Carbon Materials in Electrical Double Layer Capacitors and Pseudocapacitors

Introduction

- A capacitor is a device which is used to store the charge in an electrical circuit. Basically a capacitor is made up of two conductors separated by an insulator called dielectric.

- Supercapacitors are modern electric energy storage devices with very high capacity and a low internal resistance. They can store and deliver enegy so quickly.

- Supercapacitors utilize high surface area electrode materials and thin electrolytic dielectrics to achieve high capacitance.

Supercapacitor Cell

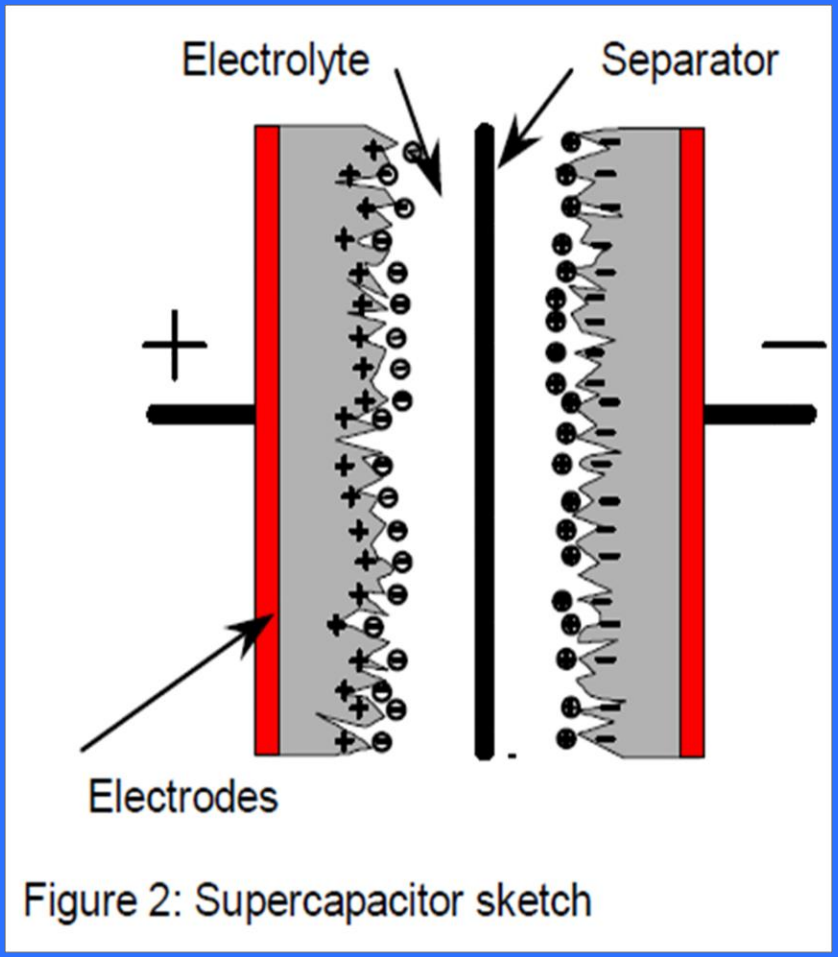


Figure 2: Supercapacitor sketch

✓ An Supercapacitor cell basically consists of two electrodes, a separator, and an electrolyte.

✓ Electrodes are made up of a metallic collector, which is the high conducting part, and of an active material, which is the high surface area part.

