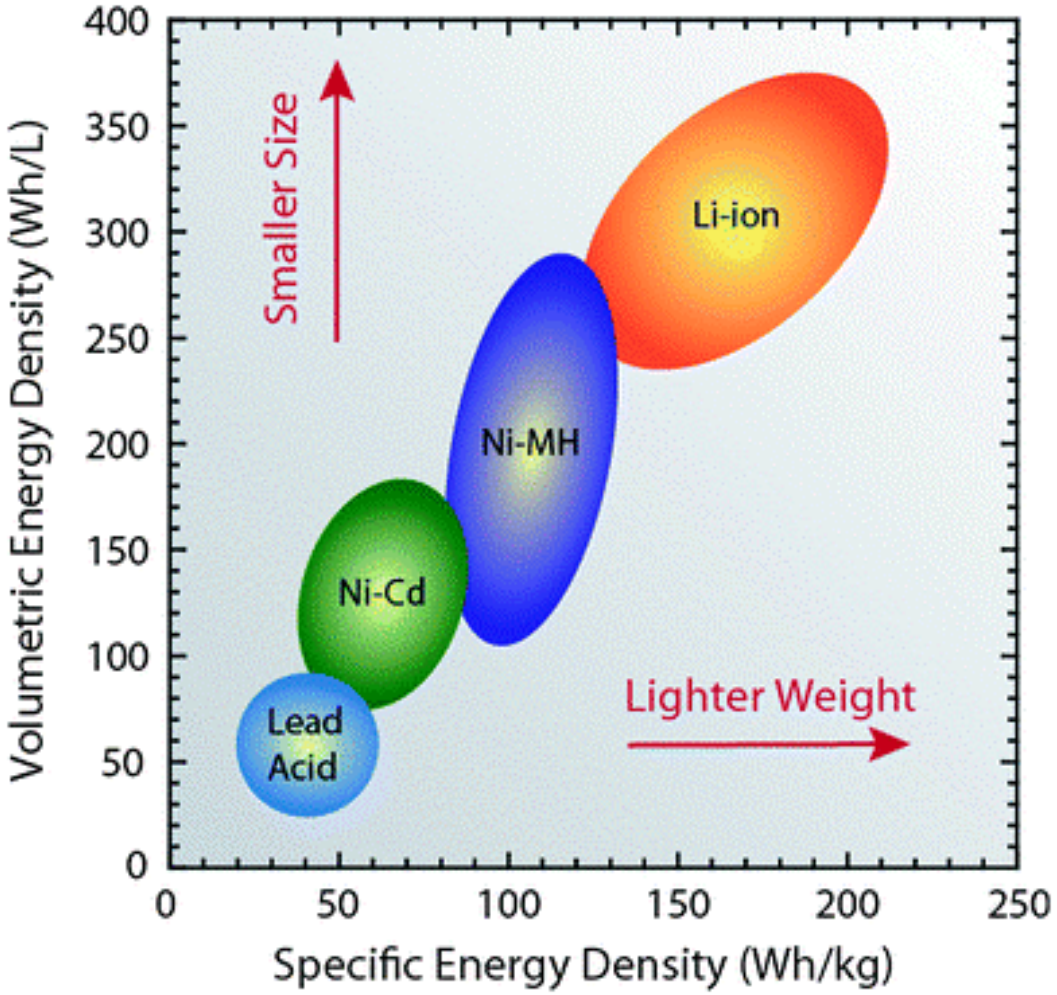
Li-ion battery (Secondary cell)



