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Aproject

Ion Lithium battery

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ABSTRACT

Batteries are a major technological challenge in this new century as they are a vital method to make use of energy efficiently. Nowadays Lithium-ion batteries (LIBs) appeared to be one of the most crucial energy storage technologies. Today's Li-ion technology has conquered the portable electronic markets and still on the track of fast development. The success of lithium-ion technology will depend mainly on the cost, safety, cycle life, energy, and power, which are in turn determined by the component materials used for its fabrication. Accordingly, this review focuses on the challenges of organic based materials and prospects associated with the electrode materials. Specifically, the issues related to organic based batteries, advances and opportunities are presented. This review aims to summarize the fundamentals of the polymer-based material for lithium-ion batteries (LIBs) and specifically highlight its recent significant advancement in material design, challenges, performance and finally its prospects. We anticipate that this Review will inspire further improvement in organic electrolyte materials and the electrode for the battery as energy device storages. Some of these concepts, relying on new ways to prepare electrode materials by the use of eco-efficient processes, on the use of organic rather than inorganic materials to overcome environmental issues associated with their use. Organic electrodes are essential for solid electrode batteries because they can make device cost-effective, allow flexibility, and can also enable the use of multivalent ions without the problems typically associated with inorganic compounds.

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INTRODUCTION

A lithium-ion battery or Li-ion battery (abbreviated as LIB) is a type of rechargeable battery in which lithium ions move from the negative electrode to the positive electrode during discharge and back when charging. Li-ion batteries use an intercalated lithium compound as one electrode material, compared to the metallic lithium used in a non-rechargeable lithium battery.

Lithium-ion batteries are common rechargeable batteries for portable electronics, with a high energy density, tiny memory effect[1] and low self-discharge. LIBs are also growing in popularity for military, battery electric vehicle and aerospace applications.[2]

Lithium-ion batteries can be a safety hazard since they contain a flammable electrolyte and may be kept pressurized. A battery cell charged too quickly could cause a short circuit, leading to explosions and fires.[3] Because of these risks, testing standards are more stringent than those for acid-electrolyte batteries, requiring both a broader range of test conditions and additional battery-specific tests.

Research areas for lithium-ion batteries include life extension, energy density, safety, cost reduction, and charging speed,[4] among others. Research has also been under way for aqueous lithium-ion batteries, which have demonstrated fewer potential safety hazards due to their use of non-flammable electrolytes.[5]

CHAPTER-1Battery

Battery

A battery is a device which can store chemical energy and on demand convert it into electrical energy to drive an external circuit. The importance of batteries to modern life surely requires no emphasis. Even so there may be a tendency to overlook their diversity and the scale on which they are used e.g. in size they range from a small fraction of a cubic centimeter for a hearing aid battery, to many cubic decimeters for some industrial and military versions, while in the western world we manufacture some four to ten batteries per year per head of population.

The electrical energy results from a spontaneous chemical change (i.e. a redox reaction with a negative free energy) within the battery ..[6]



History

The usage of "battery" to describe a group of electrical devices dates to Benjamin Franklin, who in 1748 described multiple Leyden jars by analogy to a battery of cannon (Benjamin Franklin borrowed the term "battery" from the military, which refers to weapons functioning together) .[7]

Italian physicist Alessandro Volta built and described the first electrochemical battery, the voltaic pile, in 1800. This was a stack of copper and zinc plates, separated by brine-soaked paper disks that could produce a steady current for a considerable length of time. Volta did not understand that the voltage was due to

chemical reactions. He thought that his cells were an inexhaustible source of energy, and that the associated corrosion effects at the electrodes were a mere nuisance, rather than an unavoidable consequence of their operation, as Michael Faraday showed in 1834.

Lithium batteries were proposed by British chemist M Stanley Whittingham, now at Binghamton University, while working for Exxon in the 1970s.[8] Whittingham used titanium(IV) sulfide and lithium metal as the electrodes. However, this rechargeable lithium battery could never be made practical. Titanium disulfide was a poor choice, since it has to be synthesized under completely sealed conditions, also being quite expensive (~\$1000 per kilogram for titanium disulfide raw material in 1970s). When exposed to air, titanium disulfide reacts to form hydrogen sulfide compounds, which have an unpleasant odour and are toxic to most animals. For this, and other reasons, Exxon discontinued development of Whittingham's lithium-titanium disulfide battery.[9] Batteries with metallic lithium electrodes presented safety issues, as lithium is a highly reactive element; it autoignites exposed to normal atmospheric conditions because of spontaneous reactions with water and oxygen.[10] As a result, research moved to develop batteries in which, instead of metallic lithium, only lithium compounds are present, being capable of accepting and releasing lithium ions.

Reversible intercalation in graphite [11][12] and intercalation into cathodic oxides[13][14] was discovered during 1974–76 by J. O. Besenhard at TU Munich. Besenhard proposed its application in lithium cells.[15][16] Electrolyte decomposition and solvent co-intercalation into graphite were severe early drawbacks for battery life.

- 1973 – Adam Heller Proposed the lithium thionyl chloride battery, still used in implanted medical devices and in defense systems where greater than a 20-year shelf life, high energy density, or extreme operating temperatures are encountered.[17]
- 1982 – Godshall et al. were awarded the U.S. Patent[18] on the use of LiCoO_2 as cathodes in lithium batteries, based on Godshall's Stanford University Ph.D. thesis Dissertation and 1979 publications.
- 1983 – Michael M. Thackeray, John B. Goodenough, and coworkers further developed manganesepinel as a positive electrode material, after its 1979 identification as such by Godshall et al. in 1979 (above). Spinel showed great

promise, given its low-cost, good electronic and lithium ion conductivity, and three-dimensional structure, which gives it good structural stability. Although pure manganese spinel fades with cycling, this can be overcome with chemical modification of the material. As of 2013, manganese spinel was used in commercial cells.

- *1985* – Akira Yoshino assembled a prototype cell using carbonaceous material into which lithium ions could be inserted as one electrode, and lithium cobalt oxide (LiCoO_2), which is stable in air, as the other.[19] By using materials without metallic lithium, safety was dramatically improved. LiCoO_2 enabled industrial-scale production and represents the birth of the current lithium-ion battery.
- *1991* – Sony and Asahi Kasei released the first commercial lithium-ion battery. [20]
- *1996* – John Goodenough, AkshayaPadhi and coworkers proposed lithium ironphosphate(LiFePO_4) and other phospho-olivines (lithium metal phosphates with the same structure as mineral olivine) as positive electrode materials.[21]
- *2011* – lithium-ion batteries accounted for 66% of all portable secondary (i.e., rechargeable) battery sales in Japan.[22]
- *2012* – John Goodenough, RachidYazami and Akira Yoshino received the 2012 IEEE Medal for Environmental and Safety Technologies for developing the lithium ion battery.
- *2014* – commercial batteries from Amprius Corp. reached 650 Wh/L (a 20% increase), using a silicon anode and were delivered to customers.[23] The National Academy of Engineering recognized John Goodenough, Yoshio Nishi, RachidYazami and Akira Yoshino for their pioneering efforts in the field.[24]

As of 2016, global lithium-ion battery production capacity was 28 gigawatt-hours, with 16.4 GWh in China.[25]

1. Cell types

Many types of electrochemical cells have been produced, with varying chemical processes and designs, including galvanic cells, electrolytic cells, fuel cells, flow cells and voltaic piles.

