Biocert with a highly developed density.

The lithium-ion battery does not requirement maintenance to ensure its execution, and this is one of its most important advantages. Ni-cad cells require periodic vacuuming to ensure that they show no effect on memory. Since this does not have any effect on the Li-ion cells, maintenance measures are not required and the process to confirm the effect on memory is also unnecessary.

The main advantage of lithium ion batteries is that they can ensure their performance without active maintenance. NiMH batteries require maintenance.

A lot of the rechargeable battery's problem is the self-discharge rate. The self-discharge rate of lithium-ion batteries is much lower than other rechargeable batteries (such as Ni-Cad and NiMH batteries). The first 4 hours after charging is usually around 5%, but it drops to about 1-2% per month.

Several lithium-ion batteries are available. This feature of Li-ion batteries may mean that appropriate technology can be used for the specific application required. Certain forms of lithium-ion batteries can provide a high current density, making them ideal for electronic devices. Others can provide higher current levels that are ideal for power tools and electric vehicles. [37]. But Li-ion batteries and NiMH battteries are not flawless so it must be weighed with benefits before use.

The prevailing opinion is that batteries are the most advantageous solution for electric vehicles today and in the future. Ford, GM, Chrysler and others in the organization established by the US Department of Energy under the name of the United States Advanced Battery Consortium (USABC). Battery manufacturers are included. This consortium has set performance targets for medium and long term electric vehicle batteries. These targets are given in Table 5.1. These targets include power density, specific power. (depending on battery charge rate (SOC, State of Charge)), energy density, specific energy, lifetime, number of cycles and operating temperature, etc. has. Li-ion and NiMH battery characteristics are given in Table 5.2 [57].

Table 5.1. USABC long term battery goals [57].

Parameters	**Minimum Target Value**	**Long Term Goal**
Power density (W / L)	460	600
Specific power - 80% BBO / 30 seconds (W / kg)	300	400
Energy density - C / 3 at discharge rate (Wh / L)	230	300
Specific energy - C / 3 at discharge rate (Wh / kg)	150	200
Specific power / specific energy ratio	2:1	2:1
Battery pack size (kWh)	40	40
Lifetime (years)	10	10
Cycle life - Cycle 80% BBO	1000	1000
Selling price - 25,000 units @ 40 kWh ($ / kWh)	<150	100
Operating temperature - ambient (°C)	-40 ~ +50	-40 ~ +85
Normal charging time (h)	6	3~6
Fast charging time (h)	%20-70 BDO <30dk @150W/kg	%40-80 BDO 30dk
Continuous discharge within 1 hour (% over nominal energy capacity)	75	75

Table 5.2. Li-ion and NiMH battery characteristics [57].

Type	**Specific power (W / kg)**	**Energy density (Wh / L)**	**Specific energy (Wh / kg)**	**Cycle life (number of cycles)**	**Cost ($ / kWh)**
NiMH	150-300	130-170	60-70	600-1200	200-350
Li-iyon	250-450	140-200	90-130	800-1200	>200
Li-polimer	315	220	155	600	-

On the basis of goals of my consortium; Li-ion and NiMH battery systems used in electric vehicles and that can be used in the future have been compared (Table 5.3). In this comparison;

- For the "Cycle life - Cycle 80% BBO" parameter, the value of (600-1200) of the NiMH battery system and the value of (800-1200) of the Li-ion battery system and the value of (Long Term Goal 1200).
- For the specific power / specific energy ratio parameter, the value of (2:1) of the NiMH battery system and the value of (2:1) of the Li-ion battery system and (Long Term Goal 1200).
- For the "Specific power (W / kg)" parameter, the NiMH battery system's (150-300 W / kg) value meets (minimum Target Value: 300 W / kg), while the Li-ion battery system (250-450) (Long Term Goal 450 W / kg) with value.
- Other parameters are at the R&D stage.

Table 5.3. Compare of Important battery parameters for NiMH-Li-ion battery types.

