ENGINEERING CHEMISTRY

Class content:

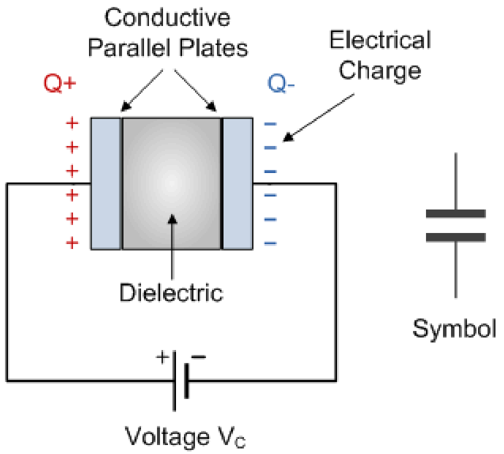
- ***Supercapacitors***
  - ***Principle***
  - ***Construction and working***
  - ***Advantages***
  - ***Disadvantages***
  - ***Applications***
- ***Ragone Plot***

Energy Storage devices- Supercapacitors

Capacitor

- A two- terminal electrical component that has the **ability to store energy** in the form of electrical charge
- Has two conducting plates separated by a dielectric
- When a DC voltage is connected across the capacitor, one plate becomes positive and the other negative
- The **charge accumulation on the plates** causes a voltage or potential difference across the capacitor

Source:https://www.electronics-tutorials.ws/capacitor/cap_1.html



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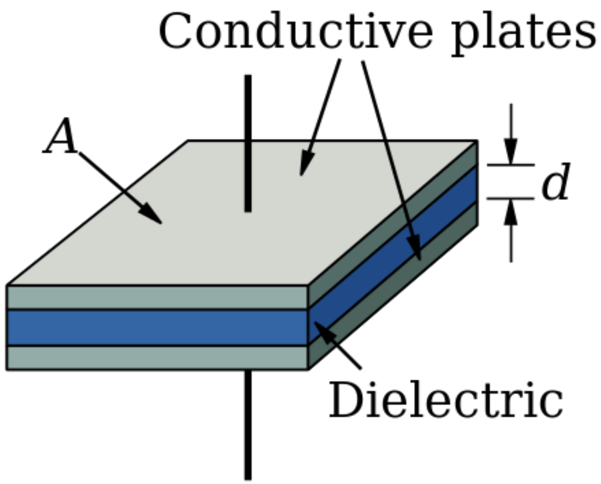
Energy Storage devices- Supercapacitors

- **Capacitance** is the charge accumulation capability of a capacitor
- Charge (Q) stored in a capacitor is directly proportional to the voltage (V) developed across the capacitor; $Q \propto V$
- **Q = C × V**, where C is the capacitance measured in **farads**
- Capacitance is directly proportional to **area of plates (A)** and inversely proportional to the **distance between the two plates (D)**; $C \propto \frac{A}{d}$



Source:https://www.wikiwand.com/en/Capacitor_typeS

Supercapacitors

- Also known as **ultra capacitors** or **electrochemical double-layer capacitors(EDLC)**
- Are energy storage devices that have **high capacitance** and are used to store large amounts of electrical charge
- **Charge and discharge** very quickly
- Capacitance is several thousand times that of a Capacitor
  - **Capacitor ----- µF**
  - **Supercapacitor ----- thousands of Farads**

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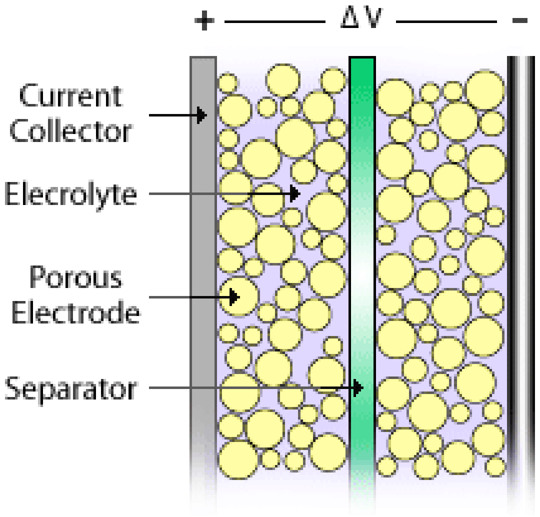
Construction:

Electrodes: made of high surface area materials such as porous carbon, graphene, carbon nanotubes and certain conducting polymers or carbon aerogel

Electrolyte: KOH, H_2SO_4, Na_2SO_4

Separator: an ion permeable separator is placed between the electrodes in order prevent electrical contact, but still allows ions from electrolyte to pass through e.g., porous polypropylene

