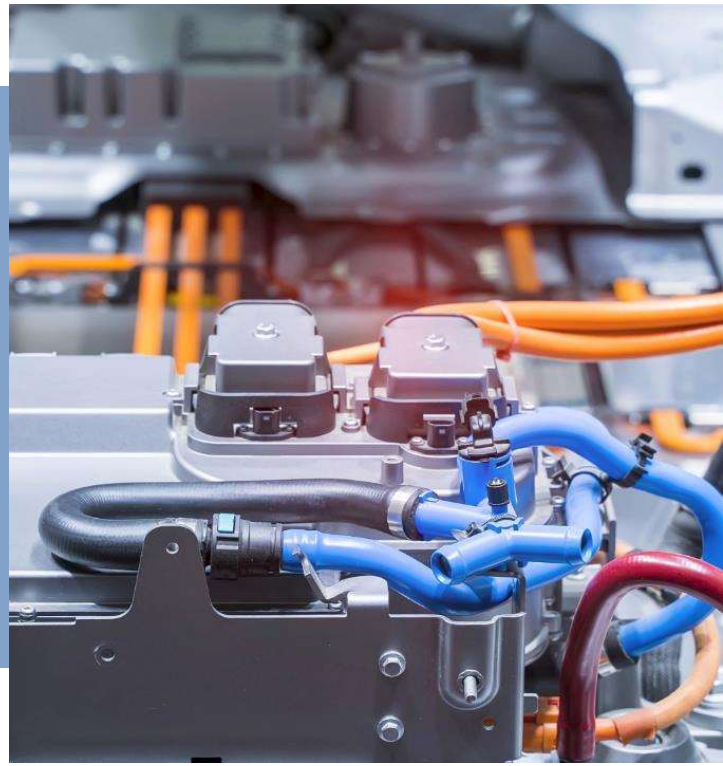
Cells, Modules and Battery Pack

Introduction to Process basics



Agenda

- Definitions (Cells, Modules and Packs)
- Battery Cells: how they works and basics
- Battery Cells: different chemistry and related behaviours
- Battery Cells: Types

Definitions: the Russian dolls

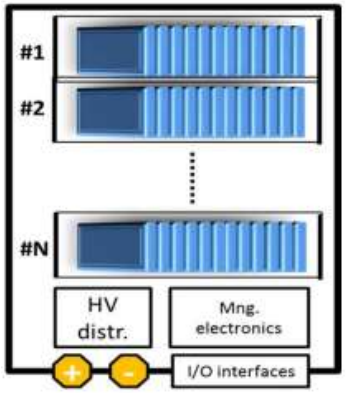
CELL
(The elementary unit)

Chemistry
&
Capacity [Ah] +
Voltage [V]
=
«Fixed» quantity stored in a CELL

MODULE

CELLS (connected in series or parallel)
+
Connection for signal monitoring and HV
+
Electronic to monitor/balance (BMS slave)
=
Single MODULE