Nobel Prize in Chemistry 2019

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John B. Goodenough

Prize share: 1/3

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M. Stanley Whittingham

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Akira Yoshino

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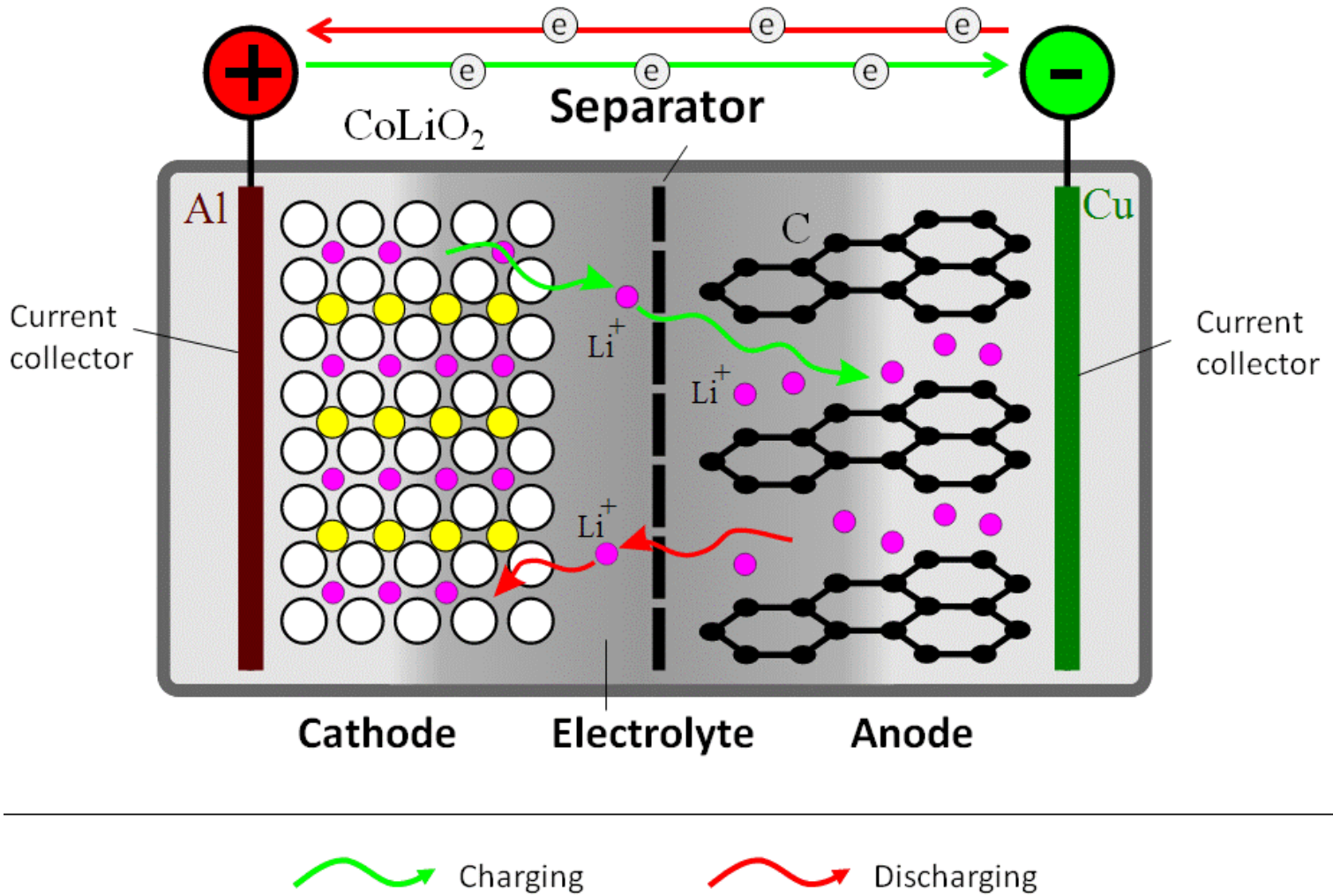
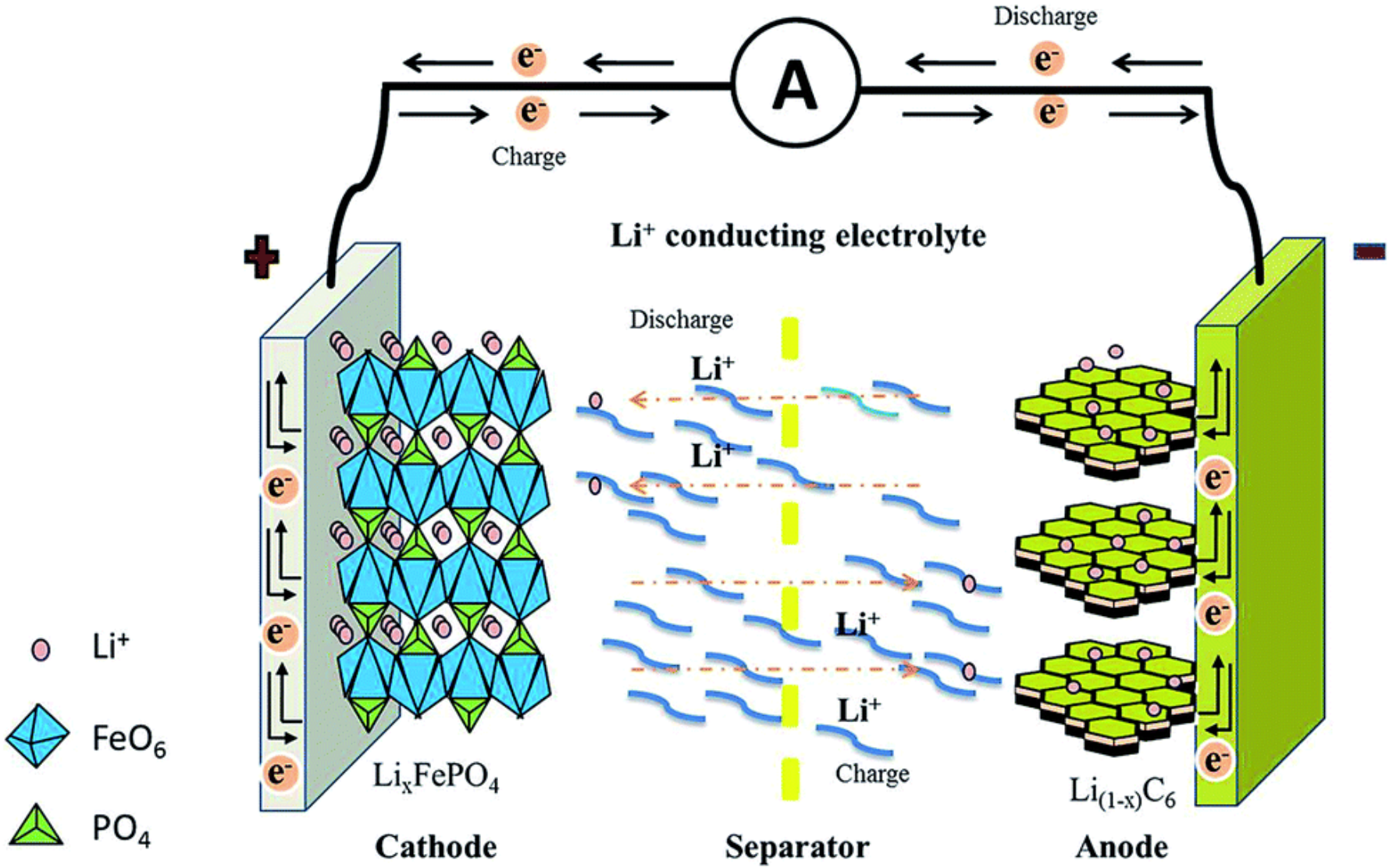
They created a rechargeable world