Separator is sandwiched between the electrodes which are soaked with **electrolyte** and sealed inside a case.
The electrodes are flanked with **current collectors**



[Source:https://www.azonano.com/article.aspx?ArticleID=3044](https://www.azonano.com/article.aspx?ArticleID=3044)

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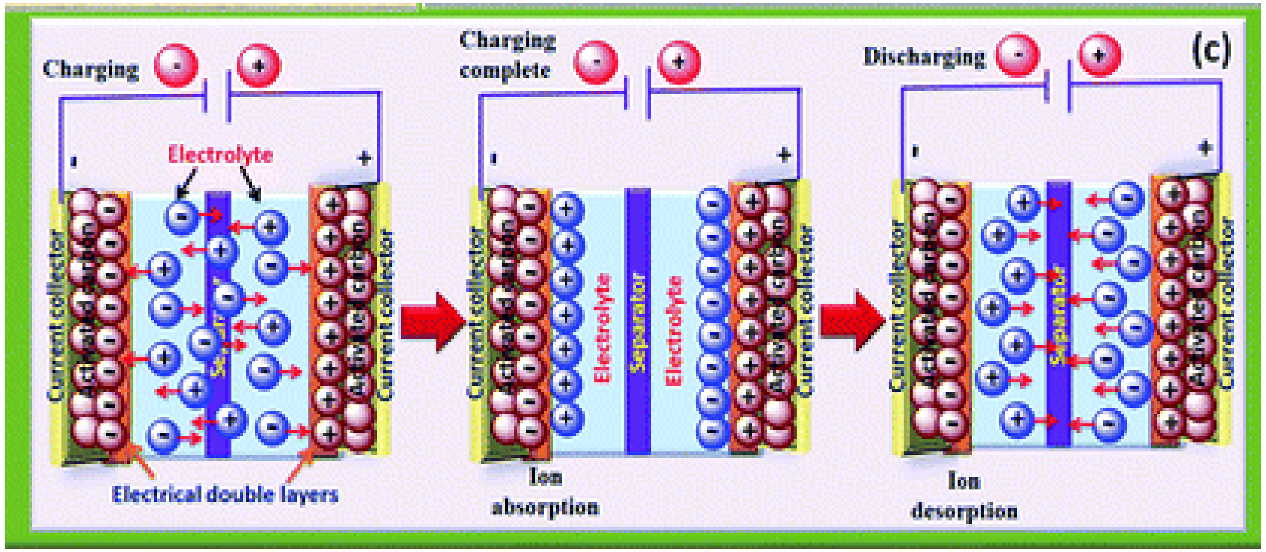
Energy Storage devices- Supercapacitors

Working:

- When a potential is applied, the positive electrode attracts negative ions in the electrolyte, while negative electrode attracts the positive ions
- Formation of electrical double layer at entire electrode /electrolyte interface with a charge separation in nanometer scale



Source:https://pubs.rsc.org/en/content/articlelanding/2019/na/c9na00374f#!divAbstract

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Energy Storage devices- Supercapacitors

- Only **absorption and desorption of ions** takes place at the electrode during charging and discharging and there are **no redox reactions**
- Distance between the charged layers in nanorange, **d is very small** and use of porous electrodes gives very high surface area , **A is large**

$C \propto \frac{A}{d}$; **Capacitance is very high**

- Formation of the electrical double-layer at each electrode/electrolyte interface, overall capacitance (C_T) is expressed as: $$\frac{1}{C_T} = \frac{1}{C_+} + \frac{1}{C_-}$$

where C_+ is the capacitance of cathode/electrolyte interface and C_- is the capacitance of anode/electrolyte interface

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Energy Storage devices- Supercapacitors

Advantages:

- **Rapid charging**; charge in a few seconds
- **High power density** as they discharge very fast
- **High cycle life**, can be cycled millions of time
- **Safe** as extremely low internal resistance and extremely low heating rates

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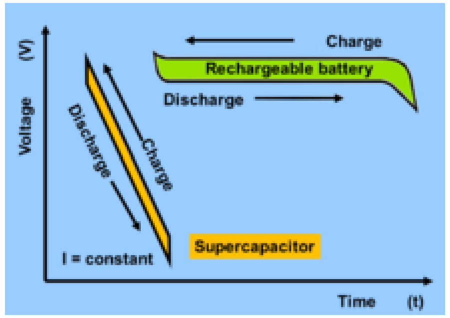
Energy Storage devices- Supercapacitors

Disadvantages:

Low energy density

High self discharge

Linear discharge voltage



Source:https://store.chipkin.com/articles/beyond-the-lithium-ion-battery-a-look-at-supercapacitors-and-other-batteries