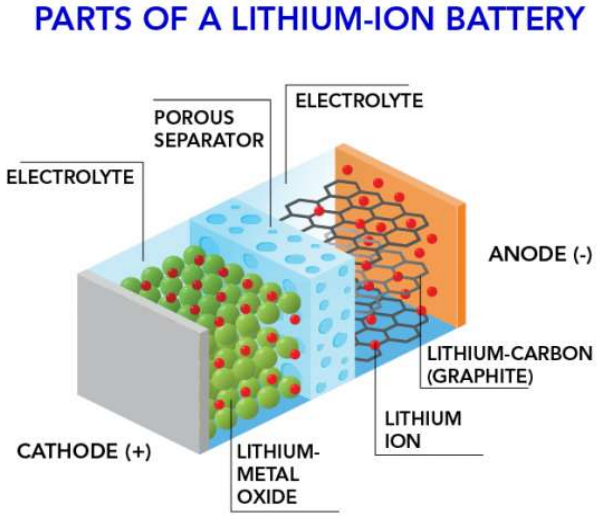
BATTERY PACK & BATTERY SYSTEM

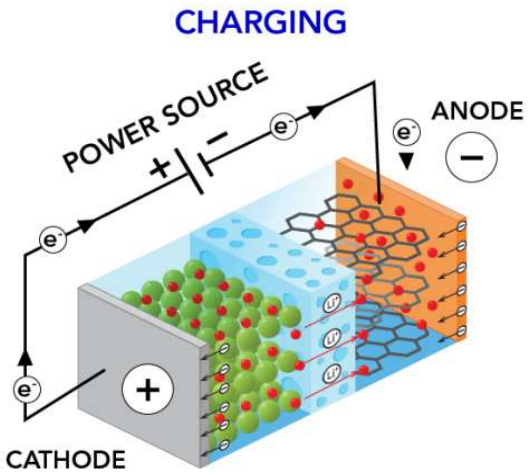


MODULES
+
Signal from each pack and HV
=
BATTERY PACK
+
Electronic management (BMS master)
+
HV distribution and relays
+
Cooling/Heating
+
External connectors
=
BATTERY SYSTEM

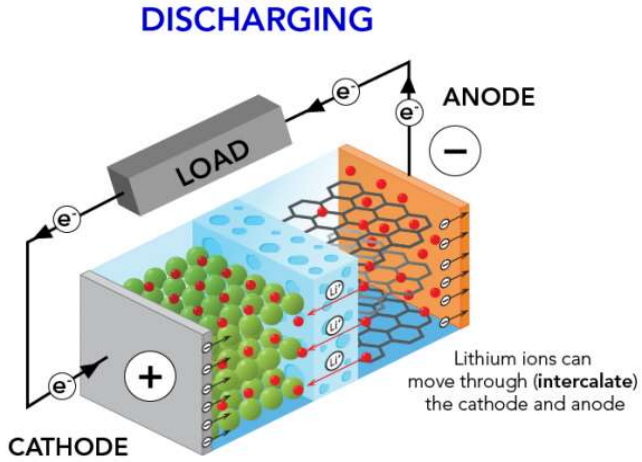
Few basics: what is a battery Cell and how it works

- A battery is a device that converts chemical energy contained within its active materials into electric energy by an electrochemical oxidation-reduction (redox) reaction.
- A cell is the actual electrochemical unit used to generate or store electric energy.
- A battery contains several cells connected in series, or parallel, or both, depending on the desired output voltage and capacity.





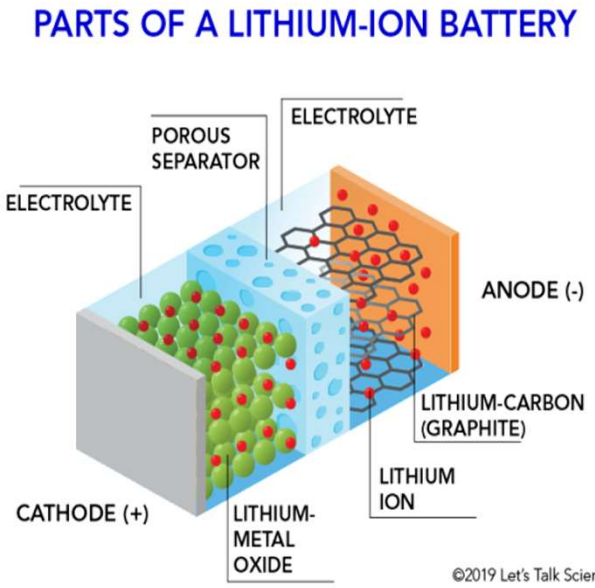
Charge : Li ions move from cathode to anode

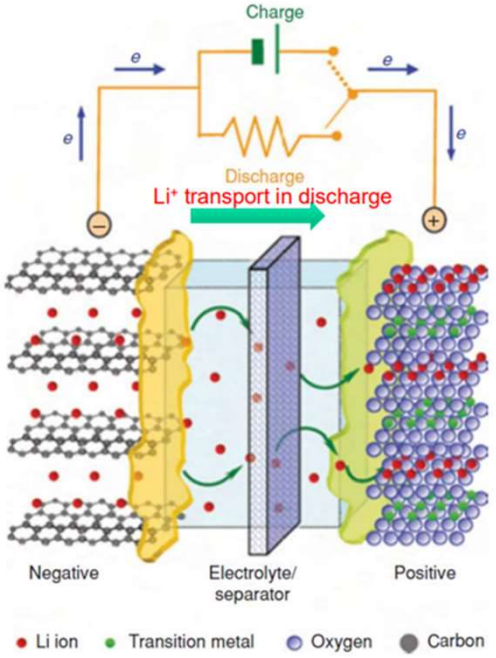


Discharge : Li ions move from anode to cathode

What is a battery Cell and how it works

- The lithium ion (Li+) moves from one part of the cell to another crossing the separator
- Anode and Cathode are two materials that can accept lithium ion inside them
- The electrolyte allows ions to move within the cell
- The separator mechanically and electrically separates the two zones of the cell, Anode and Cathode





