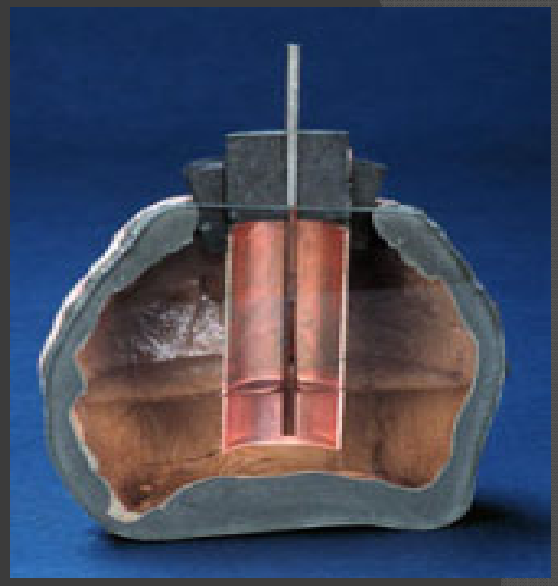
LI-ION BATTERIES

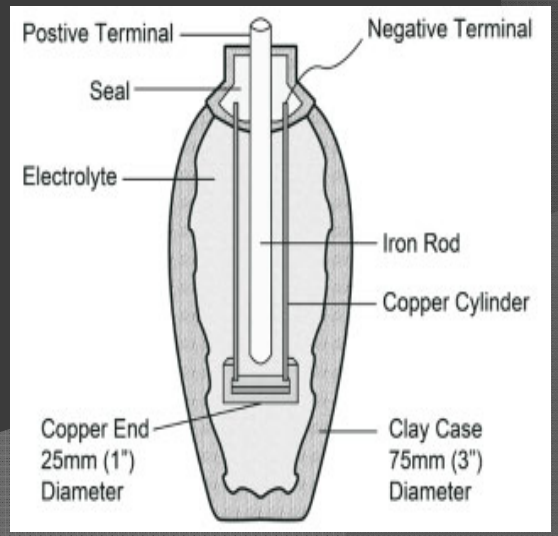
INTRODUCTION

- The word “battery” comes from the Old French word “*baterie*”.
- The battery consists of two electrodes that are isolated by a separator and soaked in electrolyte to promote the movement of ions.
- It is a feeble vessel that is slow to fill and **holds limited energy**.
- Improvements have been slow regarding capacity gain. It has been about 8 percent per year in the last two decades.
- The lithium-ion family receives the most attention.

HISTORY

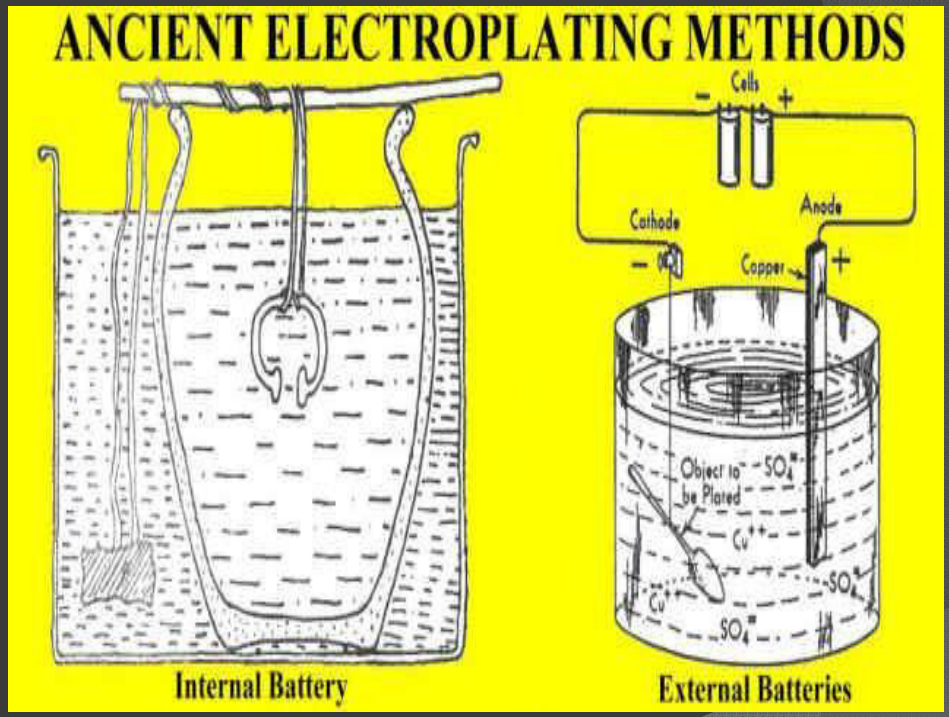
- While constructing a railway in 1936 near Baghdad, workers uncovered what appeared to be a prehistoric battery, also known as the Parthian Battery.
- The object dates back to the Parthian empire and is believed to be 2,000 years old.
- This device produced 1.1 to 2.0 volts of electricity.
- Not all scientists accept the Parthian Battery as a source of energy.