The Nobel Prize in Chemistry 2019 rewards the development of the lithium-ion battery. This lightweight, rechargeable and powerful battery is now used in everything from mobile phones to laptops and electric vehicles. It can also store significant amounts of energy from solar and wind power, making possible a fossil fuel-free society

Li-ion battery (Secondary battery)



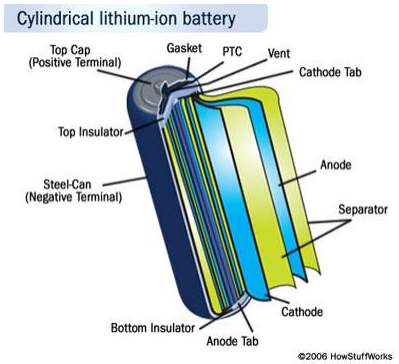
Li-ion battery (Secondary battery)



Lithium ion batteries

Cathode materials

- The most common compounds used for cathode materials are $LiCoO_2$, $LiNiO_2$ and $LiMn_2O_4$.
- Of these, $LiCoO_2$ has the best performance but is very high in cost, is toxic and has a limited lithium content range over which it is stable.
- $LiNiO_2$ is more stable, however the nickel ions can disorder.
- $LiMn_2O_4$ is generally the best value for money, and is also better for the environment.



Lithium ion batteries

Anodic materials

Sony's original lithium-ion battery used **coke as the anode** (coal product), and since 1997 most Li-ion batteries use **graphite** **to attain a flatter discharge curve**.