PARAMETERS	**MİNİMUM TARGET VALUE**	**LONG TERM GOAL**	**NiMH**	**Li-iyon**	**Li-polimer**
Specific power - 80% BBO / 30 seconds (W / kg)	300	400	150-**300**	250-**450**	**315**
Energy density - C / 3 at discharge rate (Wh / L)	230	300	130-170	140-200	220
Specific energy - C / 3 at discharge rate (Wh / kg)	150	200	60-70	90-130	155
Specific power / specific energy ratio	2:1	2:1	2:1	2:1	2:1
Cycle life - Cycle 80% BBO	**1000**	**1000**	600-**1200**	800-**1200**	600
Selling price - 25,000 units @ 40 kWh ($ / kWh)	**<150**	**100**	200-350	>200	-

NiMH batteries were used in the battery system of electric vehicles. The main reason for this is that NiMH batteries have higher energy density than lead-acid battery system, as well as show little capacity reduction at low operating temperatures. In addition, when NiMH battery technology was developed before Li-ion battery technology, NiMH battery system was preferred in early period electric vehicles. Li-ion batteries have significant advantages over NiMH with their high cell voltage, energy density and short charging time (Table 5.4).

Table 5.4. Electric vehicles in the production line [16].

Producer	GM	Honda	Nissan	Nissan
Model Name	EV1	EV Plus	Hypermini	Altra EV
Drive Type	3 phase induction	SM senkron	SM senkron	SM senkron
Battery Type	**NiMH**	**NiMH**	**Li-iyon**	**Li-iyon**
Power (kW)	102	49	24	62
Voltage (V)	343	288	-	345
Battery energy Its capacity (kWh)	26,4	-	15	32
Charging connector	inductive	conductive	conductive	conductive
Speed (km/h)	129	129	100	120
Range	130	190	115	190
Charging time (hours)	6	6-8	4	5
Sale price ($)			36 000 $	

Based on these advantages of Lithium batteries, the cells are connected in series in order to obtain high voltage in the battery system that can be used in electric vehicles. On the other hand, serial cells must be connected in parallel with another series of cells in order to increase the capacity as well as the voltage increase. In this case, the design and operation complexity of the battery system increases. In the increasingly complex battery system, a good battery management system is required for good battery safety, battery energy management and battery thermal management [57].

The future of electric land vehicles largely depends on battery technology. The energy density of the batteries is measured in Watt-hours per kg weight or Watt-hours per liter. As can be seen from Table 5.5, the energy density of the batteries is much lower than gasoline and diesel fuel. For example, a 1300-1600 cc diesel fueled vehicle travels approximately 1000 km with a 60 lt tank and 60 x 0.86 = 52 kg fuel. A similar gasoline-fueled vehicle completes a range of 1000 km with 75 lt and 54 kg gasoline. However, with today's technology, a Lithium-Ion battery requires 180 kWh = 1200 kg Lithium-

Ion batteries for approximately 1000 km. Compared to gasoline, the energy density of the Lithium battery is about 50/1000 = 1/20 or 5%. R&D activities on battery technology are continuing and the expected increase in energy density in the future is shown in the table below. It has been shown that Lithium Ion batteries are more advantageous than Nickel Metal Hydride batteries in terms of specific energy (150 Wh / kg) and weight (1200 kg) [58].

Table 5.5. Energy density and weight for 1000 km range of Nickel Metal Hydride and Lithium Ion Battery Technologies [58].

Battery Type	Nickel Metal Hydride (Ni-MH)	Lithium - Ion (Li-ion) Today's Technology	Lithium - Ion (Li-ion) In the future Will occur Super Battery	Super Battery
Specific Energy (Wh / kg)	80	150	> 200	1500
Weight (kg)	2250	1200	< 900	120

PART 6

SUMMARY

The transition to cordless electric vehicles is successfully developed with NiMH and lithium batteries. However, NiMH batteries have disadvantages such as high weight, increased self-discharge due to temperature, low cell voltage. Similarly, lithium batteries may cause battery burning due to mechanical abuse (crush, leakage, shock), electrical abuse (short circuit with dendrite n, overcharge, over discharge) or thermal abuse (external / internal overheating), leakage failure, State lithium ion batteries using solid electrolyte have the disadvantage of poor performance due to point contact. There is no fusion of the disadvantages listed in batteries, the balance between cost, safety and performance, especially the work continues to make cathodes especially in Lithium-ion batteries. Among the cobalt, nickel, manganese and aluminum oxides and other materials, the most reliable materials are Iron phosphates. Li-cobalt threshold 130-150 °C (266-302 °F) at full charge; Manganese-Nickel-Cobalt (NMC) 170-180 °C (338-356 °F) and Li-manganese about 250 °C (482 °F); Li-phosphate is similar to manganese and has better temperature stability. The most widely used thin-film solid-state electrolyte, LiPON (lithium-phosphorus-oxy-nitride) electrolyte, which is the most commonly used contact with liquid electrolytes, in case batteries using non-combustible solid electrolytes of lithium-ion batteries, R&D continues on several Materials.