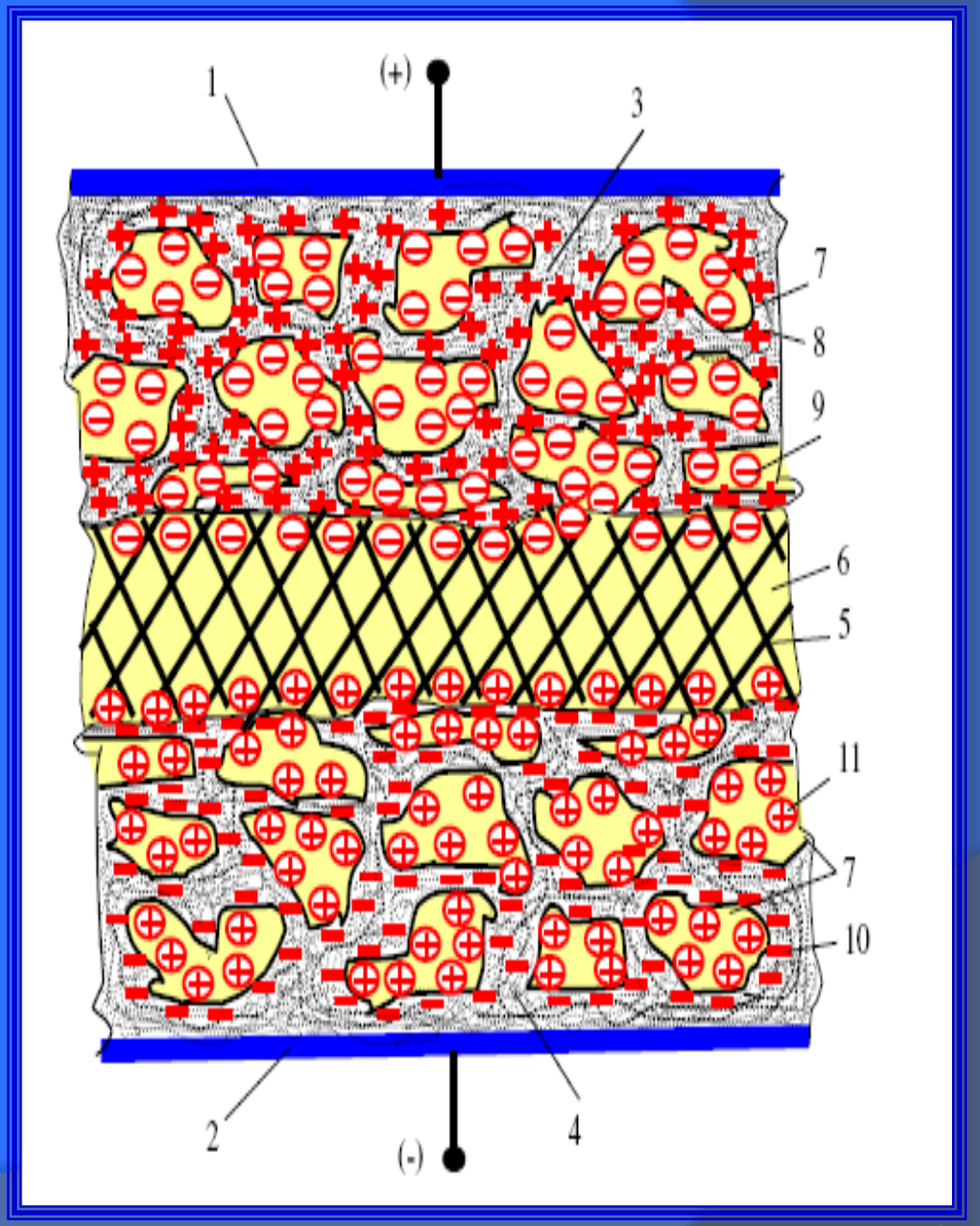
✓The two electrodes are separated by a membrane, the separator, which allows the mobility of the charged ions but forbids the electronic conductance. Then the system is impregnated with an electrolyte.

✓ Working voltage is determined by decomposition voltage of electrolyte and depends mainly on environment temperature, current intensity and required lifetime.

A charged supercapacitor

1-2. Current collector
3-4. Electrodes
5. Seperator
6. Electrolyte
7. Pores in the electrode material

As voltage is applied, ions in the electrolyte solution diffuse across the separator into the pores of the electrode of opposite charge.