Developments also occur on the anode and several additives are being tried, including silicon-based alloys. Silicon achieves a 20 to 30 % increase in specific energy at the cost of lower load currents and reduced cycle life.

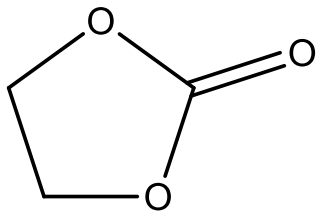
Nano-structured *lithium-titanate* as anode additive shows promising cycle life, good load capabilities, excellent low-temperature performance and superior safety, but the specific energy is low.

Lithium ion batteries

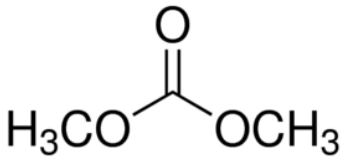
Electrolyte

- Since lithium reacts violently with water, and the cell voltage is so high that water would decompose, a non-aqueous electrolyte must be used.
- A typical electrolyte is $LiPF_6$ dissolved in an ethylene carbonate and dimethyl carbonate mixture.

$LiPF_6$



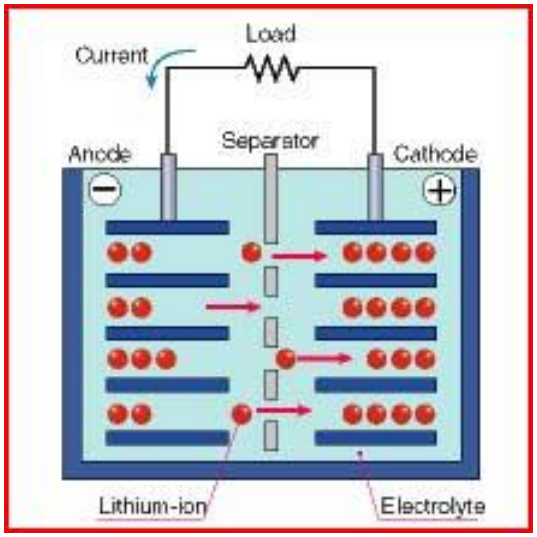
ethylene carbonate



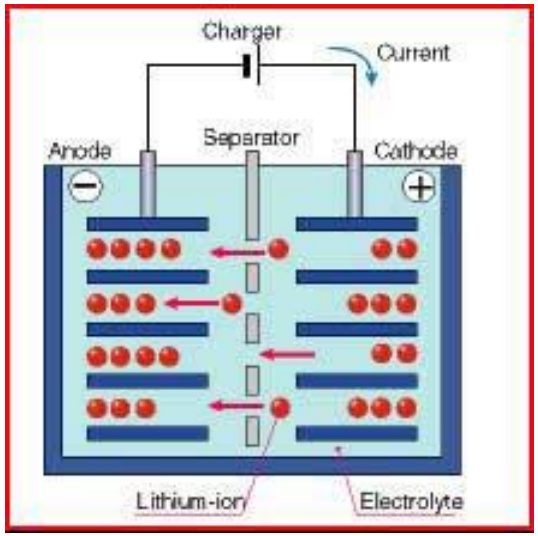
dimethyl carbonate

Lithium ion Cells

Discharging



Charging



Anode: lithium ions in the carbon material
Cathode: lithium ions in the layered material (lithium compound)

Anode

$$Li_{1-X}CoO_2 + C_nLi_x \rightarrow LiCoO_2 + C_n$$

Cathode

$$LiCoO_2 + C_n \rightarrow Li_{1-x}CoO_2 + C_nLix$$

The lithium ion moves from the **anode to the cathode during discharge** and **from the cathode to the anode when charging**.

Applications: Laptops, cellular phones, electric vehicles

The chemical reactions for charge and discharge are as shown below:

Positive Electrode	$LiCoO_2$	Charge ⇌ Discharge	$Li_{1-x}\ CoO_2 + xLi^+ + xe^-$
Negative Electrode	$C + xLi^+ + xe^-$	Charge ⇌ Discharge	$CLix$
Battery as a Whole	$LiCoO_2 + C$	Charge ⇌ Discharge	$Li_{1-x}\ CoO_2 + CLix$

The principle behind the chemical reaction in the lithium ion battery is one where the lithium in the positive electrode lithium cobalt oxide material is ionized during charge, and moves from layer to layer in the negative electrode. During discharge, the ions move to the positive electrode and return to the original compound

