Inadequecy Representation of Supercapacitor Batteries Models

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Outline

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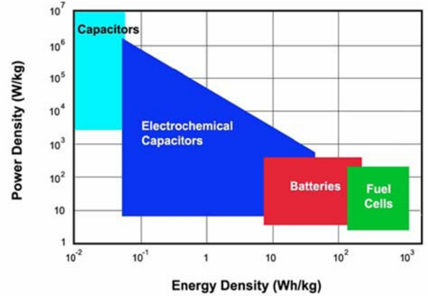
What are supercapacitors?

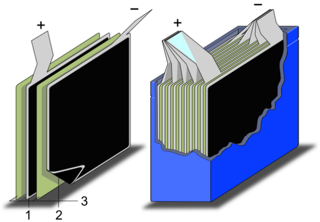
Supercapacitors are intermediate power/energy storage/supply devices that bridge the gap between *electrolytic capacitors* and *rechargeable batteries*. They can provide

- higher energy density (capacitance) than capacitors
- higher power density (faster charge delivery) than batteries
- many more charge and discharge cycles than batteries

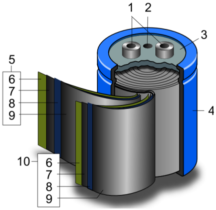


Supercapacitors are suitable in applications where a large amount of power is needed for a relatively short time, where a very high number of charge/discharge cycles or a longer lifetime is required. e.g. Low supply current for memory backup in SRAM, power for cars, etc.

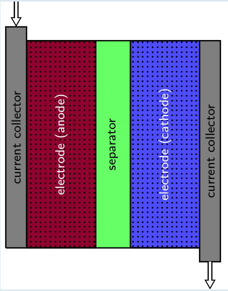
What are supercapacitors?



Supercapacitor with stacked electrodes



Wound supercapacitor



Unit cell:

- Anode current collector
- Porous anode electrode: solid matrix filled with liquid electrolyte
- Separator: electronic insulator and ion permeable
- Porous cathode electrode: solid matrix and liquid electrolyte
- Cathode current collector.

Storage principles

Capacitance value of an electrochemical capacitor is determined by two storage principles

- double-layer capacitance: electrostatic storage of the electrical energy by separation of charge in a double layer at the interface between electrode/electrolyte . The amount of electric charge stored is linearly proportional to the applied voltage and depends primarily on the electrode surface.
- pseudo capacitance: electrochemical storage achieved by faradaic redox reactions with charge-transfer.

explanations!!!

Outline

Governing Equations

Current density following Ohm's law:

- Electrode (matrix phase) : due to electrons migration $\mathbf{i}_1 = -\sigma \nabla \phi_1$
- Electrolyte (solution phase) : due to ion migration $\mathbf{i}_2 = -\kappa \nabla \phi_2$

where ϕ_1 and ϕ_2 are potentials, and σ is solid matrix electronic conductivity and κ is liquid ionic conductivity.

conservation of charge

$$\begin{aligned} \text{total current density} : I &= \mathbf{i}_1 + \mathbf{i}_2 \\ -\nabla \cdot \mathbf{i}_1 &= \nabla \cdot \mathbf{i}_2 = a i_n \end{aligned}$$

a: interfacial area per unit volume
i_n: current transferred from the matrix to the electrolyte

$$i_n = \underbrace{C \frac{\partial}{\partial t} \eta}_{\text{double}-\text{layer}} + \underbrace{i_0 (\exp(\frac{\alpha_a F}{RT} \eta) - \exp(-\frac{\alpha_a F}{RT} \eta))}_{\text{faradaic}}$$

overpotential: $\eta = \phi_1 - \phi_2$.