1.1. Wet cell

A wet cell battery has a liquid electrolyte. Other names are flooded cell, since the liquid covers all internal parts, or vented cell, since gases produced during operation can escape to the air. Wet cells were a precursor to dry cells and are commonly used as a learning tool for electrochemistry

Wet cells are still used in automobile batteries and in industry for standby power for switchgear, but in many places batteries with gel cells have been used instead. These applications commonly use lead–acid or nickel–cadmium cells

1.2. Dry cell

A dry cell uses a paste electrolyte, with only enough moisture to allow current to flow. Unlike a wet cell, a dry cell can operate in any orientation without spilling, as it contains no free liquid, making it suitable for portable equipment. By comparison, the first wet cells were typically fragile glass containers with lead rods hanging from the open top and needed careful handling to avoid spillage. Lead–acid batteries did not achieve the safety and portability of the dry cell until the development of the gel battery.

2. Types of Batteries

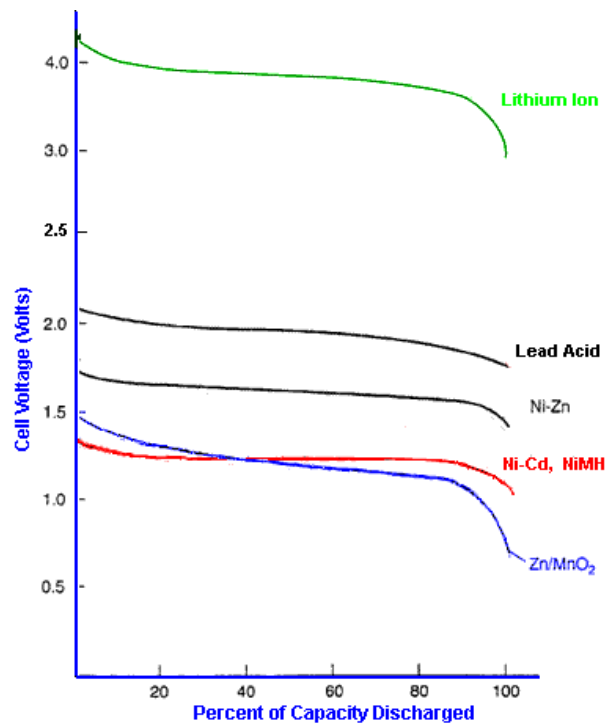


figure1:charging of cell voltage with the discharge capacity

All batteries can be described as either primary or secondary.

1. Primary batteries, or primary cells, can produce current immediately on assembly. These are most commonly used in portable devices that have low current drain, are used only intermittently, or are used well away from an alternative power source, such as in alarm and communication circuits where other electric power is only intermittently available. Disposable primary cells cannot be reliably recharged.
2. Secondary batteries, also known as secondary cells, or rechargeable batteries, must be charged before first use; they are usually assembled with active materials in the discharged state[26]. Rechargeable batteries are recharged by applying electric current.

- alkaline batteries (standard and high-performance)
- Lithium Ion Polymer (Li ion polymer)
- Nickel Cadmium (NiCd)
- Nickel-Metal Hydride (NiMH)
- Zinc air batteries
- Silver-oxide batteries
- Lead Acid battery

2.1.alkaline batteries

the zinc anode is a zinc powder in the center of the can, surrounding a brass current collector. The electrolyte is potassium hydroxide, and the zinc and potassium hydroxide are combined in a gel. The manganese-dioxide cathode is contained between the can wall and the separator, which keeps the cathode and anode from direct contact. The can wall in alkaline is steel, rather than zinc

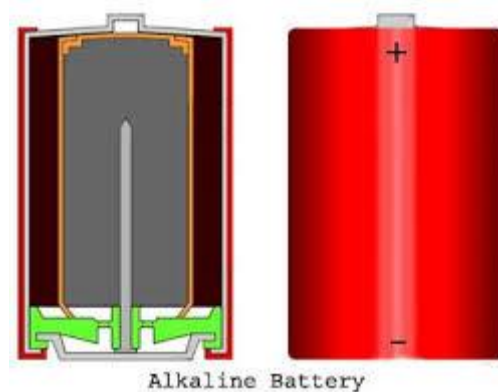


figure 2:alkaline batteries

2.2.Lithium batteries

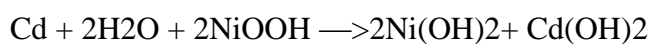
have a lithium foil anode, a manganese dioxide cathode, and a lithium-based electrolyte. Lithium manganese batteries use a variety of shapes and constructions, with the most common being button cells, solid-core cylindrical batteries and wound-core cylindrical batteries



figure3:Lithium batteries

2.3.Nickel-cadmium battery

uses nickel oxide in its positive electrode (cathode), a cadmium compound in its negative electrode (anode), and potassium hydroxide solution as its electrolyte. The Nickel Cadmium Battery is rechargeable, so it can cycle repeatedly. A nickel cadmium battery converts chemical energy to electrical energy upon discharge and converts electrical energy back to chemical energy upon recharge. In a fully discharged NiCd battery, the cathode contains nickel hydroxide $[\text{Ni}(\text{OH})_2]$ and cadmium hydroxide $[\text{Cd}(\text{OH})_2]$ in the anode. When the battery is charged, the chemical composition of the cathode is transformed and the nickel hydroxide changes to nickel oxy hydroxide $[\text{NiOOH}]$. In the anode, cadmium hydroxide is transformed to cadmium. As the battery is discharged, the process is reversed, as shown in the formula.



Nickel cadmium is the most commonly used battery for Low Earth Orbit (LEO) missions. A spacecraft battery consists of series-connected cells, the number of which depends upon bus voltage requirements and output voltage of the individual cells.



figure4:Nickel-cadmium batteries

2.4. Nickel-Metal Hydride (NiMH) battery

was introduced as another option to the Nickel-Cadmium batteries. Like Ni-Cds, NiMH batteries are available in the standard cylindrical sizes (AA, AAA, etc.). They differ from Ni-Cds, however, in that they are capable of a higher capacity without developing what is often referred to as the Ni-Cd memory Issue.

The image to the left is a typical Nickel-Metal Hydride battery. You may note that the general construction is the same as for a Ni-Cd battery. The main difference between these two battery types is the substitution of a metal hydride instead of cadmium. Additional information and a more detailed cutaway view are available by clicking on the image.

2.5. Zinc air batteries

is operate very similarly to other button-cell batteries, with the significant difference being that other button-cell batteries are entirely self-contained. In contrast, zinc air batteries require oxygen from the external atmosphere in order to operate. This saves space as well as eliminates the need for an internal, often toxic, material. Zinc air batteries are neither reactive nor flammable to a great degree.

The disadvantage of zinc air batteries is that they must be sealed from the outside atmosphere prior to use in order to prevent the battery from self-discharging. This in turn Leads to a longer shelf life.

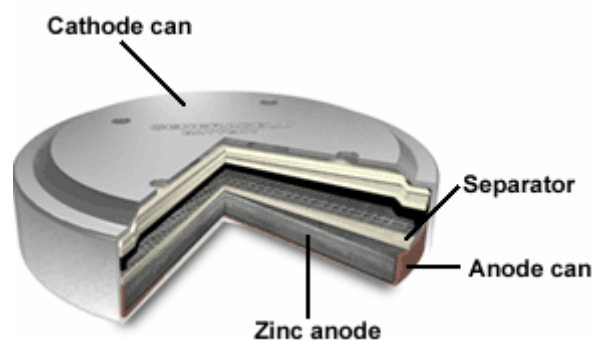


figure5:Zinc air batteries

2.6. Silver Oxide

is the nickname for a silver oxide-alkaline-zinc primary battery. And it's nicely priced for the dependability and power it delivers. Two types of Silver Oxide

batteries are available, one type with a sodium hydroxide (NaOH) electrolyte and the other with a potassium hydroxide (KOH) electrolyte. Sodium hydroxide types last two to three years making them highly suitable for quartz analog digital watches or digital watches without backlights. Potassium hydroxide types are better for the short bursts of higher current drains that are required from LCD watches with backlights. Hearing aids and electronic measuring instruments also use batteries with a potassium hydroxide electrolyte in combination with a special separator to match the application.