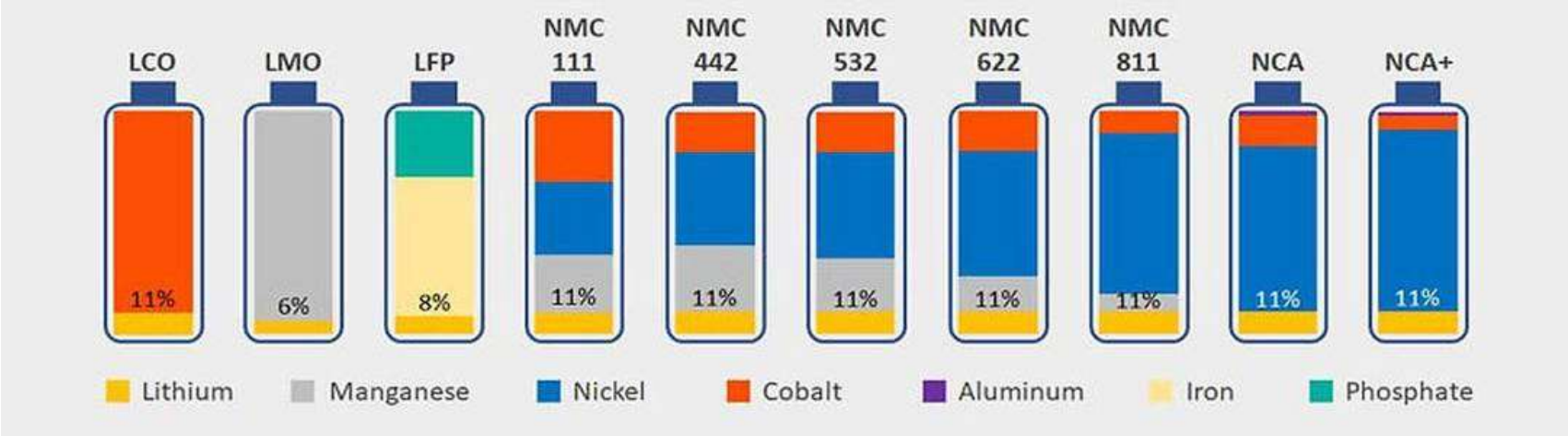
Cells components (Summary)

- **Anodic paste** = paste mainly composed of graphite
- **Anodic Current collector** = copper tape as wide as the cell and a few tenths thick
- **Cathodic paste** = paste composed of various mixtures of metal oxides
- **Cathodic Current collector** = aluminum tape as wide as the cell and a few tenths thick
- **Separator** = tape in porous plastic material
- **Electrolyte** = organic-based liquid (such as petrol – solvent for paints, etc.), in solid-state cells the electrolyte is solid in the form of a ribbon

Different Cathode chemistry

- There're different cathode chemistry, the anode is always graphite, changing the composition of the cathode with different mixtures we can grant different performance/behavior of the cell.

- The trend is to remove Cobalt because it is the most expensive element, **to date NMC 811 and NCA+ (i.e.Tesla) are the most common chemicals for cars**, buses instead use LFP which to date is the cheapest and most absolutely safe (but with lower performance than NMC and NCA)



How to evaluate the Cells Performances

There are 5 main drivers on which evaluate the performances of different cells with different chemistry:

1. **Specific Energy** [Wh/Kg]**:** is the ratio of the amount of energy contained (Wh = V x Ah) to the weight of the battery.

2. **Safety**: which is closely related to thermal stability because intrinsic safety depends very much on how thermally stable the components are

3. **C-Rate**: charge/discharge rate, that is closely linked to the cell's ability to generate power.

4. **Life cycle**: Number of times the cell can be discharged and charged until the end of life is reached, normally considered when 80% residual capacity is reached.