HISTORY

- It is possible that the device was used for electroplating, adding a layer of gold or other precious metals to a surface.



- The Egyptians are said to have electroplated antimony onto copper over 4,300 years ago.

- Archeological evidence suggests the Babylonians were the first to discover and employ a galvanic technique in the manufacturing of jewelry.

HISTORY

- The first practical use of static electricity was the “electric pistol” that Alessandro Volta invented in 1799. He thought of providing long-distance communications.
- In 1791, while working at Bologna University, Luigi Galvani discovered that the muscle of a frog would contract when touched by a metallic object.
- Prompted by these experiments, Volta initiated a series of experiments using zinc, lead, tin and iron as positive plates (cathode); and copper, silver, gold and graphite as negative plates (anode). Then was when galvanic electricity had born.

HISTORY

Rechargeable batteries

- In 1859, the French physician Gaston Planté invented the first rechargeable battery based on lead acid, a system that is still used today. Until then, all batteries were primary, meaning they could not be recharged.
- In 1899, Waldmar Jungner from Sweden invented the nickel-cadmium (NiCd) battery.
- In 1932 that Shlecht and Ackermann achieved higher load currents .
- In 1947, Georg Neumann succeeded in sealing the cell.
- Most research activities today revolve around improving **lithium-based** systems, first commercialized by Sony in 1991.

TYPES OF BATTERIES NOWADAYS

Batteries are classified into **primary** and **secondary** forms:

- **Primary batteries** irreversibly transform chemical energy to electrical energy. They can produce current immediately on assembly.

- These are most commonly used in portable devices that have low current drain and are usually used intermittently.

TYPES OF BATTERIES NOWADAYS

- **Secondary batteries** can be recharged; that is, they can have their chemical reactions reversed by supplying electrical energy to the cell. Must be charged before first use.

- The oldest form of rechargeable battery is the lead–acid battery in an unsealed container.

- The sealed valve regulated lead–acid battery (VRLA battery) is popular in the automotive industry as a replacement for the lead–acid wet cell. There are two types:
  - Gel batteries
  - Absorbed Glass Mat (AGM)

TYPES OF BATTERIES NOWADAYS

- According to its **cell**, there are two types:

- In **wet cell batteries** the liquid covers all internal parts of the device. They were a precursor to dry cells and may be primary cells or secondary cells.

- **Dry cell batteries.** 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

BATTERIES LI-ION

- **Introducing to batteries Li-ion**

- Pioneering work of the lithium battery began in 1912 under G.N. Lewis, but it was not until the early 1970s that the first non-rechargeable lithium batteries became commercially available, but failed because of instabilities in the metallic lithium used as anode.

- Lithium is the lightest of all metals, has the greatest electrochemical potential and provides the largest specific energy per weight.