The Silver Oxide battery has a higher closed circuit voltage than a Mercuric Oxide battery and a flatter discharge curve than the Alkaline Manganese Dioxide battery.

2.7. Lead Acid Battery

cells consist of a Lead (Pb) electrode and a Lead oxide (PbO_2) electrode immersed in a solution of water and sulfuric acid (H_2SO_4). When the battery is connected to a load, the Lead combines with the sulfuric acid to create Lead sulfate (PbSO_4), and the Lead oxide combines with hydrogen and sulfuric acid to create Lead sulfate and water (H_2O). As the battery discharges, the Lead sulfate builds up on the electrodes, and the water builds up in the sulfuric acid solution. When the battery is charged, the process reverses, with the Lead sulfate combining with water to build up Lead and Lead oxide on the electrodes. Common examples of Lead acid batteries are car batteries, alarm system backup batteries, and camcorder batteries. Lead acid batteries should never be fully discharged; this will effectively kill the battery, making it impossible to charge. [27]

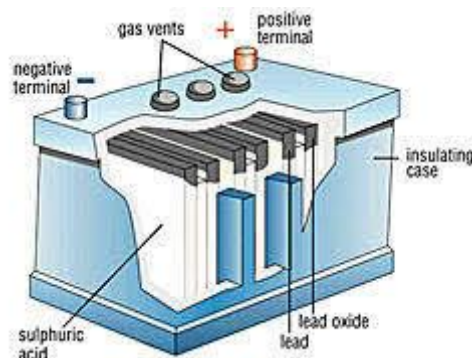


figure6:Lead-acid battery

CHAPTER-2

Lithium Ion Battery working mechanism

Batteries store and releases energy by moving electrons from one “end” of the battery to the other. Then we can use the energy from those moving electrons to do work for us, like power a drill. These two battery “ends” are known as electrodes. One is called the anode and the other is called the cathode. Generally, the anode is made from carbon and the cathode from a chemical compound known as a metal oxide (cobalt oxide, for example). The final battery ingredient is known as the electrolyte, and it sits in between the two electrodes. In the case of lithium-ion batteries, the electrolyte is a salt solution that contains lithium ions—hence the name.

When you place the battery in a device, the positively charged lithium ions are attracted to and move towards the cathode. Once it is bombarded with these ions, the cathode becomes more positively charged than the anode, and this attracts negatively charged electrons

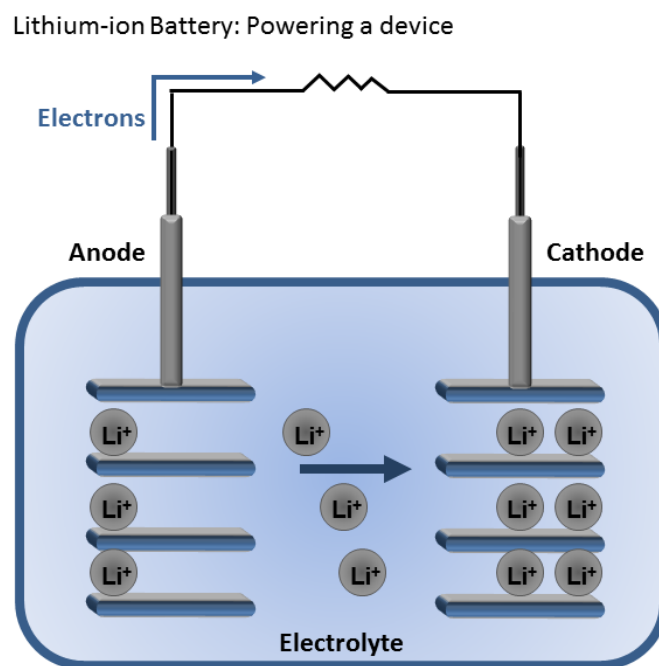


figure7:Lithium-ion battery produces electricity

As the electrons start moving toward the cathode, we force them to go through our device and use the energy of the electrons “flowing” toward the cathode to generate power. You can think of this kind of like a water wheel, except instead of water flowing, electrons are flowing

Lithium-ion batteries are great because they are rechargeable. When the battery is connected to a charger, the lithium ions move in the opposite direction as before. As they move from the cathode to the anode, the battery is restored for another use.

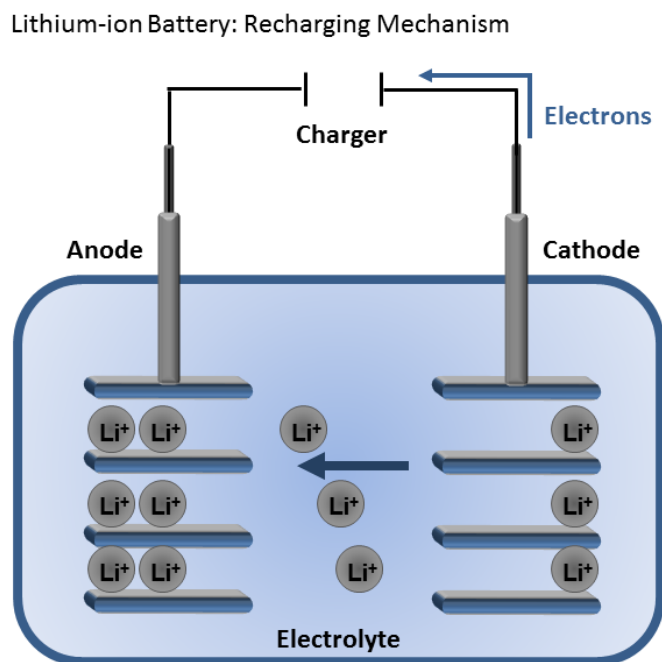


figure8:Recharging a lithium-ion battery

Of course the fact that the lithium ion battery is rechargeable makes it more desirable and sustainable, but why else are these batteries so widely used?

One reason is that lithium ion batteries can produce a lot more electrical power per unit of weight than other batteries. This means that lithium-ion batteries can store the same amount of power as other batteries, but accomplish this in a lighter and smaller package.

However, one downside to lithium-ion batteries is that they take much longer to charge than other batteries. And of course, there is always room for improvement in efficiency. This is where nanotechnology comes in. In order to improve the efficiency and decrease the charge time of lithium-ion batteries, many companies and researchers are using nanotechnology to make better battery materials.

A lot of research is focused on using nanotechnology to make better electrodes. Using nanomaterials in the electrodes increases their surface area, which provides more places for the lithium ions to make contact. This makes the battery more efficient and also makes it recharge faster. These changes should make electronic devices that use lithium-ion batteries (e.g. laptops), lighter, and also allow them to go a longer time before recharging..[28]

1. Types of Lithium-ion

1.1.Lithium Cobalt Oxide(LiCoO₂)

Its high specific energy makes Li-cobalt the popular choice for mobile phones, laptops and digital cameras. The battery consists of a cobalt oxide cathode and a graphite carbon anode. The cathode has a layered structure and during discharge, lithium ions move from the anode to the cathode. The flow reverses on charge. The drawback of Li-cobalt is a relatively short life span, low thermal stability and limited load capabilities (specific power).

Very high specific energy, limited specific power. Cobalt is expensive. Serves as Energy Cell. Market share has stabilized.

Applications Mobile phones, tablets, laptops, camerasFigure 9 illustrates the structure.