5. **Cost**

6. **What else…?**

The «C»: The ration between Power and Capacity

- Batteries of the same chemistry can be **optimized** for power density **or** energy density
- The first type (Power) can accept fast charges/discharges
- The second type (Energy) focus on the maximum stored energy at the expense of the deliverable currents.
- The cells with more energy have more active material (paste) those with more power have thicker metal collectors (ribbons)

Power ⟷ **Energy**

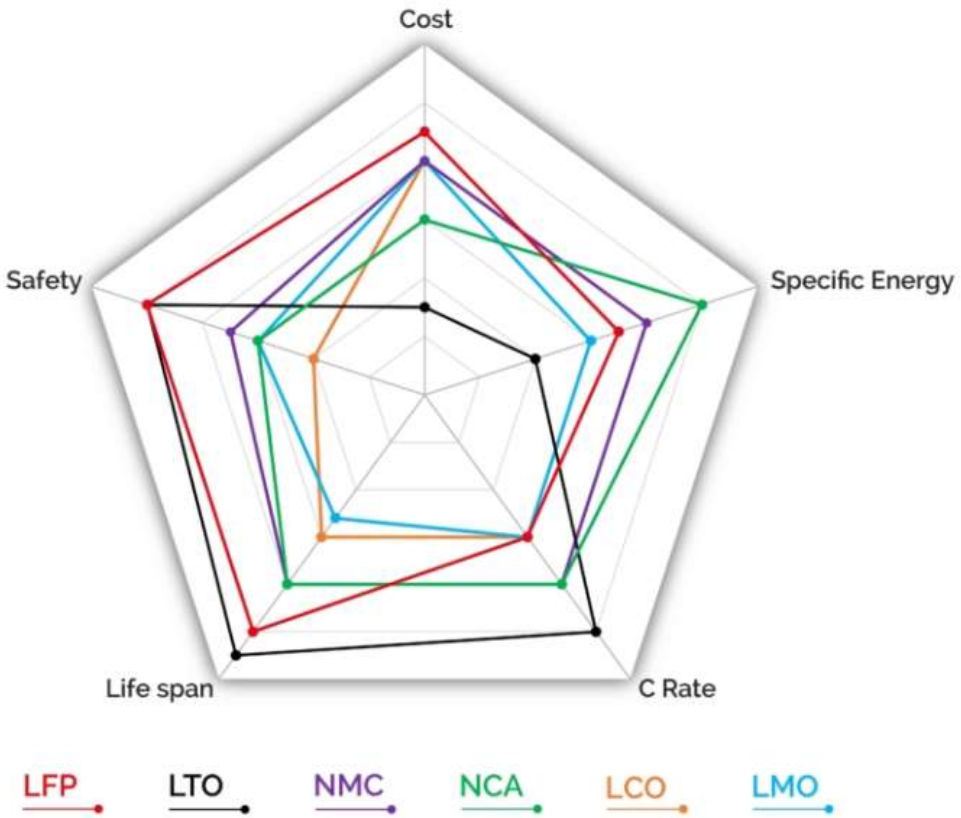
- KERS
- HEV (hybrid vehicles)
- Electrical Dragster
- Fast Charging