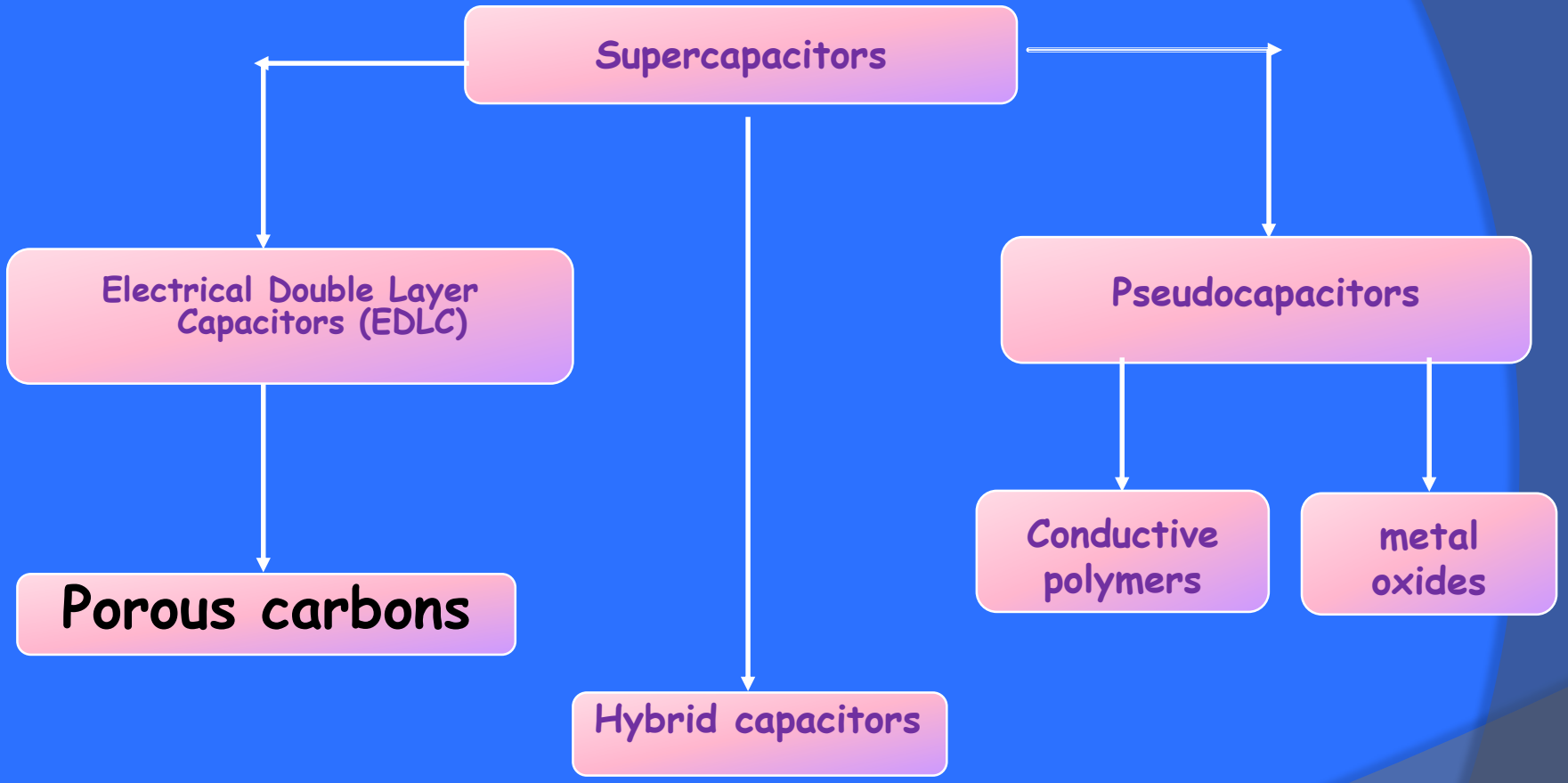
Electrodes

- Electrochemical inert materials with the highest specific surface area are utilized for electrodes in order to form a double layer with a maximum number of electrolyte ions.
- The main difficulties are to find cheap materials, which are chemically and electrically compatible with the electrolyte.
- As high surface active materials, carbon is the most interesting.
- Capacitors for high energy applications require electrodes made of high surface area carbon with appropriate surface properties.