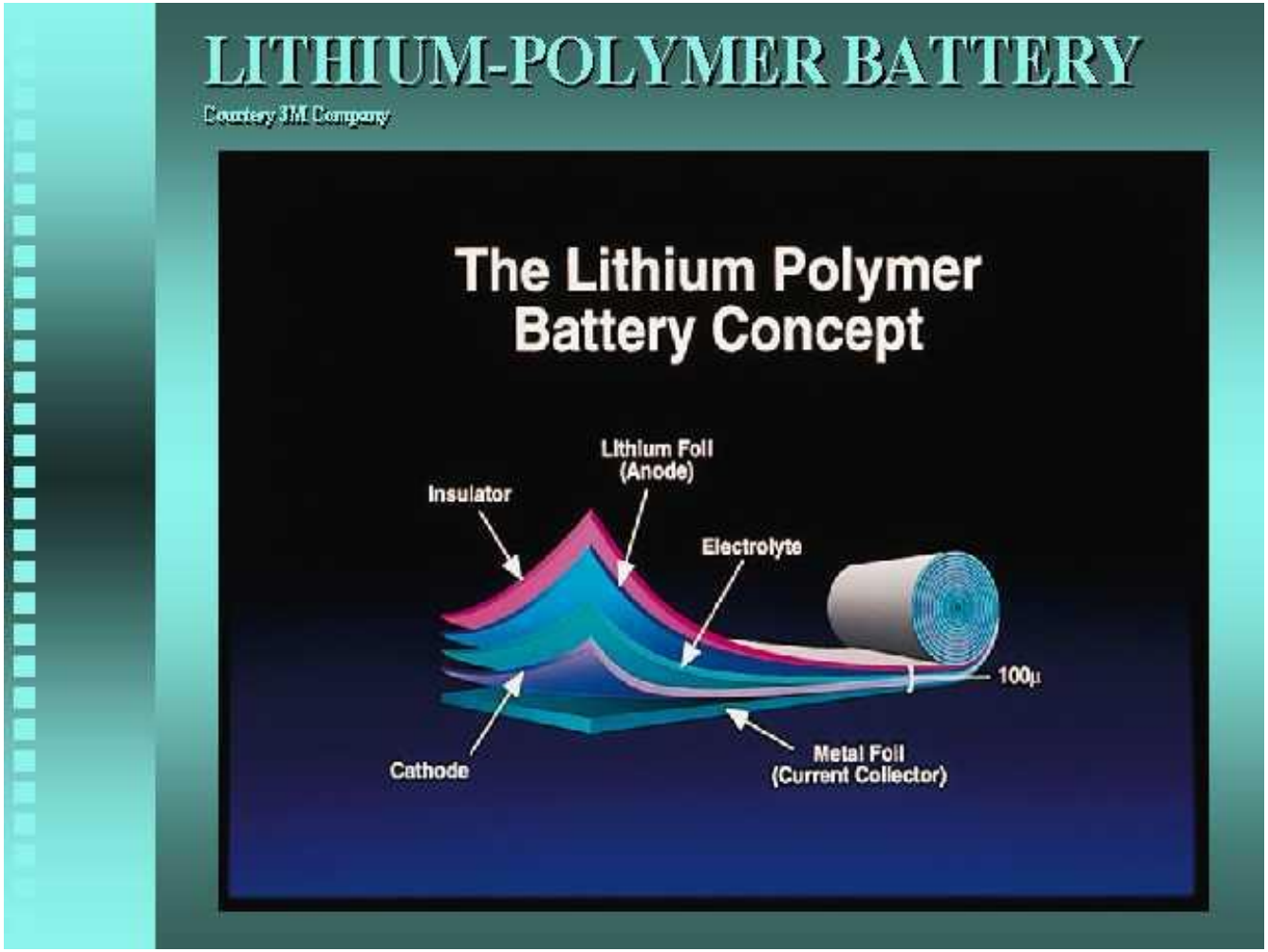
Lithium Polymer batteries are better than Lithium ion batteries

Exploded laptop

- Li-ion batteries use organic solvents to suspend the lithium ions.
- In situations where the structure of the battery is compromised, that solvent can ignite and vent from the pressurized battery.
- The result is a dangerous explosion
- The main advantage of Li-poly batteries is their reluctance to explode under pressure