High C for Charging and Discharging

- Long Range
- BEV
- Normal Charging
- Price / kwh

Low C for Charging and Discharging

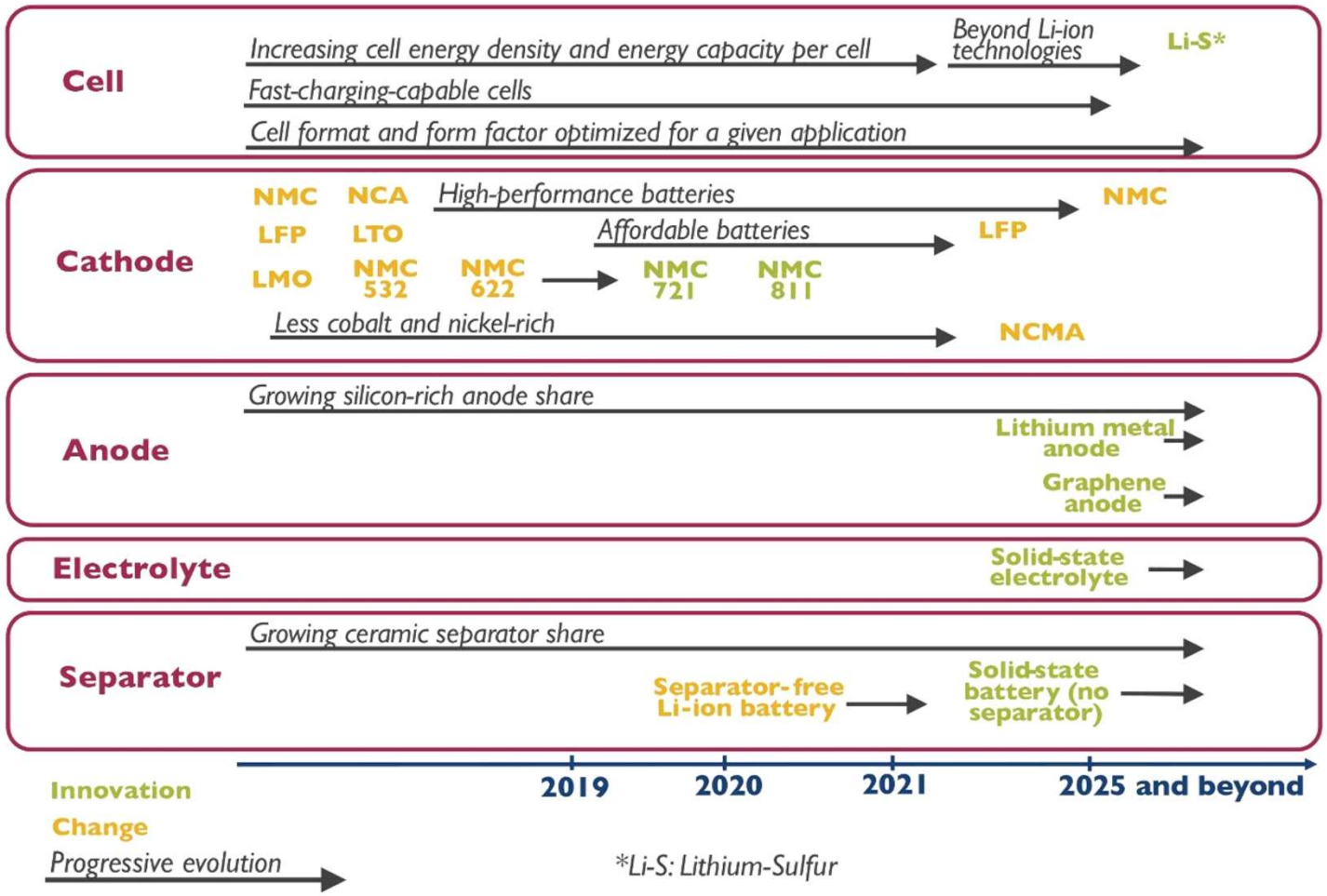
Different Cathode chemistry vs. Performance



We have outlined the 6 main types of lithium-based chemistry that are currently most widely used in the various electrification areas. But we must not think that these chemistries are in competition with each other, quite the contrary! They are all valuable and high-performing, but **each lithium chemical works best in different areas of use**.

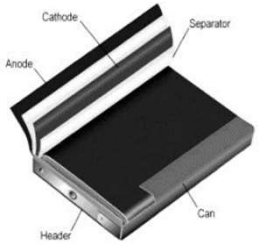
Why are NMC and NCA more widely used in the automotive sector? Because this requires a very high energy density, which can give a great power in a small space

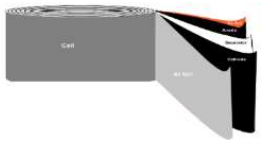
Cells Chemistry Trend (2025 and beyond)



Different cell types

PRISMATIC



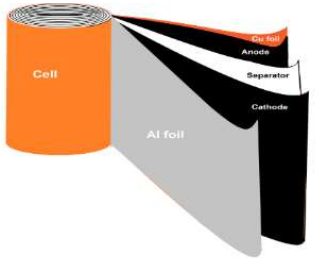


Jelly Roll design

Stacked design

Metal cell can
- Easy to integrate and cool / heat
- Needs minimum mechanical support
- **Expensive manufacturing**
- **Rolled design sensitive to uneven pressure**