BATTERIES LI-ION

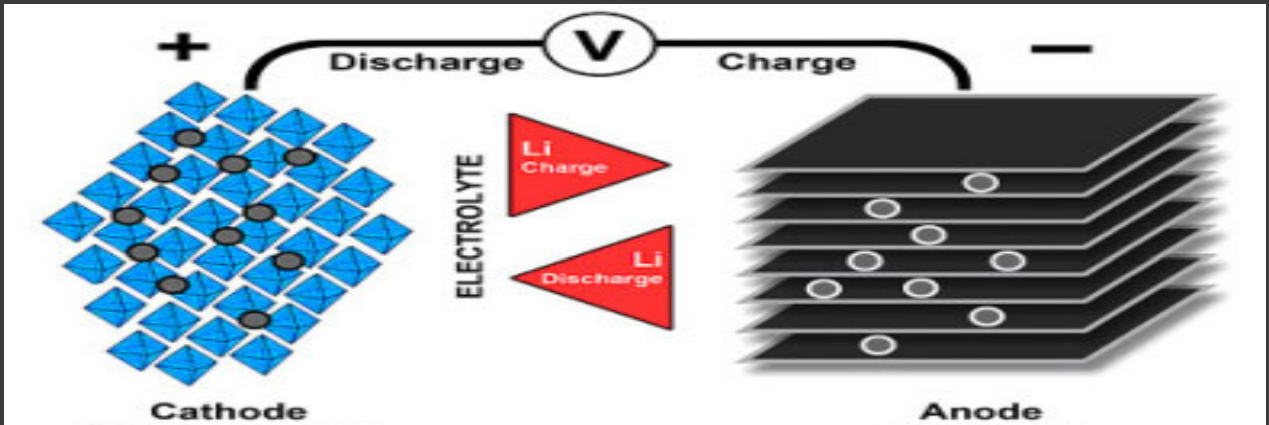
- **Mass production and Commercialization**

- In 1994, the cost to manufacture Li-ion in the 18650 cylindrical cell was over US$10 and the capacity was 1,100mAh.
- In 2001, the price dropped to below $3 while the capacity rose to 1,900mAh.
- Today, high energy-dense 18650 cells deliver over 3,000mAh and the costs are dropping.

BATTERIES LI-ION

Way of working

- Lithium-ion uses a cathode (positive electrode), an anode (negative electrode) and electrolyte as conductor.



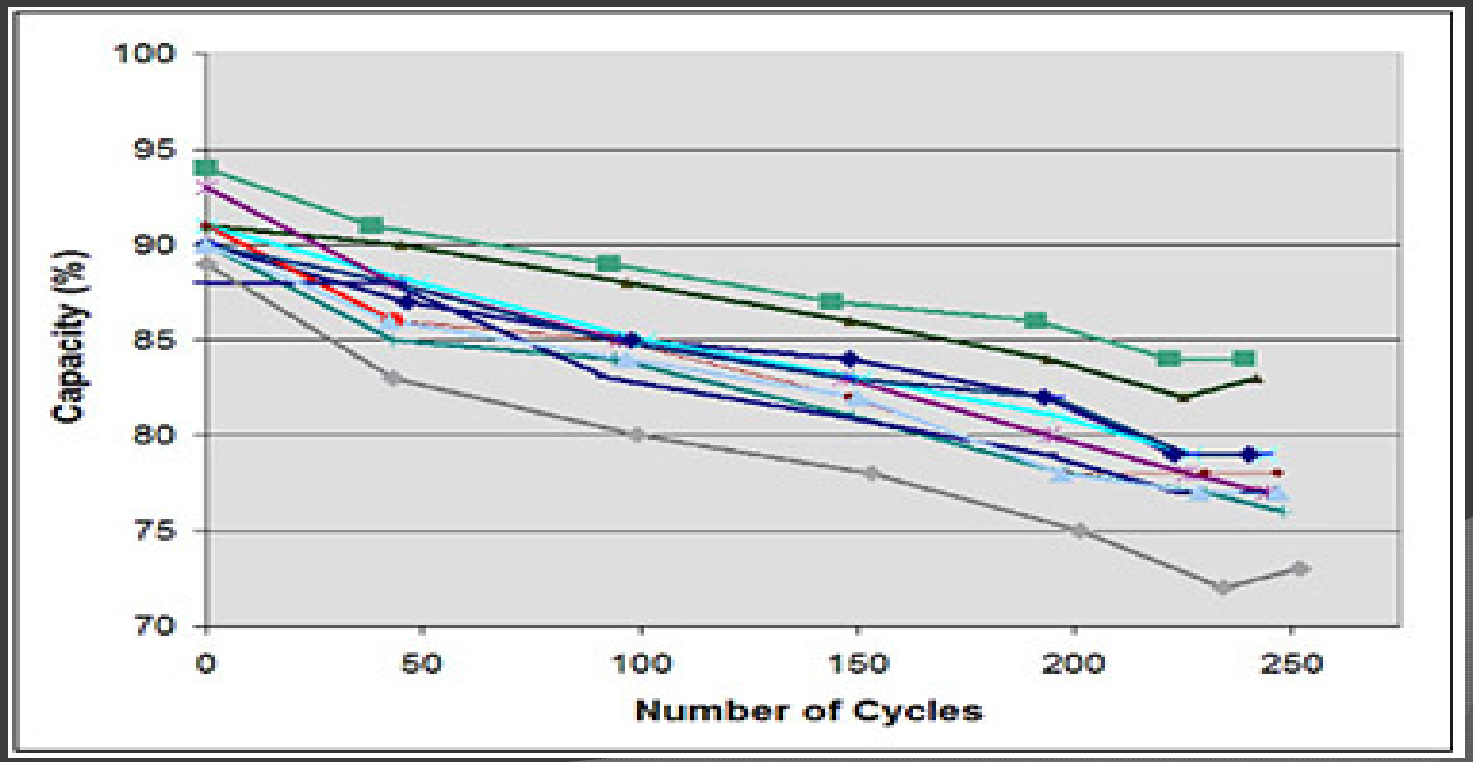
- During discharge, the ions flow from the anode to the cathode through the electrolyte and separator.
- Charge reverses the direction and the ions flow from the cathode to the anode.
- Nanotube carbons have not yet found commercial use in Li-ion as they tend to entangle and affect performance.