6.1. RESULTS & DISCUSSION

Ford, GM, Chrysler and battery manufacturers are involved in the organization established by the American Ministry of Energy under the name of the United Advanced Battery Consortium (USABC). This consortium has set performance targets for medium and long term electric vehicle batteries. This Monday, on the basis of goals of my consortium; Li-ion and NiMH battery systems used in electric vehicles and that can be used in the future have been compared. In this comparison;

- For the "Cycle life - Cycle 80% BBO" parameter, the value of (600-1200) of the NiMH battery system and the value of (800-1200) of the Li-ion battery system and the value of (Long Term Goal 1200).
- For the specific power / specific energy ratio parameter, the value of (2:1) of the NiMH battery system and the value of (2:1) of the Li-ion battery system and (Long Term Goal 1200).
- For the "Specific power (W / kg)" parameter, the NiMH battery system's (150-300 W / kg) value meets (minimum Target Value: 300 W / kg), while the Li-ion battery system (250-450) (Long Term Goal 450 W / kg) with value.
- Energy density - C / 3 at discharge rate (Wh / L), Specific energy - At discharge rate C / 3 (Wh / kg), Sale price - at 40 kWh ($ / kWh), MINIMUM TARGET VALUE and LONG-TERM TARGET not met, in R&D phase.

Research and development studies on secondary (rechargeable) lithium ion batteries are gaining value day by day with the increasing demand for electrical and electronic devices as well as the increasing importance of electric vehicles in the transportation sector. Lithium-ion batteries are preferred by environmentally conscious designers and consumers to examine the low level of CO_2 gas emission they provide in mobile phones, laptops and small household appliances, due to their high energy density and lack of health.

Lithium ion batteries are much lighter than NiMH batteries, their recharge density is at the highest level. Low weight in vehicles positively affects fuel economy and range.

It can be seen from the comparison was held between the Li-ion batteries and Ni-MH batteries in the Figure 6.1 and Figure 6.2 it can be seen that the Li-ion batteries are more favorable for customers than the Ni-MH batteries. So it has more economic and it has more power and more eco-friendly to environment [59].

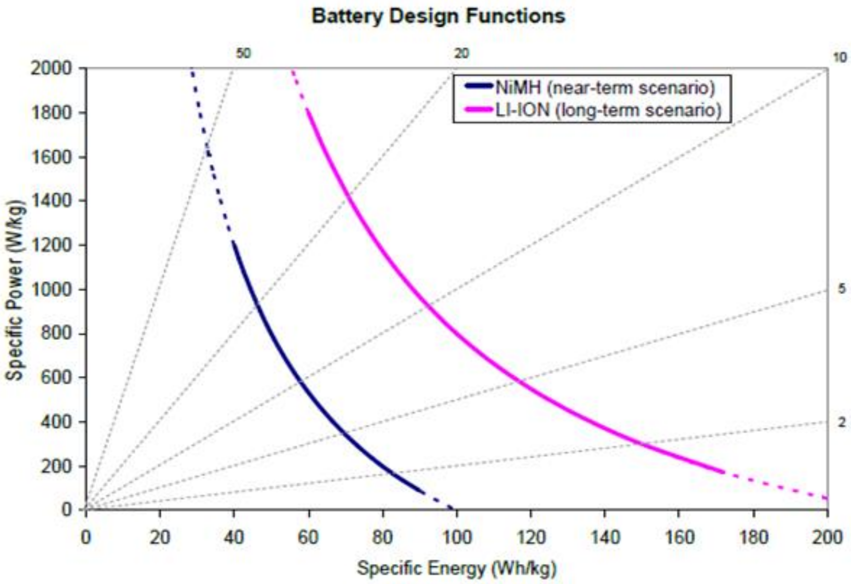


Figure 6.1. Comparison in specific energy between Li-ion battery and Ni-MH battery [59].