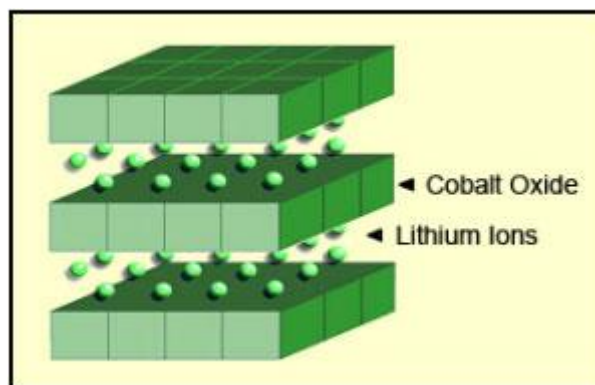


figure9:Li-cobalt structure

The cathode has a layered structure. During discharge the lithium ions move from the anode to the cathode; on charge the flow is from cathode to anode.

Courtesy of Cadex

1.2.Lithium Manganese Oxide (LiMn_2O_4)

Li-ion with manganese spinel was first published in the *Materials Research Bulletin* in 1983. In 1996, Moli Energy commercialized a Li-ion cell with lithium manganese oxide as cathode material. The architecture forms a three-dimensional spinel structure that improves ion flow on the electrode, which results in lower internal resistance and improved current handling. A further advantage of spinel is high thermal stability and enhanced safety, but the cycle and calendar life are limited.

Low internal cell resistance enables fast charging and high-current discharging.

High power but less capacity; safer than Li-cobalt; commonly mixed with NMC to improve performance.(Lithium Nickel Manganese Cobalt Oxide (LiNiMnCoO_2 or NMC))

ApplicationsPower tools, medical devices, electric powertrains

Figure 10 illustrates the formation of a three-dimensional crystalline framework on the cathode of a Li-manganese battery. This spinel structure, which is usually composed of diamond shapes connected into a lattice, appears after initial formation

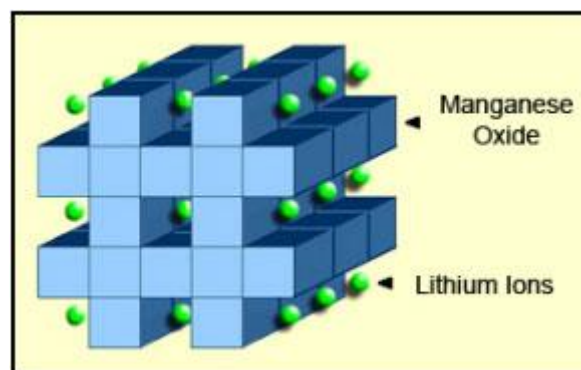


figure10:Li-manganese structure

The cathode crystalline formation of lithium manganese oxide has a three-dimensional framework structure that appears after initial formation. Spinel provides low resistance but has a more moderate specific energy than cobalt.

Courtesy of Cadex

1.3.Lithium Iron Phosphate(LiFePO₄)

In 1996, the University of Texas (and other contributors) discovered phosphate as cathode material for rechargeable lithium batteries. Li-phosphate offers good electrochemical performance with low resistance. This is made possible with nano-scale phosphate cathode material. The key benefits are high current rating and long cycle life, besides good thermal stability, enhanced safety and tolerance if abused.

Li-phosphate is more tolerant to full charge conditions and is less stressed than other lithium-ion systems if kept at high voltage for a prolonged time.

Very flat voltage discharge curve but low capacity. One of the safest Li-ions. Used for special markets. Elevated self-discharge.

Applications Portable and stationary needing high load currents and endurance.

1.4.Lithium Titanate (Li₄Ti₅O₁₂)

Batteries with lithium titanate anodes have been known since the 1980s. Li-titanate replaces the graphite in the anode of a typical lithium-ion battery and the material forms into a spinel structure. The cathode can be lithium manganese oxide or NMC. Li-titanate has a nominal cell voltage of 2.40V, can be fast charged and delivers a high discharge current of 10C, or 10 times the rated capacity. The cycle count is said to be higher than that of a regular Li-ion. Li-titanate is safe, has excellent low-temperature discharge characteristics and obtains a capacity of 80 percent at -30°C (-22°F).

Long life, fast charge, wide temperature range but low specific energy and expensive. Among the safest Li-ion batteries.

Applications solar-powered street lighting [29]

Applications

Li-ion batteries provide lightweight, high energy density power sources for a variety of devices. To power larger devices, such as electric cars, connecting many small batteries in a parallel circuit is more effective[30] and more efficient than connecting a single large battery.[31] Such devices include:

- *Portable devices*: these include mobile phones and smartphones, laptops and tablets, digital cameras and camcorders, electronic cigarettes, handheld game consoles and torches (flashlights).
- *Power tools*: Li-ion batteries are used in tools such as cordless drills, sanders, saws, and a variety of garden equipment including whipper-snippers and hedge trimmers.[32]
- *Electric vehicles*: electric vehicle batteries are used in electric cars, hybrid vehicles, electric motorcycles and scooters, electric bicycles, personal transporters and advanced electric wheelchairs. Also radio-controlled models, model aircraft, aircraft,[33][34][35] and the Mars *Curiosity* rover.

Li-ion batteries are used in telecommunications applications. Secondary non-aqueous lithium batteries provide reliable backup power to load equipment located in a network environment of a typical telecommunications service provider. Li-ion batteries compliant with specific technical criteria are recommended for deployment in the Outside Plant (OSP) at locations such as Controlled Environmental Vaults (CEVs), Electronic Equipment Enclosures (EEEs), and huts, and in uncontrolled structures such as cabinets. In such applications, li-ion battery users require detailed, battery-specific hazardous material information, plus appropriate fire-fighting procedures, to meet regulatory requirements and to protect employees and surrounding equipment.[36]

Lithium Ion Battery Advantages & Disadvantages

Lithium ion battery advantages

There are many advantages to using a li-ion cell of battery. These li-ion battery advantages include:

- **High energy density:** The much greater energy density is one of the chief advantages of a lithium ion battery or cell. With electronic equipment such as mobile phones needing to operate longer between charges while still consuming more power, there is always a need to batteries with a much higher energy density. In addition to this, there are many power applications from power tools to electric vehicles. The much higher power density offered by lithium ion batteries is a distinct advantage.
- **Self-discharge:** One issue with batteries and cells is that they lose their charge over time. This self-discharge can be a major issue. One advantage of lithium ion cells is that their rate of self-discharge is much lower than that of other rechargeable cells such as Ni-Cad and NiMH forms.
- **No requirement for priming:** Some rechargeable cells need to be primed when they receive their first charge. There is no requirement for this with lithium ion cells and batteries.
- **Low maintenance:** One major lithium ion battery advantage is that they do not require and maintenance to ensure their performance. Ni-Cad cells required a periodic discharge to ensure that they did not exhibit the memory effect. As this does not affect lithium ion cells, this process or other similar maintenance procedures are not required.
- **Variety of types available:** There are several types of lithium ion cell available. This advantage of lithium ion batteries can mean that the right technology can be used for the particular application needed. Some forms of lithium ion battery provide a high current density and are ideal for consumer mobile electronic equipment. Others are able to provide much higher current levels and are ideal for power tools and electric vehicles. [37]

Lithium ion battery disadvantages

- **Protection required:** lithium ion cells and batteries are not as robust as some other rechargeable technologies. They require protection from being over charged and discharged too far. In addition to this, they need to have the current

maintained within safe limits. Accordingly one lithium ion battery disadvantage is that they require protection circuitry incorporated to ensure they are kept within their safe operating limits. Fortunately with modern integrated circuit technology, this can be relatively easily incorporated into the battery, or within the equipment if the battery is not interchangeable.