CYLINDRICAL

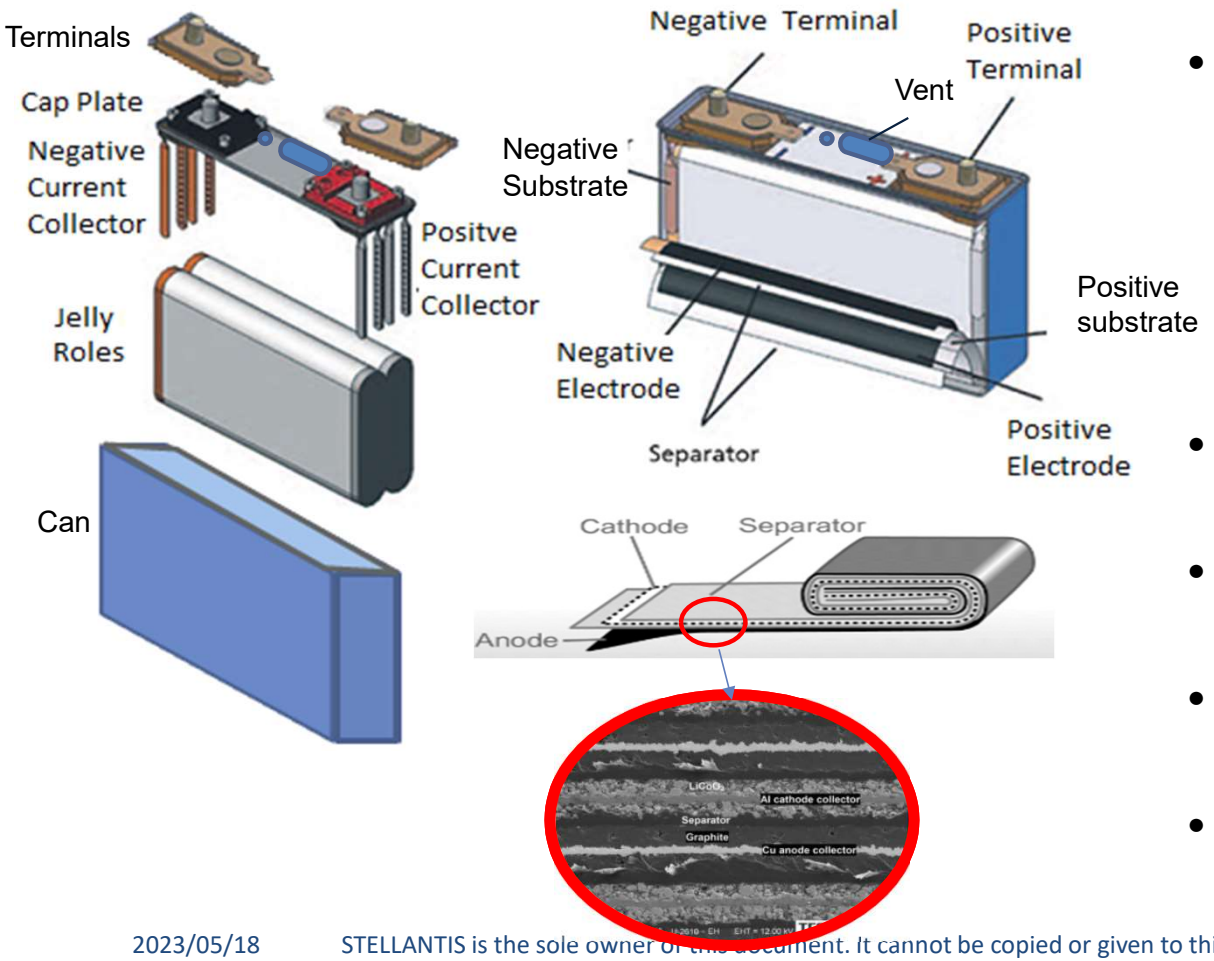


Metal cell can
- Easy and cheap to manufacture
- More difficult to pack inside module
- Flexible module design
- **Difficult to heat / cool**
- **May suffer from uneven/high pressure and temperature**

POUCH

Vacuum-sealed metalized plastic bag, “Coffee bag”
- Cheap and flexible manufacturing
- Optimized for weight, performance & cost
- **Need significant mechanical support in module**
- **Sensitive to internal gassing, abusive conditions & mech. stress**

Structure of a Prismatic Cell



- "Jelly-rolled" or "staked" electrodes placed in Aluminum Can
  - Terminals: Screw type, bolt type, busbar type
  - Can is insulated using PET tape or paint
  - Sealed with laser welding
- Can provides rigidity to structure and hermetic environment
- Electrolyte added via electrolyte filling hole
- Vent is provided for pressure release and gas removal in case of thermal event
- In built safety, such as fuse and overcharge protection device