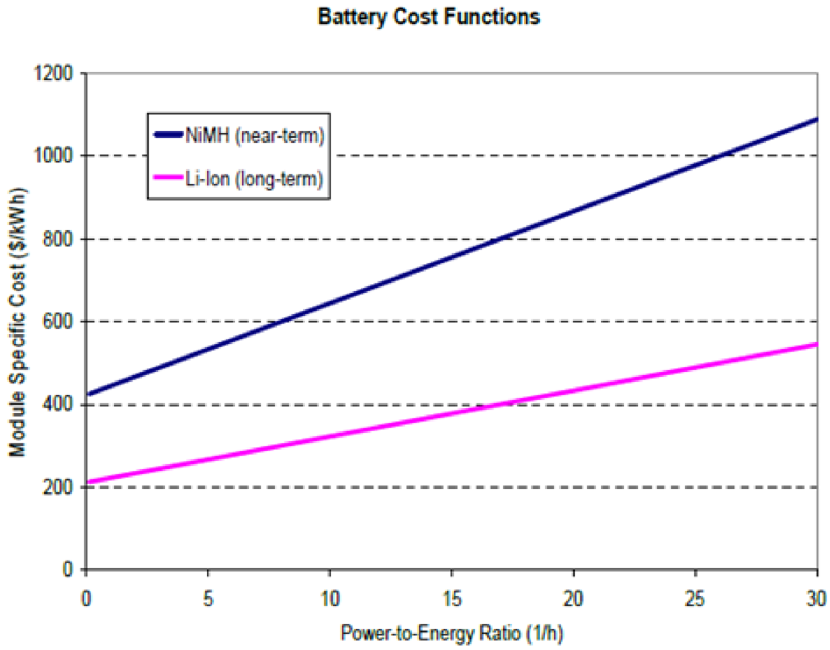


Figure 6.2. Comparison in power output between Li-ion battery and Ni-MH battery [59].

The exponential growth in portable electronic devices such as cellular phones and laptop computers during the past decade has created enormous interest in compact, light-weight batteries offering high energy densities. Also, growing environmental concerns around the globe are driving the development of advanced batteries for electric vehicles. Lithium-ion batteries are appealing for theese applications as they provide higher energy density compared to the other rechargeable battery systems such as nickel-metal hydride batteries as shown in Figure 6.3 [60].

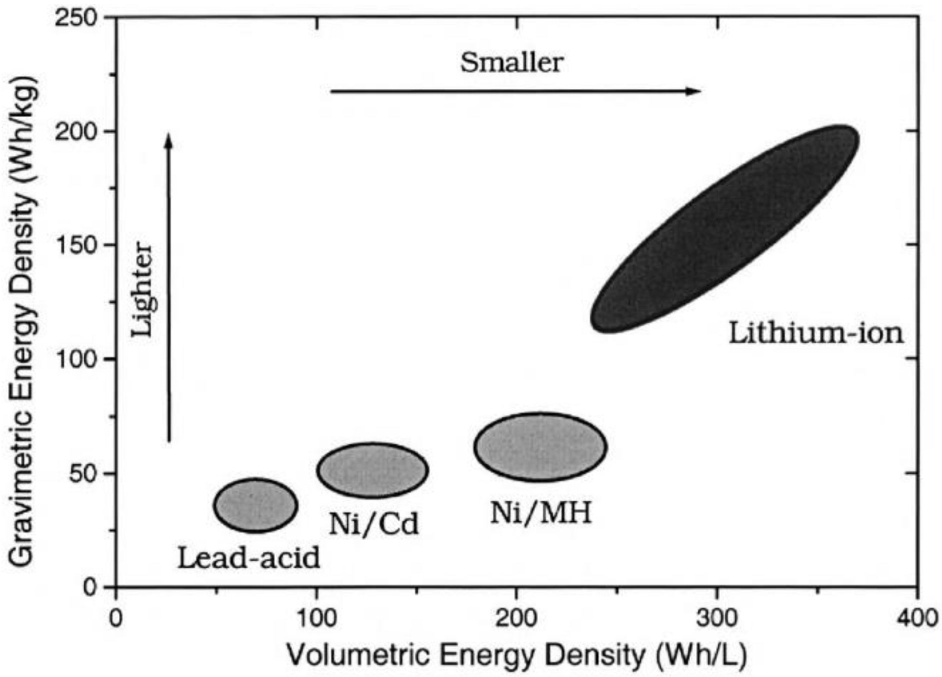


Figure 6.3. Comparison of the gravimetric and volumetric energy densities of various rechargeable battery systems [60].