- Ageing : One of the major lithium ion battery disadvantages for consumer electronics is that lithium ion batteries suffer from ageing. Not only is this time or calendar dependent, but it is also dependent upon the number of charge discharge cycles that the battery has undergone. When a typical consumer lithium cobalt oxide, LCO battery or cell needs to be stored it should be partially charged - around 40% to 50% and kept in a cool storage area. Storage under these conditions will help increase the life.
- Cost: A major lithium ion battery disadvantage is their cost. Typically they are around 40% more costly to manufacture than Nickel cadmium cells. This is a major factor when considering their use in mass produced consumer items where any additional costs are a major issue. [37]

CHAPTER-3

Construction of Ion - Lithium Battery

Li-ion batteries consist of Largely four main components :-

1. cathode
2. anode
3. Electrolyte
4. separator

Every single component of a Li-ion battery is essential as it cannot function when one of the components is missing .

1. Cathode

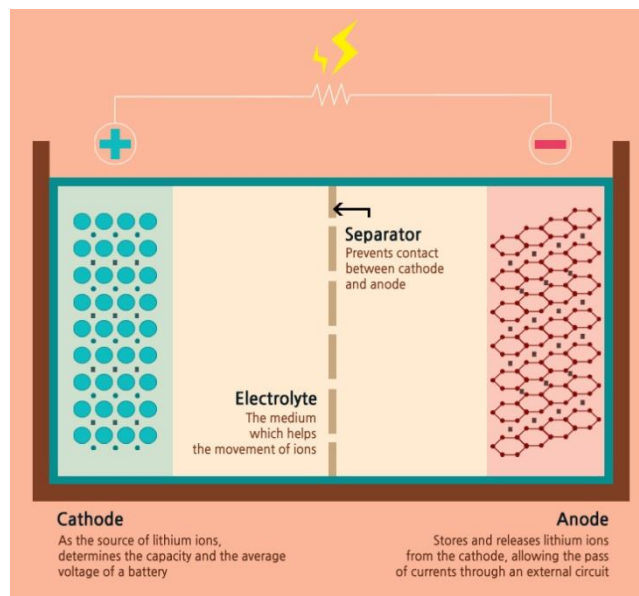


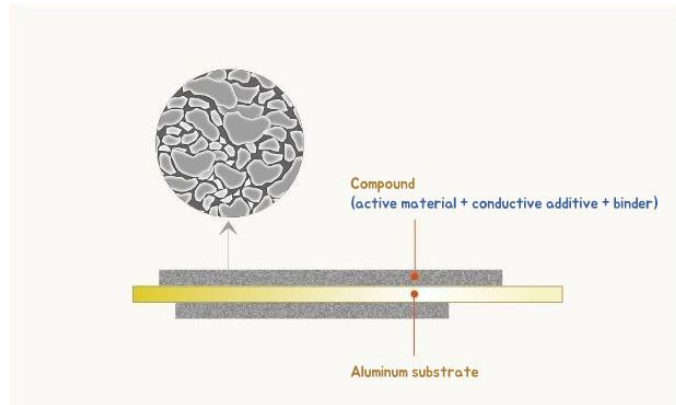
figure11:construction of ion-Lithium battery

Cathode determines the capacity and voltage of a Li-

ion Battery A Li-ion battery generates electricity through chemical reactions of lithium. This is why, of course, lithium is inserted into the battery and that space for lithium is called "cathode".

However, since lithium is unstable in the element form, the combination of lithium and oxygen, lithium oxide is used for cathode.

The material that intervenes the electrode reaction of the actual battery just like lithium oxide is called "active material". In other words, in the cathode of a Li-ion battery, lithium oxide is used as an active material.



If you take a closer look at the cathode, you will find a thin aluminum foil used to hold the frame of the cathode coated with a compound made up of active material, conductive additive and binder.

The active material contains lithium ions, the conductive additive is added to increase conductivity; and the binder acts as an adhesive which helps the active material and the conductive additive to settle well on the aluminum substrate.

The cathode plays an important role in determining the characteristics of the battery as the battery's capacity and voltage are determined by the active material type used for the cathode.

The higher amount of lithium, the bigger the capacity; and the bigger potential difference between cathode and anode, the higher the voltage.

The potential difference is small for the anode depending on its type but for the cathode, the potential difference is relatively high in general.

As such, the cathode plays a significant role in determining the voltage of the battery.

2. Anode

The anode sends electrons through a wire. Just like the cathode, the anode substrate is also coated with active material. The anode's active material performs the role of

enabling Electric current to flow through the external circuit while allowing reversible absorption/emission of lithium ions released from the cathode.

When the battery is being charged, lithium ions are stored in the anode and not the cathode.

At this point, when the conducting wire connects the cathode to the anode (discharge state), lithium ions naturally flow back to the cathode through the electrolyte, and the electrons (e) separated from lithium ions move along the wire generating electricity.

For anode graphite which has a stable structure is used, and the anode substrate is coated with active material, conductive additive and a binder.

Thanks to graphite's optimal qualities such as structural stability, low electrochemical reactivity, conditions for storing much lithium ions and price, the material is considered suitable to be used for anode.

3. Electrolyte

Electrolyte allows the movement of ions only. When explaining about cathode and anode, it was mentioned that lithium ions move through the electrolyte and electrons move through the wire.

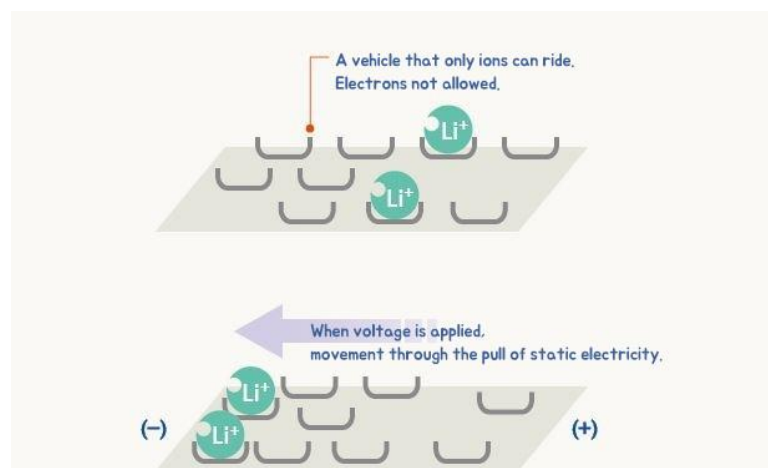
This is the key in enabling the use of electricity in a battery.

If ions flow through the electrolyte, not only can't we use electricity but safety will be jeopardized.

Electrolyte is the component which plays this important role.

It serves as the medium that enables the movement of only lithium ions between the cathode and anode.

For the electrolyte, materials with high ionic conductivity are mainly used so that lithium ions move back and forth easily.



The electrolyte is composed of salts, solvents and additives.

The salts are the passage for lithium ions to move, the solvents are organic liquids used to dissolve the salts, and the additives are added in small amounts for specific purposes.

Electrolyte created in this way only allows ions to move to the electrodes and doesn't let electrons to pass.

In addition, the movement speed of lithium ions depends on the electrolyte type.

Thus, only the electrolytes that meet stringent conditions can be used.

4. Separator

Separator is the absolute barrier between cathode and anode. While the cathode and anode determine the basic performance of a battery, electrolyte and separator determine the safety of a battery.

The separator functions as a physical barrier keeping cathode and anode apart.

It prevents the direct flow of electrons and carefully lets only the ions pass through the internal microscopic holes.

Therefore, it must satisfy all the physical and electrochemical conditions.

Commercialized separators we have today are synthetic resin such as polyethylene (PE) and polypropylene (PP).

So far, we have looked at the four main components which determine the performance of Li-ion batteries. Currently, Samsung SDI is strengthening R&D of new materials for the enhancement of battery performance while ceaselessly continuing its efforts to improve the performance of existing materials and core technologies.