High cost

Power available for a short duration

Energy Storage devices- Supercapacitors

Applications:

- Memory back-up
- Hybrid cars for start-stop application
- Flash photography devices in digital cameras, flash lights, portable media players
- As an intermediate energy storage for FM radios, cell phones, and emergency kits

Ragone Plot

- **Energy density** (Wh/kg) is plotted against **Power density** (W/kg)

- To **compare performance** of various energy storage devices

- Since it uses a double-logarithmic chart, storage technologies with very different storage properties can be compared in one plot

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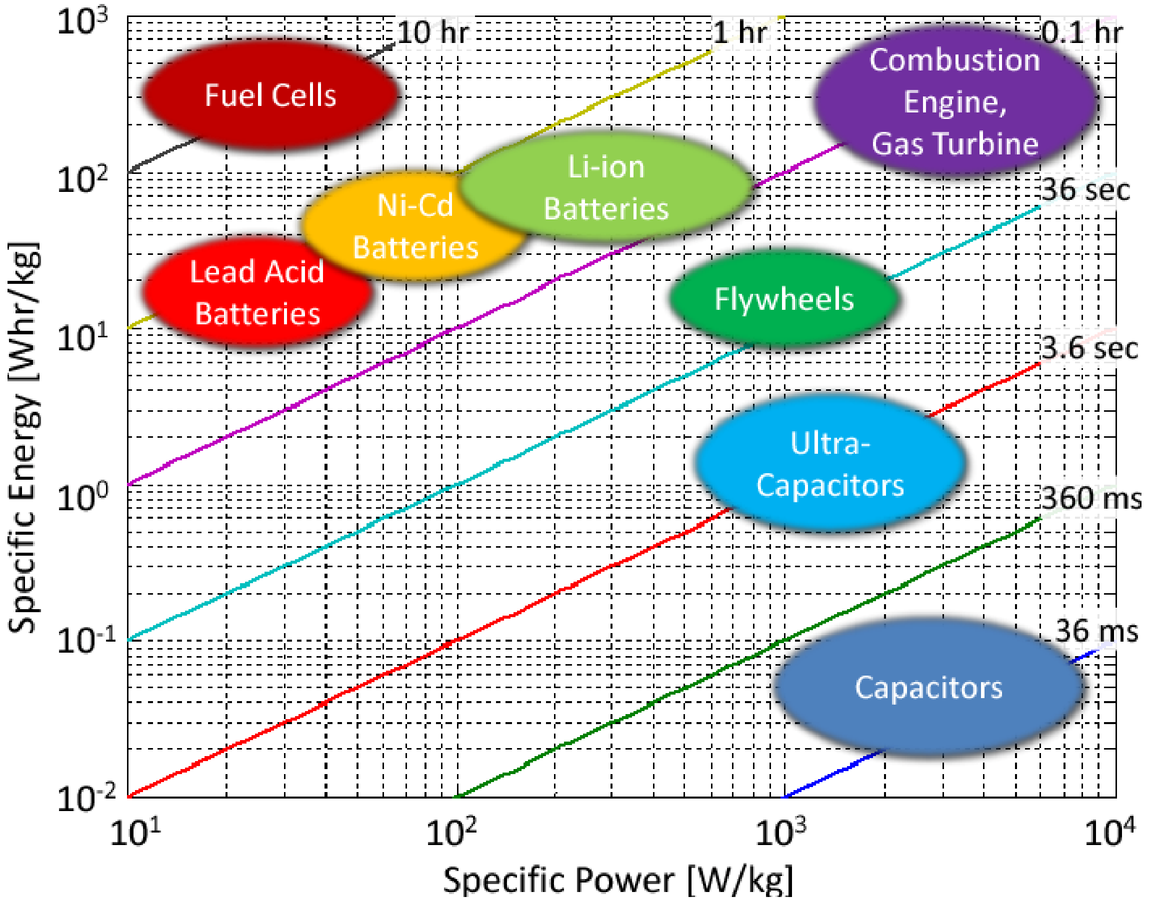
Energy Storage devices- Supercapacitors



Source:https://www.semanticscholar.org/paper/Education-on-vehicle-electrification%3A-Battery-Fuel-Moura-Siegel/7e83f03396b55f2a894461480dda7e9c154f5721/figure/0

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Energy Storage devices- Supercapacitors

- **Fuel cells** have high energy density as the electroactive species can be continuously supplied but the power density is low due to slow kinetics of redox reactions at electrodes
- **Battery systems** offer moderate energy density and power density.
- **Ultracapacitors** (supercapacitors) can deliver very high power density as they can discharge a large amount of charge quickly (because no redox reaction is involved) but energy density is very limited because the charge cannot be stored for a long time

THANK YOU