For lithium ion batteries, there is no memory effect problem like NiMH. So it's about to wait for them to name these batteries exactly to charge. Also, for the same reason, half the charge does not have a negative effect on the battery. These batteries take longer to lose their unused energy. This feature of lithium-ion batteries matches the instantaneous instant charge-discharge cycle feature of vehicles in use.

Thanks to Li-ion batteries, high energy density and long life, these batteries continue to dominate the entire battery market rapidly. Lithium ion batteries are accepted and widespread due to the high energy capacity and high power they provide compared to their weight and size. They are also leaders in powering electric vehicles. Figure 6.4 continues the past and growth in the Li-ion battery market, especially for automotive applications. This message is expected to reduce demand for NiMH [15].

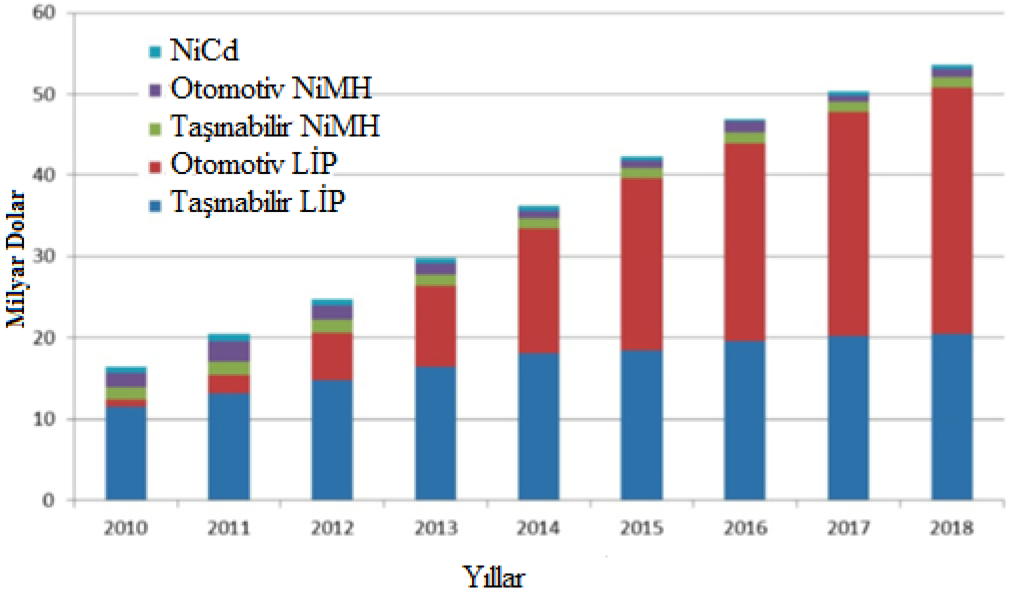


Figure 6.4. Rechargeable battery demand worldwide [15].

Although lithium batteries do not have a memory effect, they are not as long-lasting as nickel metal hydride or nickel cadmium batteries. They can be dangerous if used incorrectly. Ignition or explosion may occur if they are exposed to high temperature or direct sunlight. Leaving it in the car especially in hot weather carries a risk. Risk of ignition or explosion also arises in case of short circuit of the lithium-ion battery (Figure 6.5) [61].

Figure 6.5. Lithium 12.8 V-160Ah Smart LiFePO4 battery [61].

As security measures; Short circuits, very deep discharges and very high charging currents should be avoided. Very deep discharges can seriously damage the Li-ion battery and even be dangerous. Therefore, the use of an external safety relay is mandatory. Li-ion Batteries are sensitive to mechanical impact. If the Li-ion battery is charged after discharging below the Discharge cut-off voltage or when the Li-ion battery is damaged or overcurrent, it can release a harmful gas mixture such as phosphate.

Lithium iron phosphate (LiFePO4 or LFP) is the safest of the commercially available Li-ion battery types, but other properties are low (Table 6.1, Figure 6.6, Table 6.2,). The nominal voltage of a LFP cell is 3.2V (lead-acid: 2V / cell). Therefore, a 12.8V LFP battery consists of 4 cells connected in series and a 25.6V battery consists of 8 cells connected in series [62].