Through high capacity/high efficiency Li-ion battery innovation, Samsung SDI seeks to take the lead in the future battery industry which will enrich the lives of human beings all across the world. [38]

CHAPTER-4

Battery characteristics

Lithium-ion batteries: characteristics

Characteristics of lithium-ion (li-ion) batteries include:

- They generally weigh less than comparably sized rechargeable batteries.
- They hold a charge well. Li-ion batteries typically lose no more than 5% of their charge per month (Ni-MH batteries typically lose up to 20% per month).
- They can be fully re-charged approximately 300 times.
- Frequent charging does not reduce battery performance. Li-ion batteries exhibit no "charge memory" as some Ni-Cd and Ni-MH rechargeable batteries do, and they will retain the same charge capacity for the life-span of the battery.

NOTE: Always use a battery charger specifically designed for li-ion batteries, or charge them in the camera.

- 1) no heavy metal pollution in the process of producing lithium-ion batteries, use process without acid mist emissions, is the real green environmental protection battery.
- 2) lithium battery fully enclosed design, without any maintenance, do not need to worry about the damage to the battery due to improper maintenance.
- 3) lithium battery light collision, squeezing, acupuncture, fire, high and low temperature impact are not fire, explosion, completely solve the problem of forklift battery safety hidden trouble.
- 4) normal lithium battery charging and discharging after 4000 time, capacity remains rate exceeds 75%, battery use time for 10 years. Far in excess of the lead-acid battery industry cycle time of 800 ~ 1200 times.

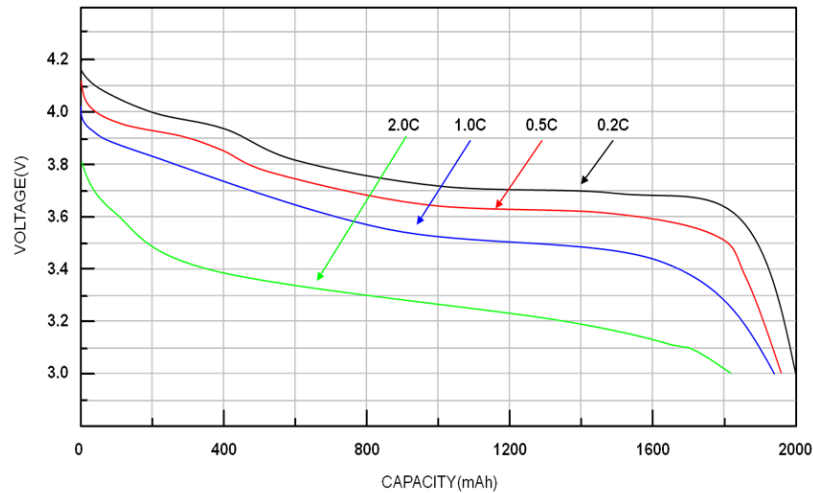


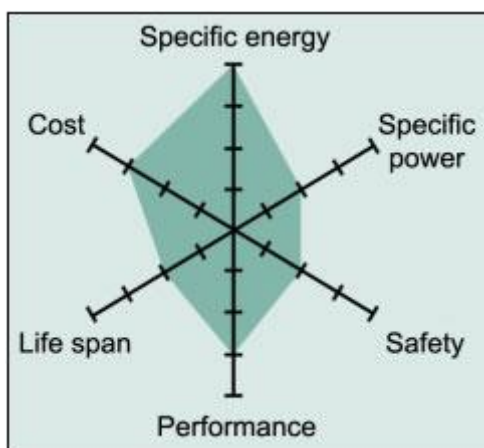
figure12:Typical discharge curves of Li-ion battery

- 5) lithium battery charging efficiency as high as 98%, far more than 70% of lead-acid battery charging and discharging efficiency.
- 6) lithium-ion batteries can charge the battery for 2 c and 5 c discharge, can be the fastest for 1 hour and quick charge.
And can use increases with the increasing charge, need not equipped with backup battery, for customers to save the cost.
- 7) in lithium-ion batteries - 40°C ~ 60°C all can work normally, the width of high and low temperature performance is lithium battery forklift truck of winning security used in cold storage..[39]

CHAPTER-5

Ion– lithium batteries design & Cell voltage

design of ion-lithium battery



1. Design of Li-cobalt battery.

Li-cobalt excels on high specific energy but offers only moderate performance specific power, safety and life span.

2. Design of Li-manganese battery.

Although moderate in overall performance, newer designs of Li-manganese offer improvements in specific power, safety and life span.

3. Design of NMC.

NMC has good overall performance and excels on specific energy. This battery is the preferred candidate for the electric vehicle and has the lowest self-heating rate.

4. Design of NCA.

High energy and power densities, as well as good life span, make NCA a candidate for EV powertrains. High cost and marginal safety are negatives.

5. Design of Li-titanate.

Li-titanate excels in safety, low-temperature performance and life span. Efforts are being made to improve the specific energy and lower cost.

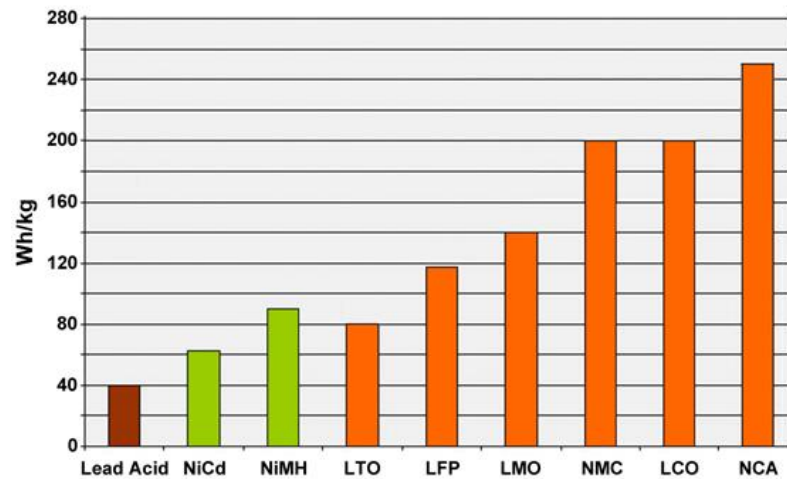


figure13:Typical specific energy of lead, nickel, and lithium based batteries

Figure 13 compares the specific energy of lead-, nickel- and lithium-based systems. While Li-aluminum (NCA) is the clear winner by storing more capacity than other systems, this only applies to specific energy. In terms of specific power and thermal stability, Li-manganese (LMO) and Li-phosphate (LFP) are superior. Li-titanate (LTO) may have low capacity but this chemistry outlives most other batteries in terms of life span and also has the best cold temperature performance. Moving towards the electric powertrain, safety and cycle life will gain dominance over capacity. (LCO stands for Li-cobalt, the original Li-ion.)[29]. NCA enjoys the highest specific energy; however, manganese and phosphate are superior in terms of specific power and thermal stability. Li-titanate has the best life span. [29]

Cell voltage

The cell potential, E_{cell} , is the measure of the potential difference between two half cells in an electrochemical cell. The potential difference is caused by the ability of electrons to flow from one half cell to the other. Electrons are able to move between electrodes because the chemical reaction is a redox reaction. A redox reaction occurs when a certain substance is oxidized, while another is reduced. During oxidation, the substance loses one or more electrons, and thus becomes positively charged. Conversely, during reduction, the substance gains electrons and becomes negatively charged. This relates to the measurement of the cell potential because the difference between the potential for the reducing agent to become oxidized and the oxidizing agent to become reduced will determine the cell potential. The cell potential (E_{cell}) is measured in voltage (V), which allows us to give a certain value to the cell potential. [57]