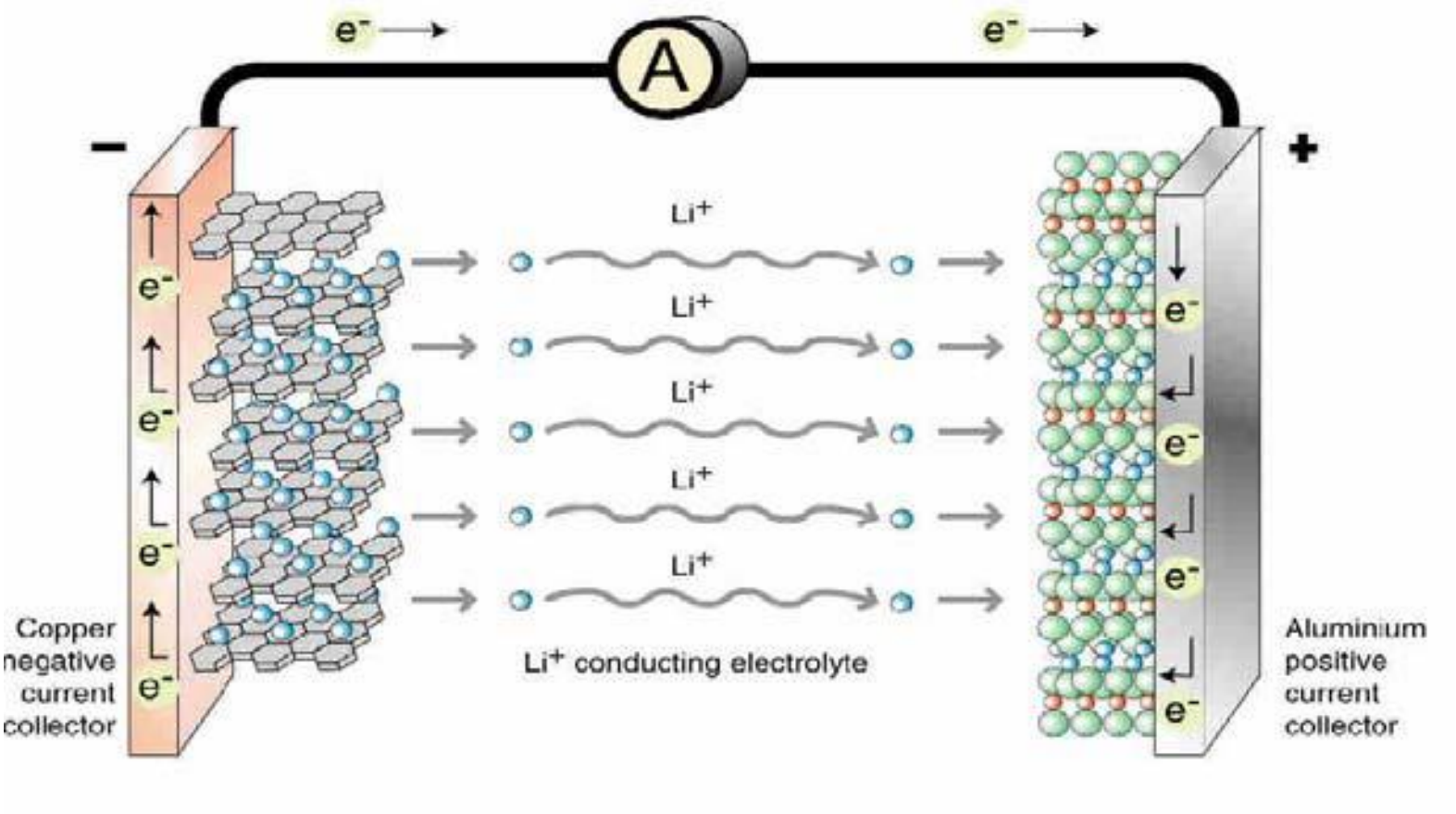
Lithium Polymer Battery

- Electrolyte is a polymer



Lithium polymer (Poly-Carbon Monofluoride) batteries

← Charging



- scientists from Stanford University have found a way to use **silicon nanowires** to produces 10 times the amount of electricity of existing lithium-ion, known as Li-ion, batteries that power laptops, iPods, video cameras, cell phones, and countless other devices. **A laptop that now runs on battery for two hours could operate for 20 hours.**