CAPACITY, CHARGE AND DISCHARGE

- **A battery's capacity** is the amount of electric charge it can deliver at the rated voltage. The more electrode material contained in the cell the greater its capacity.
- The rated capacity of a battery is usually expressed as the product of 20 hours multiplied by the current that a new battery can consistently supply for 20 hours at 20 °C, while remaining above a specified terminal voltage per cell. For example, a battery rated at 100 A·h can deliver 5 A over a 20-hour period at room temperature.
- There is a **capacity loss** over the number of cycles it charge and discharge

CAPACITY, CHARGE AND DISCHARGE

- The expected capacity loss of Li-ion batteries was uniform over the delivered 250 cycles and the batteries performed as expected.



CAPACITY, CHARGE AND DISCHARGE

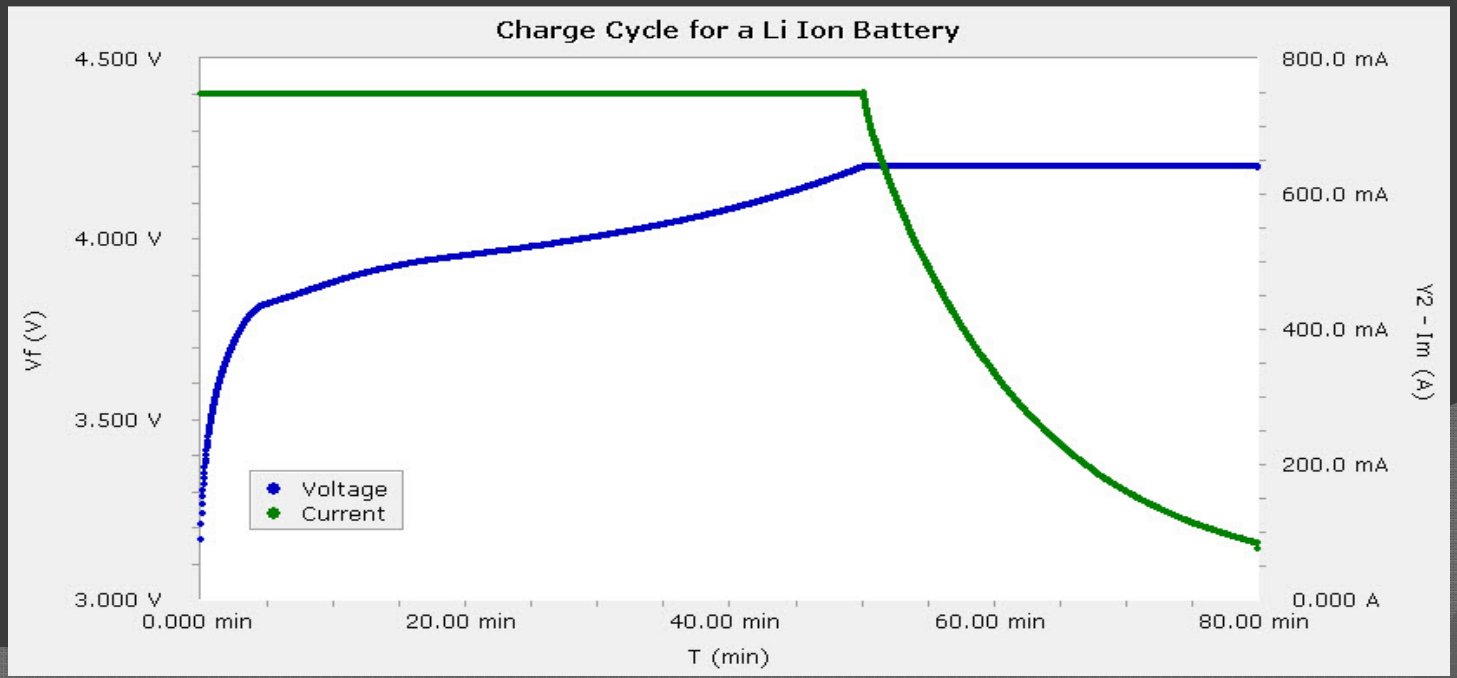
- The relationship between current, discharge time and capacity for a lead acid battery is approximated by Peukert's Law:

$$t = \frac{Qp}{I^k}$$

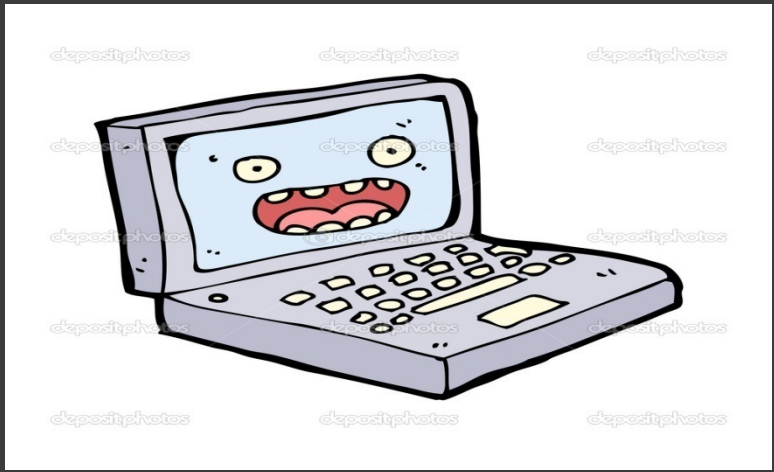
Qp is the capacity.
I is the current drawn from battery (A).
t is the amount of time (h) that a battery can sustain.
k is a constant around 1.3.

CAPACITY, CHARGE AND DISCHARGE

- **The Li ion charger** is a voltage-limiting device that has similarities to the lead acid system. The differences with Li-ion lie in a higher voltage per cell, tighter voltage tolerances and the absence of loss of charge at full charge.



COMMON APPLICATIONS



ADVANTAGES AND DISADVANTAGES OF LI-ION BATTERIES

Advantages

- High specific energy and high load capabilities.
- Long cycle and extend shelf-life; maintenance-free.
- High capacity, low internal resistance, good coulombic efficiency.
- Simple charge algorithm.
- Low self-discharge (less than half that of NiCd and NiMH).

ADVANTAGES AND DISADVANTAGES OF LI-ION BATTERIES

Limitations

- Requires protection circuit to prevent runaway if stressed.
- Degrades at high temperature and when stored at high charges.
- No rapid charge possible at freezing temperatures (<0°C).
- Transportation regulations required when shipping in larger quantities.