Table 6.1. Characteristics of commercial Li-ion battery cathode materials [63].

Material	*Structure*	*Potential vs. Li/Li^+, average V*	*Specific Capacity, mAh/g*	*Specific Energy, Wh/kg*
$LiCoO_2$	layered	3.9	140	546
$LiNi_{0.8}Co_{0.15}Al_{0.05}O_2$ (NCA)	layered	3.8	180-200	680-760
$LiNi_{1/3}Co_{1/3}Mn_{1/3}O_2$ (NMC)	layered	3.8	160-170	610-650
$LiMn_2O_4$ and variants (LMO)	spinel	4.1	100-120	410-492
$LiFePO_4$ (LFP)	olivine	3.45	150-170	518-587

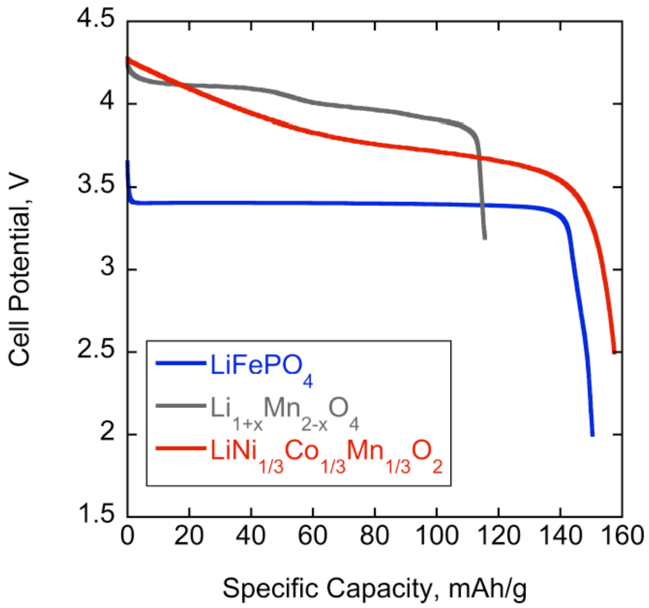


Figure 6.6. Discharge profiles of lithium cells containing LiFePO4, Li1+xMn2- xO4, or LiNi1/3Co1/3Mn1/3O2 electrodes [63].

Table 6.2. Relative merits of selected commercial Li-ion battery cathode materials for vehicular [63].

Cathode	*Cost*[a]	*Energy Density*	*Specific Power*	*Safety*[b]	*Lifespan*
NCA	lowest	high	high	lowest	highest
NMC	medium	high	medium	medium	medium
LMO	medium	medium	medium	medium	lowest
LFP	medium	lowest	medium	highest	highest

- Includes both raw material and processing costs. Processing costs may
- decrease over time, particularly for newer cathodes.
- Intrinsic safety of material, apart from engineering controls in the battery
- itself.

However, scaling up the lithium battery technology for these applications is still problematic since issues such as safety, costs, wide operational temperature and materials availability, are still to be resolved [11].

The main focus of current research is battery systems. Adaptation of traditional battery/battery used in various devices to larger systems (automobile etc.) should be developed more safely and more efficiently for many years. In this case, Lithium-ion battery systems have the potential to be an alternative powertrain for next generation vehicles. Li-ion battery technology, which has a history of about forty years, has been used as a commercial product for about thirty years. R&D studies continue in the direction of solid-state lithium-ion batteries that use solid electrolyte instead of Li-ion batteries using liquid electrolyte and do not explode [15].

6.2. RECOMMENDATION

Currently, new researches on lithium R&D have increased and showing the properties of this substance and its impressive results. But the issues associated with translating promising lab results into an efficient real-world energy system cannot be underestimated. Such development is currently under way and should be evaluated in future studies.

Studies can be carried out to control battery factories, improve the impact of the energy mix used to produce batteries on environmental change and climate, the maximum life of the battery and low strength of carbon thickness, ensure battery recycling, and establish the environmental efficiency of the battery structure.

All unique and dynamic properties of a battery must also be taken into account (for example, temperature, current, open circuit voltage). In conclusion, models can also be mainly developed for other sources of battery energies and innovations.

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RESUME

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