The equation of cell voltage in lithium ion battery

$$E = E^{\circ} + \frac{RT}{nF} \ln \left(\frac{\theta}{1-\theta} \right)$$

E = potential at a given *State of charge*
 E° = *energy at standard molar concentration*

R = gas constant (8.314 J/K.mole)

T = 298 K

F = Faradays constant (96485.33 coulombs)

n = 1

θ = State of charge (0.05:0.95)

$(RT/nF) = 0.059$

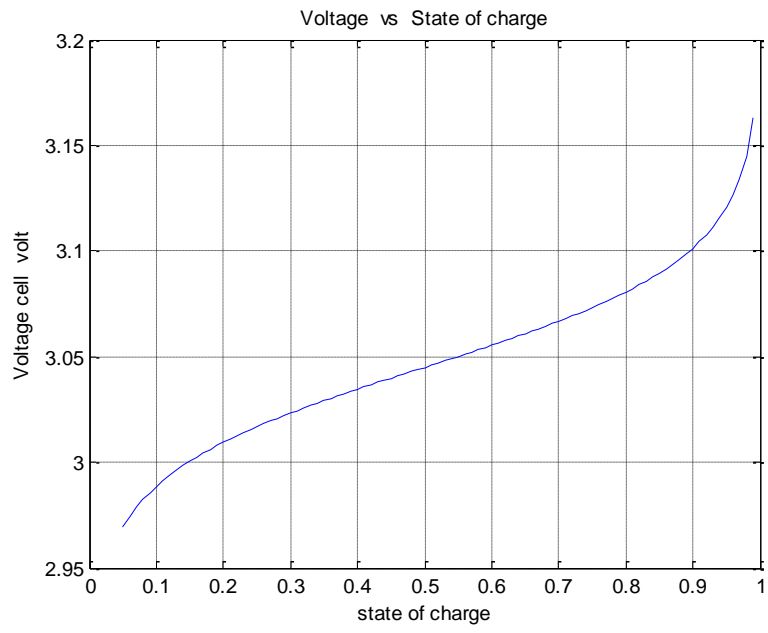


figure14:relation between the voltage vs state of charge

CHAPTER-6
Battery safety & recycling

Safety

If overheated or overcharged, Li-ion batteries may suffer thermal runaway and cell rupture.[40][41] In extreme cases this can lead to leakage, explosion or fire. To reduce these risks, many lithium-ion cells (and battery packs) contain fail-safe circuitry that disconnects the battery when its voltage is outside the safe range of 3–4.2 V per cell.[42][43] or when overcharged or discharged. Lithium battery packs, whether constructed by a vendor or the end-user, without effective battery management circuits are susceptible to these issues. Poorly designed or implemented battery management circuits also may cause problems; it is difficult to be certain that any particular battery management circuitry is properly implemented. Lithium-ion cells are susceptible to damage outside the allowed voltage range that is typically 2.5 to 3.65 V for most LFP cells. Exceeding this voltage range, even by small voltages (millivolts) results in premature aging of the cells and, furthermore, results in safety risks due to the reactive components in the cells.[44] When stored for long periods the small current draw of the protection circuitry may drain the battery below its shutoff voltage; normal chargers may then be useless since the BMS may retain a record of this battery (or charger) 'failure'. Many types of lithium-ion cells cannot be charged safely below 0 °C.[45]

Other safety features are required in each cell:[42]

- Shut-down separator (for overheating)
- Tear-away tab (for internal pressure relief)
- Vent (pressure relief in case of severe outgassing)
- Thermal interrupt (overcurrent/overcharging/environmental exposure)

These features are required because the negative electrode produces heat during use, while the positive electrode may produce oxygen. However, these additional devices occupy space inside the cells, add points of failure, and may irreversibly disable the cell when activated. Further, these features increase costs compared to nickel metal hydride batteries, which require only a hydrogen/oxygen recombination device and a back-up pressure valve.[43] Contaminants inside the cells can defeat these safety devices. Also, these features can not be applied to all kinds of cells, e.g. prismatic high current cells cannot be equipped with a vent or thermal interrupt. High current

cells must not produce excessive heat or oxygen, lest there be a failure, possibly violent. Instead, they must be equipped with internal thermal fuses which act before the anode and cathode reach their thermal limits.

Short-circuiting a battery will cause the cell to overheat and possibly to catch fire. Adjacent cells may then overheat and fail, possibly causing the entire battery to ignite or rupture. In the event of a fire, the device may emit dense irritating smoke.[46] The fire energy content (electrical + chemical) of cobalt-oxide cells is about 100 to 150 kJ/(A·h), most of it chemical.

Replacing the lithium cobalt oxide positive electrode material in lithium-ion batteries with a lithium metal phosphate such as lithium iron phosphate (LFP) improves cycle counts, shelf life and safety, but lowers capacity. As of 2006 these 'safer' lithium-ion batteries were mainly used in electric cars and other large-capacity battery applications, where safety is critical.[47]

Lithium-ion batteries, unlike rechargeable batteries with water-based electrolytes, have a potentially hazardous pressurised flammable liquid electrolyte, and require strict quality control during manufacture.[48] A faulty battery can cause a serious fire. Faulty chargers can affect the safety of the battery because they can destroy the battery's protection circuit. While charging at temperatures below 0 °C, the negative electrode of the cells gets plated with pure lithium, which can compromise the safety of the whole pack.

While fire is often serious, it may be catastrophically so. In about 2010 large lithium-ion batteries were introduced in place of other chemistries to power systems on some aircraft; as of January 2014 there had been at least four serious lithium-ion battery fires, or smoke, on the Boeing 787 passenger aircraft, introduced in 2011, which did not cause crashes but had the potential to do so.[49][50]

In addition, several aircraft crashes have been attributed to burning Li-Ion batteries. UPS Airlines Flight 6 crashed in Dubai after its payload of batteries spontaneously ignited, progressively destroying critical systems inside the aircraft which eventually rendered it uncontrollable.

Battery recycling



Battery recycling is a recycling activity that aims to reduce the number of batteries being disposed as municipal solid waste. Batteries contain a number of heavy metals and toxic chemicals and disposing of them by the same process as regular trash has raised concerns over soil contamination and water pollution.

Lithium ion batteries

Lithium-ion batteries and lithium iron phosphate (LiFePO_4) batteries often contain among other useful metals high-grade copper and aluminum in addition to – depending on the active material – transition metals cobalt and nickel as well as rare earths. To prevent a future shortage of cobalt, nickel, and lithium and to enable a sustainable life cycle of these technologies, recycling processes for lithium batteries are needed. These processes have to regain not only cobalt, nickel, copper, and aluminum from spent battery cells, but also a significant share of lithium. In order to achieve this goal, several unit operations are combined into complex process chains, especially considering the task to recover high rates of valuable materials with regard to involved safety issues.[51][52]

These unit operations are

- Deactivation or discharging of the battery (especially in case of batteries from electric vehicles)
- Disassembly of battery systems (especially in case of batteries from electric vehicles)
- Mechanical processes (including crushing, sorting, and sieving processes)
- Hydrometallurgical processes
- Pyrometallurgical processes

Specific dangers associated with lithium-ion battery recycling processes are: electrical dangers, chemical dangers, burning reactions, and their potential interactions. A complicating factor is the water sensitivity: lithium hexafluorophosphate, a possible electrolyte material, will react with water to form hydrofluoric acid; cells are often immersed in a solvent to prevent this. Once removed, the jelly rolls are separated and the materials removed by ultrasonic agitation, leaving the electrodes ready for melting down and recycling.

Pouch cells are particularly easier to recycle in this way and some people already do this to salvage the copper despite the safety issues.