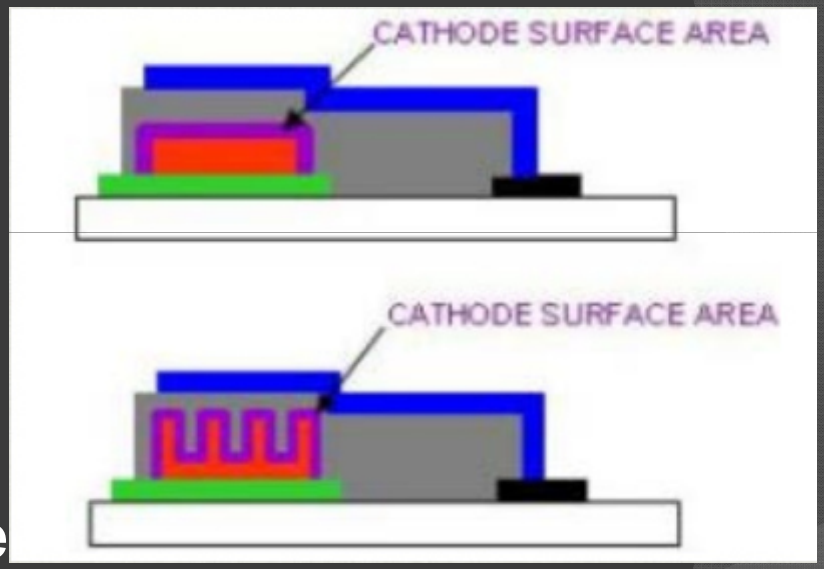
NANOTECHNOLOGY FOR LI-ION BATTERIES

- A key factor in battery efficiency is the power density, or how much electrical power a battery can supply per weight. (that's why lithium is used).

- However, lithium-ion batteries are relatively slow to charge and have safety issues.

NANOTECHNOLOGY FOR LI-ION BATTERIES

- Many companies are exploring the use of nanotechnology to change the material used in lithium-ion battery electrodes.
- Manufacturers are constantly researching about how to improve the performance of Li-ion.
- Both to reduce the risk of battery fires and to incorporate the capability of a **nanostructured** surface to increase the surface area on the electrodes.



MYTHS AND ADVICES ABOUT LI-ION BATTERIES

- **Myth 1**: Rechargeable batteries needs priming. (you need to charge X hours before you can use it for the first time).

- **Fact 1**: Some older rechargeable battery types like Nickel Cadmium (NiCd) and Nickel Metal Hydrate (NiMH) needs priming. (because of crystalization)

MYTHS AND ADVICES ABOUT LI-ION BATTERIES

- **Myth 2**: Unplug it from the charger once it is fully charged. Leaving the charger connected will blow up the battery or reduce the battery's life by overcharging.

- **Fact 2**: Manufacturers have built in circuits to cut power to it once it's fully charged. However, it is still a good idea to remove the battery. Although the batteries will not over-charge, the heat from charging or due to poor heat ventilation will still cause it to blow up.

MYTHS AND ADVICES ABOUT LI-ION BATTERIES

- **Myth 3**: You shall drain every last watt of it before recharging it, and charge it up to the 100% (because they suffer from ‘memory effect’).

- **Fact 3**: Some types of rechargeable batteries will gradually lose their maximum capacity if you do not discharge it completely before recharging (as NiCd). But Li-ion do not suffer from memory effect, at all.

MYTHS AND ADVICES ABOUT LI-ION BATTERIES

- **Environmental conditions** govern the longevity of lithium-ion batteries.
- The worst situation is keeping a fully charged battery at **elevated temperatures.**
- **Lower charge voltages and current** prolong battery life.
- The **best temperature range to charge Li-ion** batteries is **between 10°C and 30°C**. But technically it is allowed to charge them between 0°C to 45°C.
- The **temperature range to discharge is wider**, from –20°C to 60°C.

FUTURE BATTERIES

- Experimental batteries live mostly in sheltered laboratories and communicate to the outside world with promising results.
- Researchers have also developed an anode structure for Li-ion batteries that is based on **silicon-carbon nanocomposite** materials.
- A silicon anode could theoretically store 10 times the energy of a graphite anode, but expansions and contractions during charge and discharge make the system unstable.

FUTURE BATTERIES

- **Lithium-air (Li-air)**
- The theoretical specific energy of lithium-air is 13 kWh/kg
- In comparison to Li-ion's, it is 0.41 kWh/kg limit.
- There are some problems as the sudden death syndrome, working at low temperatures, and the number of cycles. Lab tests currently produce only 50 cycles. (Li-ion produce 250 cycles at 80% of capacity)

FUTURE BATTERIES

- **Lithium-metal (Li-metal)**
  - With a capacity of 0.3 kWh/kg.
  - DBM Energy (german) manufacturer of this battery, claims 2,500 cycles.
- **Solid-state Lithium**
- **Lithium-sulfur (Li-S)**
- **Sodium-ion (Na-ion)**

CONCLUSION

Going deeper into the knowledge of batteries:

- Learn how to treat properly any battery in order to improve the long term performance of it.
- Enlarge the life time of the device where the battery is placed in, postponing the obsolescence.
- Interesting field to invest on. As a researcher, as a Startup, as material dealer and so on.

THANK YOU FOR YOUR ATTENTION