Electrolyte

- The electrolyte may be of the solid, organic or aqueous type.
- Organic electrolytes are produced by dissolving quaternary salts in organic solvents. Their dissociation voltage may be greater than 2.5 V.
- Aqueous electrolytes are typically KOH or H_2SO_4, presenting a dissociation voltage of only 1.23 V.
- However, if power density is important, the increase in the internal resistance (ESR) due to the lower electrolyte conductivity has to be considered as well. The electrolyte solution should therefore provide high conductivity and adequate electrochemical stability to allow the capacitor being operated at the highest possible voltages.

- There are two carbon sheets separated by a separator.
- The geometrical size of carbon sheets is taken in such a way that they have a very high surface area.
- The highly porous carbon can store more energy than any other electrolytic capacitor.
- When the voltage is applied to positive plate, it attracts negative ions from electrolyte. When the voltage is applied to negative plate, it attracts positive ions from electrolyte.
- Therefore, there is a formation of a layer of ions on both sides of the plate. This is called ‘Double layer’ formation.
- The ions are then stored near the surface of carbon.


Supercapacitors
Electrical Double Layer Capacitors (EDLC)
Porous carbons
Hybrid capacitors
Pseudocapacitors
Conductive polymers
metal oxides

Hybrid capacitors

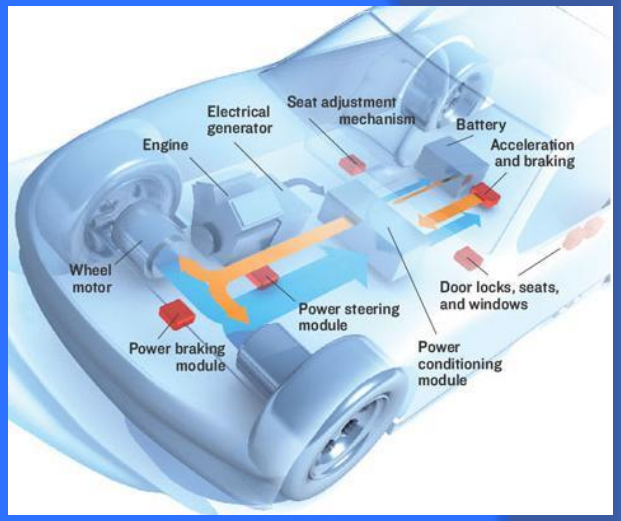
- Hybrid capacitors attempt to exploit the relative advantages and mitigate the relative disadvantages of EDLCs and pseudocapacitors to realize better performance characteristics.

- Utilizing both Faradic and non-Faradic processes to store charge, hybrid capacitors have achieved energy and power densities greater than EDLCs without the sacrifices in cycling stability and affordability that have limited the success of pseudocapacitors.

Applications of supercapacitors

- Considered as environmentally friendly solutions because they can perform reliably in all weather conditions without having to be replaced and disposed to landfills.
- Function well in temperatures as low as -40 ^{o}C , they can give electric cars a boost in cold weather, when batteries are at their worst.
- Used in military projects such as starting the engines of battle tanks and submarines or replacing batteries in missiles.

- Back up for uninterruptable power supplies (UPS)
- Light weight power supplies for small aircraft
- Provide short duration power for various vehicle systems such as breaking or steering



- Used to absorb power during short periods of generation such as Regenerative Braking
- Extend range and battery life in Hybrid Electric Vehicles (HEV)