As of 2017, the recycling of Li-Ion batteries generally does not extract lithium since the many different types of Li-Ion batteries require a different extraction process. Another reason why it isn't done is because the extraction of lithium from old batteries is 5x more expensive than mined lithium but efforts are being made to commercialize an industry in expectation of large quantities of disused batteries to come[53][54][55]

Recupyl

The Recupyl process, developed by Recupyl SA, was piloted in France and implemented in Singapore. The is able to treat 320 tpa of lithium batteries, including primary and secondary battery types. The process uses a combination of physical and chemical treatment steps to produce lithium carbonate. The battery scrap is first treated by crushing, magnetic separation and density separation to produce a fine powder. The powder is then fed to a hydrometallurgical process, consisting of hydrolysis, leaching and precipitation steps. Lithium is recovered as Li_2CO_3 and cobalt is recovered as cobalhydroxide.

Crushing of the batteries is a two-step process, taking place in a rotary shredder. The crusher operates in an atmosphere of CO₂ and 10-35% argon (Tedjar&Foudraz, 2010). The CO₂ reacts with any elemental lithium to form Li₂CO₃, which is less reactive than elemental lithium. The crushed batteries are fed to a physical separation process. Some of the off-gas from the crushing step is used to create an inert atmosphere above the hydrolysis reaction. The remaining off-gas is fed to the lithium precipitation step.

The components of the crushed battery scrap are separated by screening, magnetic separation and densimetric separation. For the screening step, vibrating screens of 3mm and 500 μm are used (Tedjar&Foudraz, 2010). The -3 mm fraction contains metal oxides and carbons. This is further screened on the 500 μm screen. The -500 μm fraction is rich in cobalt. Lithium is contained in this fraction. The +500 μm fraction is rich in copper. The cobalt-rich fraction is sent to the hydrometallurgical treatment process and the copper-rich fraction is combined with the steel and sold. The +3 mm fraction is treated by magnetic separation.

The magnetic fraction contains the steel from the battery casings. The non-magnetic fraction is further separated on a densimetric table. The low-density, non-magnetic fraction contains paper and plastics. Non-ferrous metals report to the high-density, non-magnetic fraction. Each of these fractions is sold.

The fine material from the physical separation process is treated by hydrolysis. The material is suspended in stirred water. A solution of lithium hydroxide is added to achieve a pH of 12-13 (Tedjar&Foudraz, 2010). Lithium from the electrodes dissolves to produce lithium salts in solution. The hydrolysis reaction generates hydrogen. Inert gas from the crushing step is used to vent off the hydrogen. The metal oxides and carbon are suspended in solution and are separated out by filtration. The lithium-containing solution is sent to a lithium precipitation step.

Lithium is precipitated from the alkaline leach solution as Li₂CO₃, using CO₂ gas. The source of CO₂ is the off-gas from the crushing stage. Precipitation occurs at a pH of 9, which is achieved by the addition of acid. The precipitate is washed with a CO₂-saturated solution and dried at 105°C (Tedjar&Foudraz, 2010). The stream containing suspended solids from the hydrolysis step is leached in sulfuric acid at a pH of 3 and a temperature of 80°C (Tedjar&Foudraz, 2010). The metal oxides dissolve, leaving carbon in the residue. The leach product is filtered and

the solution is purified prior to cobalt precipitation.

In the purification process, copper and iron are removed from solution. Copper is cemented out by the addition of steel shots. Soda is added to increase the pH to 3.85 in order to precipitate iron. The copper- and iron-free solution is fed to cobalt precipitation.

Cobalt is recovered from solution either by electrolysis, or by precipitation as $\text{Co}(\text{OH})_3$ through the addition of sodium hypochlorite. The remaining solution contains some lithium and is sent to the lithium precipitation step. The steps involved in the Recupyl process are shown in Figure 15 (Tedjar&Foudraz, 2010).

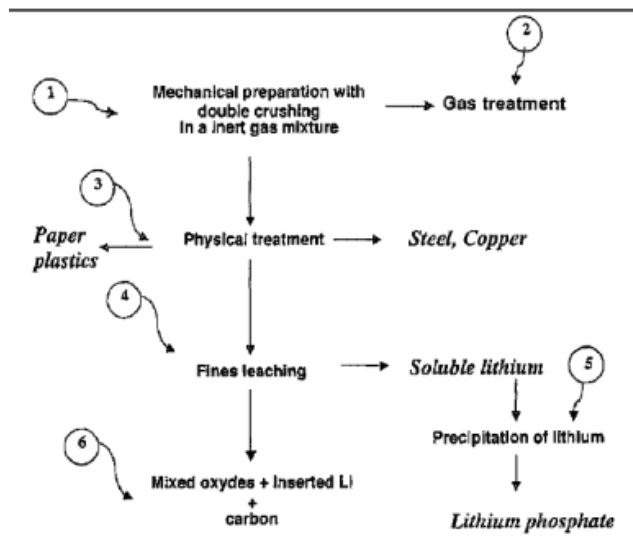


figure15:flow diagram for recupyl process (tedjar & foudraz,2010)

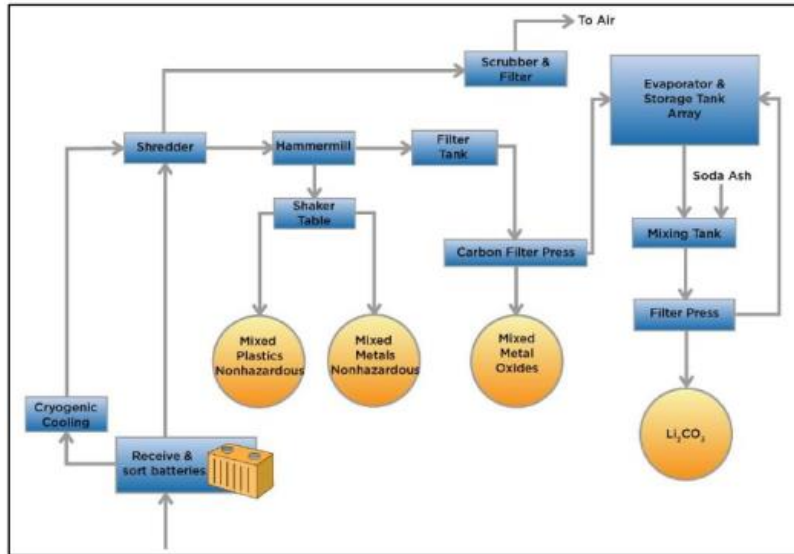


figure16:flow diagram for toxco process(Gaines et al., 2011)

Cost

□ Another important point, cost, is also a major challenge. This is because batteries are expendable supplies that need to be replaced regularly. If the price is too high, then regularly replacing them will be a huge cost burden to customer. Previous studies have found that, for a high-energy Li-ion battery, the main factors involved in adjusting the cost are the cathode-active material (~49%), electrolyte(~23%), anode-active material(~11%), with the rest due to manufacturing and other costs(~17%).¹⁰ This tells us that the price of the raw materials used to make the cathode-active and anode-active materials are the key to the total battery pricing. Materials containing Co and Ni change the final battery price, illustrating the need to focus on developing better cathode active material. The disadvantage of using Co and Ni is resource limitation and high cost[56]

Conclusion

The Li-ion battery is one of the important rechargeable battery. and has a wide application starting from small batteries for electronic equipments like watch , mobiles to large batteries for electric vehicles and space applications.

This kind of battery has a high energy densities, which reduce the weight and the volume of battery,

in this research are study the characteristic of the battery ,and this battery can be used as a deep charge battery . Also the life cycle of the battery can be improved the battery used in Wright way the Li-ion battery is can be recycled and so it is safe to use and not harm to the environment.

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